1. Motivation

Special Requirements of Data Management for Engineering Applications

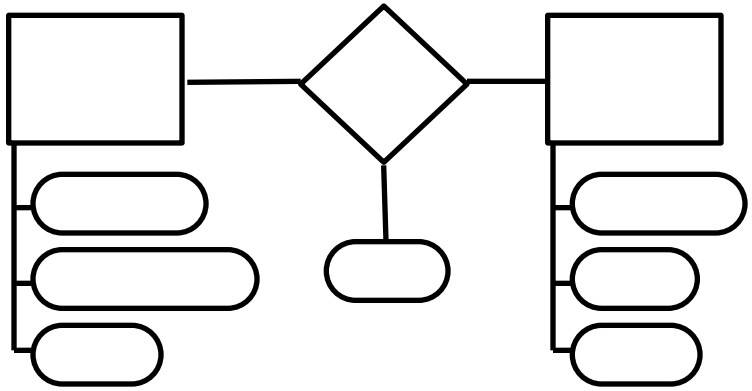
Overview

- What are typical/conventional applications?
- Why is it necessary to talk about engineering data?
  - What is different about engineering data?
    - Typical structure
    - Special requirements
  - What is different about how data is accessed in engineering applications?
    - Queries
    - Updates
  - How is engineering data used differently?
    - Transactions
    - Processes
    - Applications
- What is the current state of the art for DMEA?

Conventional Applications

- Document-oriented (files), e.g.
  - Textprocessing
  - Desktop Publishing
  - Web
  - Spreadsheets
  - Media: Image, Video, Audio

- Structured Data (Databases), e.g.
  - Administration of Company / Organization
  - Enterprise Ressource Planning
  - Customer Relationship Management
  - Finance and Banking

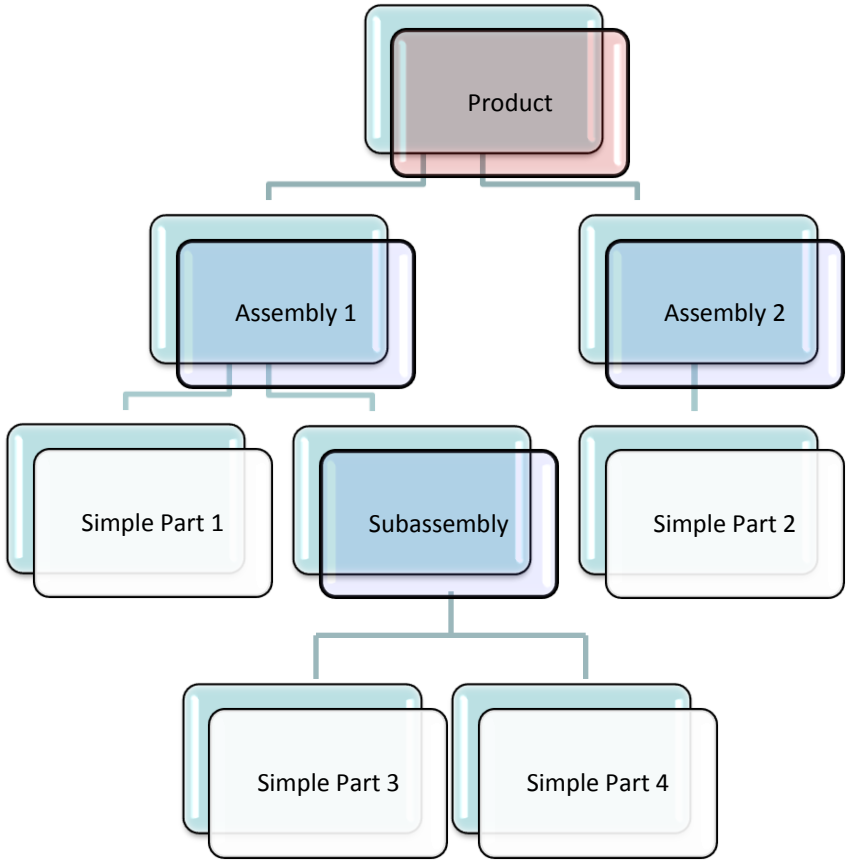


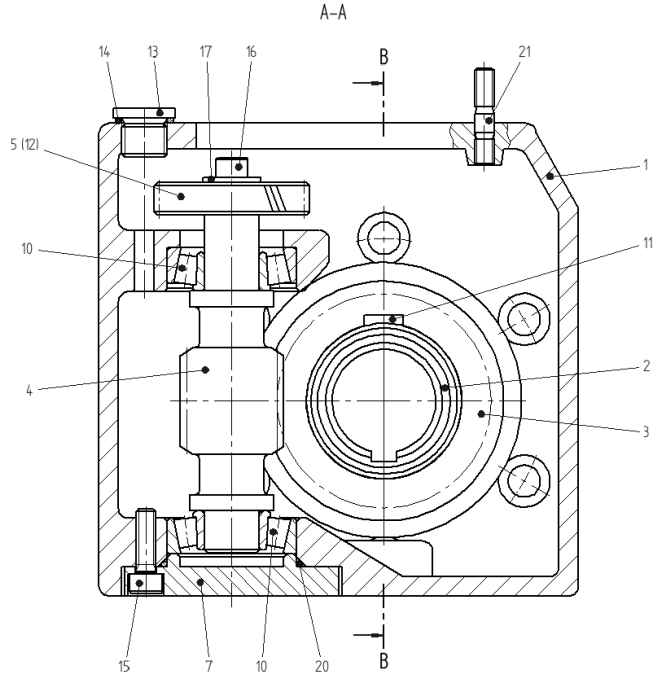
Conventional vs. Engineering Data

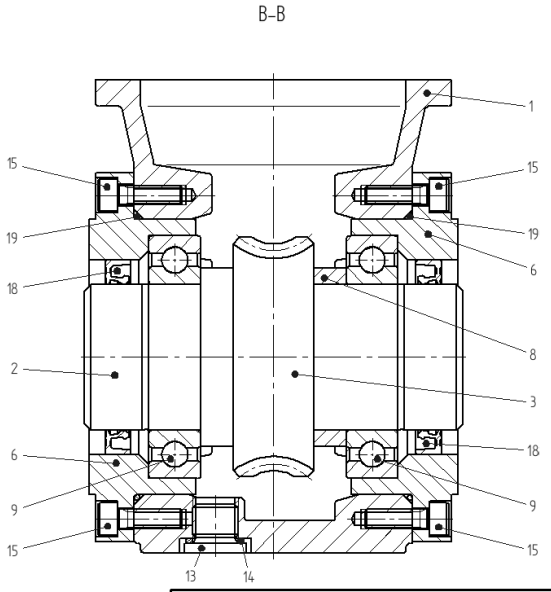
Conventional Data	**Engineering Data**
Simple (flat) records • One record represents one real-world object • Simple relationships (e.g. by identifying keys)	**Complex** Objects • **Hierarchical structures:** an object may contain other objects, etc. • **Network structures:** objects may form new structures from complex relations
Records represent current state	Need to represent development of objects as **versions**
Records as a single representation of a real-world fact	Need to represent concurrent/parallel manifestations of one object as **variants** or **configurations**
Records have a fixed structure	Engineering data is unpredictable and requires **flexibile structures**
Different records are most often loosely connected along relations	There are **strong dependencies** between different objects, often existential

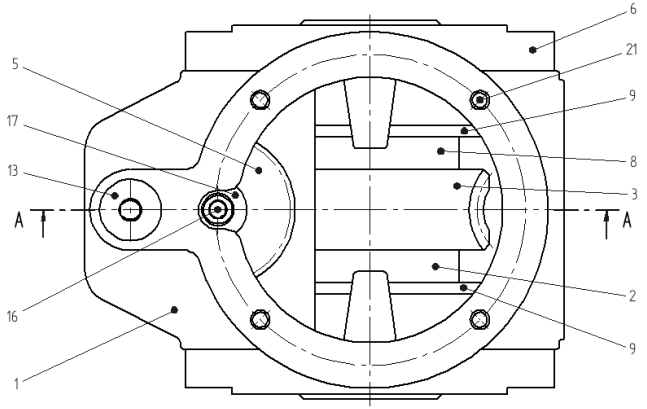
Hierarchical Structures

- Typical **product structure**: a complete product consisting of parts or assemblies, where assemblies again may consist of assemblies or parts
- Each simple part or composition may be complex itself
- E.g. input for production planning (Bill of Material) etc.









1	2	3	4	5	6
Pos.	Menge	Einheit	Benennung	Sachnummer / Norm – Kurzbezeichnung	Bemerkung
1	1	Stck.	Gehäuse		G — AlSi10Mg
2	1	Stck.	Hohlwelle		34CrMo4
3	1	Stck.	Schneckenrad		G — CuSn12Ni
4	1	Stck.	Schneckenwelle		16MnCr5
5	1	Stck.	Zahnrad		16MnCr5
6	2	Stck.	Lagerdeckel groß		S235JR
7	1	Stck.	Lagerdeckel klein		S235JR
8	1	Stck.	Distanzring		S235JR
9	2	Stck.	Rillenkugellager	DIN 625 — 6009	
10	2	Stck.	Kegelrollenlager	DIN 720 — 30203	
11	1	Stck.	Passfeder groß	DIN 6885 — B 12 x 8 x 22	
12	1	Stck.	Passfeder klein	DIN 6885 — B 5 x 5 x 10	
13	2	Stck.	Verschlussschraube	DIN 908 — M14 x 1,5 — St	
14	2	Stck.	Dichtring	DIN 7603 — A 14 x 18 Vf	
15	15	Stck.	Zylinderschraube mit Innensechskant	ISO 4762 — M6 x 20 — 8.8	
16	1	Stck.	Zylinderschraube mit Innensechskant	ISO 4762 — M6 x 16 — 8.8	
17	1	Stck.	Scheibe	DIN 9021 — B 6,4	
18	2	Stck.	Radial-Wellendichtring	DIN 3760 — AS 45 x 60 x 8	
19	2	Stck.	O-Ring	DIN 3771-85x3,55-N-NBR 70	
20	1	Stck.	O-Ring	DIN 3771-40x3,55-N-NBR 70	
21	4	Stck.	Stiftschraube	Kaufteil gemäß Zeichnung	S235JR

			Datum	Name
		Bearb.	20.03.2006	
		Gepr.		
		Norm		

Schneckengetriebe

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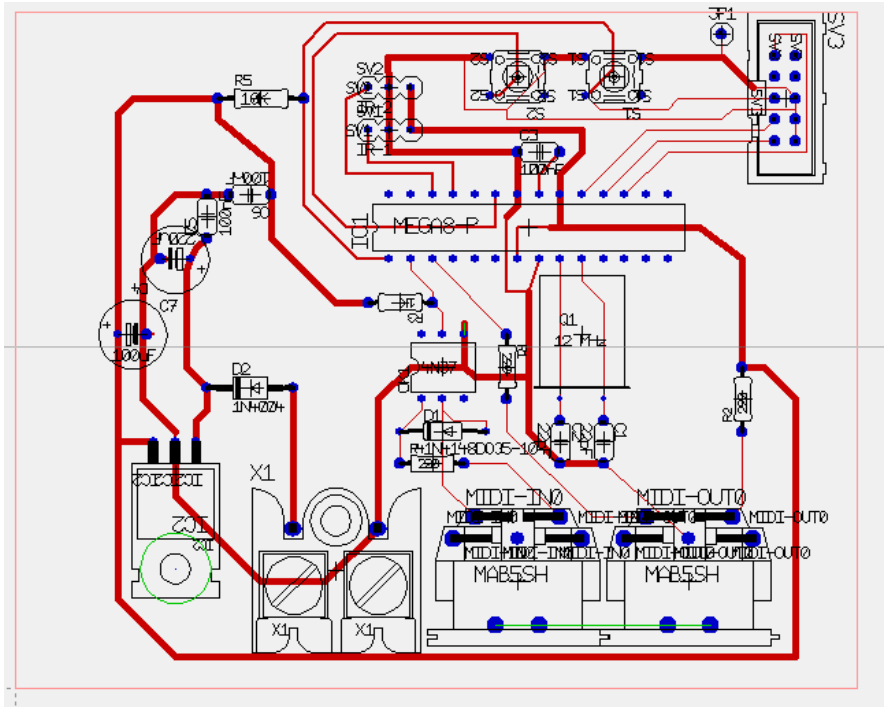
Zust.	Änderung	Datum	Name

[Source: http://en.wikipedia.org/wiki/Bill_of_materials]

Network structures

- Several components may be connected in a network and form a higher level unit
- Each component as well as the relationships can be complex
- E.g. electronical engineering, telecommunications network, embedded components connected via a fieldbus, etc.



[Source: Philipp Ludwig]

Versions

- Temporal sequence of different development states of one object
- For internal usage: milestones or consistent states for possible rollbacks
  - Work in progress
  - Fitness for certain development steps (simulation, mockup, field test, etc.)
  - Alpha, beta, release candidate
- For externaal usage: release of an improved product of the same development line

VW Golf I

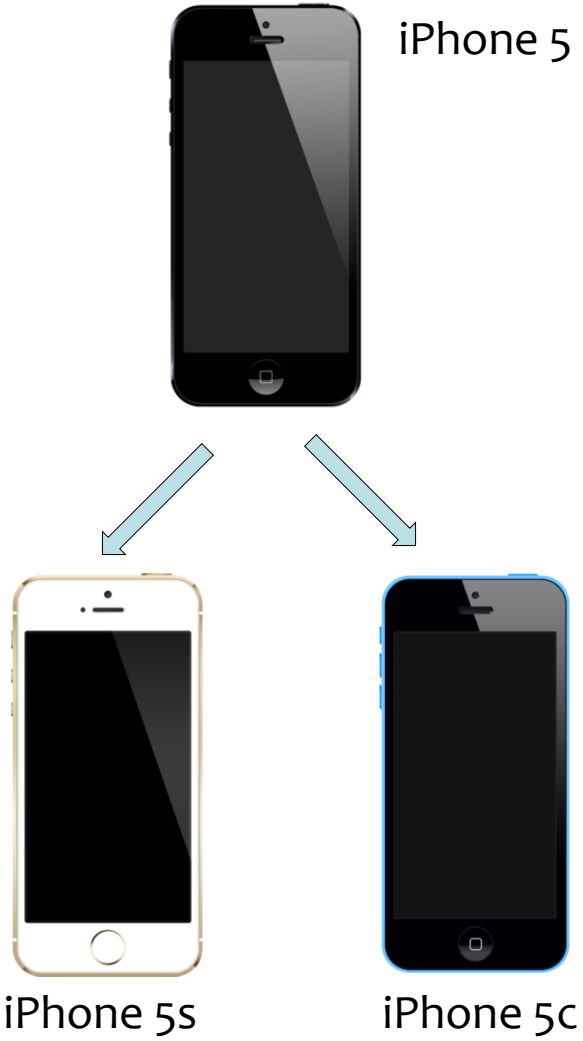
VW Golf II

VW Golf III

...

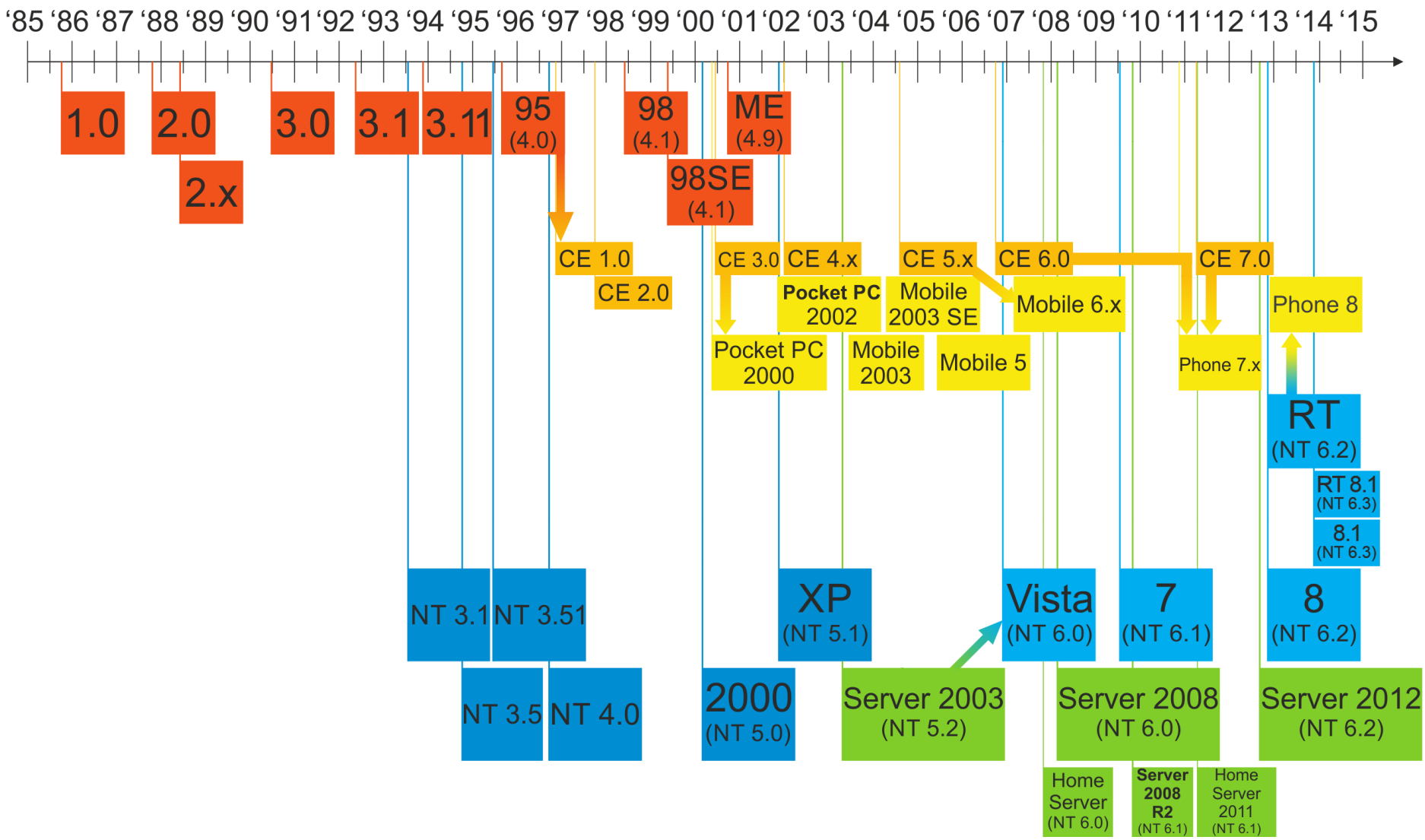
Variants

- Alternative states of one object existing in parallel
- Internal variants may exist due to concurrent design activities
- External variants exist, e.g. to address different market segments or different application scenarios
- Different external variants may have different properties, offer different functionality, and fulfill different requirements



Versions and Variants

- Both represent different alternative representations of one design object
- Are often managed in a common context
- Specialized systems offering according operations, e.g.
  - Check out
  - Branching: creating a new variant
  - Merging
- Certain naming und numbering systems to identify versions and variants internally and/or externally



[Source: http://en.wikipedia.org/wiki/Microsoft_Windows]

Flexibility

- Conventional data within one universe of discourse often has a fixed structure (records, attributes, relationships, etc.)
- The structure of engineering data on the same real-world object may vary widely for
  - different applications
  - different companies
  - different product categories
  - different process instances
  - different versions or variants

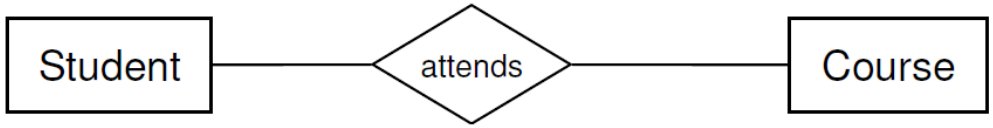
Strong dependencies

- Strong, e.g. existential, dependendcies are more common in engineering applications due to complex product structures
- Existential dependencies:
  - Relationship among objects, where a dependent object may not exist without a
  - E.g. rooms are existantially dependent on the building they are in
- Non-existential dependencies:
  - Objects in a relationship may exist independently of each other
  - E.g. students and lectures

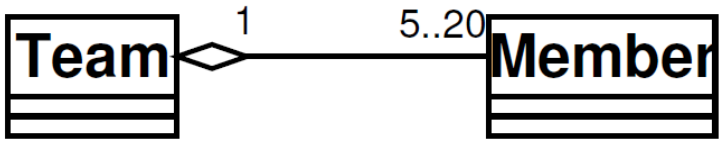
(Non-)Existential Relations in ER and UML

Non-Existential Relationship

ER

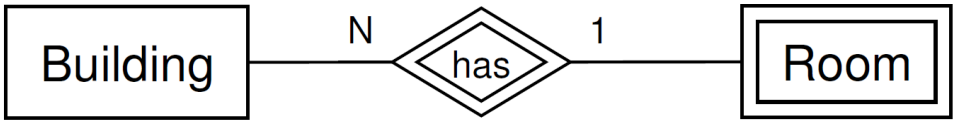


UML

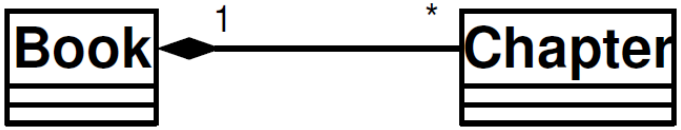


Existential Relationship

ER



UML



Predominant Access Characteristics

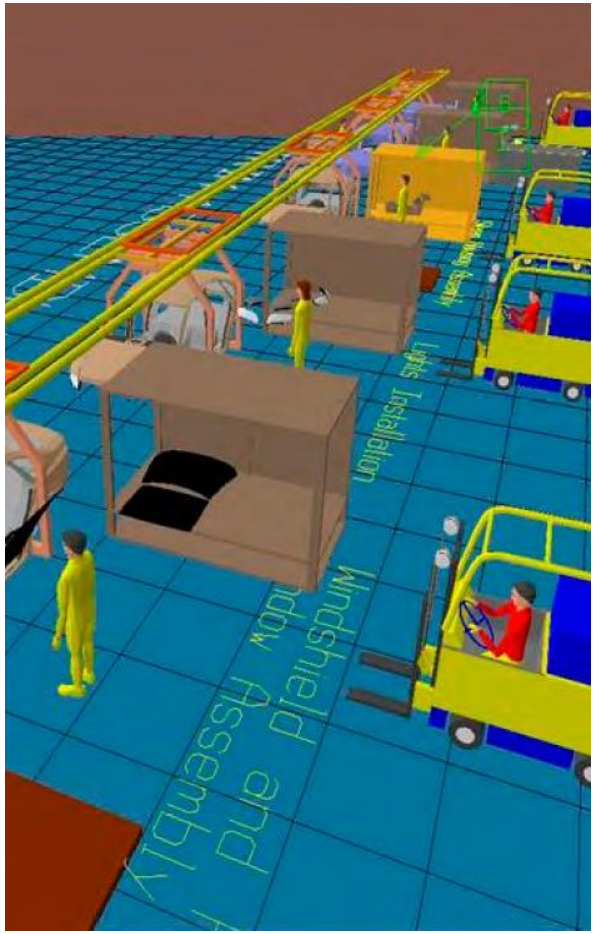
Access to Conventional Data	Access to Engineering Data
Simple access patterns for read operations • Retrieval of single records (exact match) • Partial match or range queries	**Complex access patterns** for read operations • Retrieval of complex objects (entire or partial hierarchies or networks) • Queries including complex **spatial conditions** • **Navigational access** along relationships
Update operations on single records	Updates may involve huge fractions of data
Small amounts of data in one query	Typically big to huge results
Small to possibly huge numbers of users	Small groups of users

Spatial Access

- Access to geometrical (2D or 3D shapes, geographical, architectural, etc.) often based on their position in space, e.g. objects in current viewport to be rendered
- Conforms to multi-dimensional range query, e.g. 2D-window

  $xmin \leq x \leq xmax$

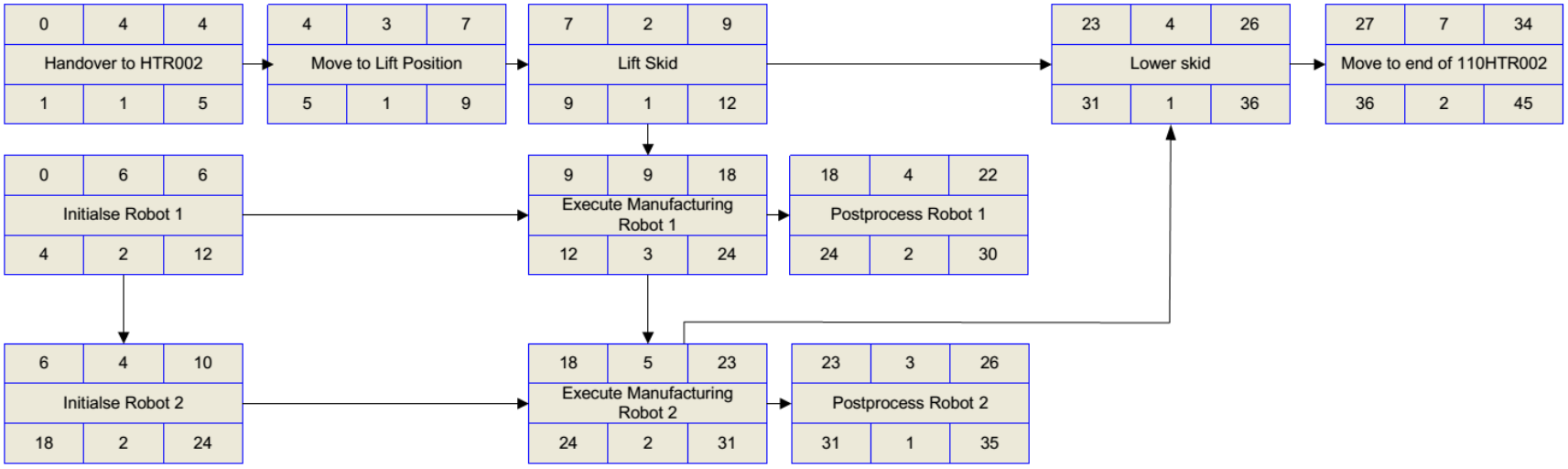
  $ymin \leq y \leq ymax$
- Special support in databases



[Source: http://en.wikipedia.org/wiki/Computer-integrated_manufacturing]

Navigational Access

- Access pattern of following relationships to retrieve objects
- E.g. computing the transitive closure or traversing a tree
- Often a programming pattern, but also carried out by users interactively



[Source: PERT Chart by Thomas Baier]

Predominant Usage Patterns

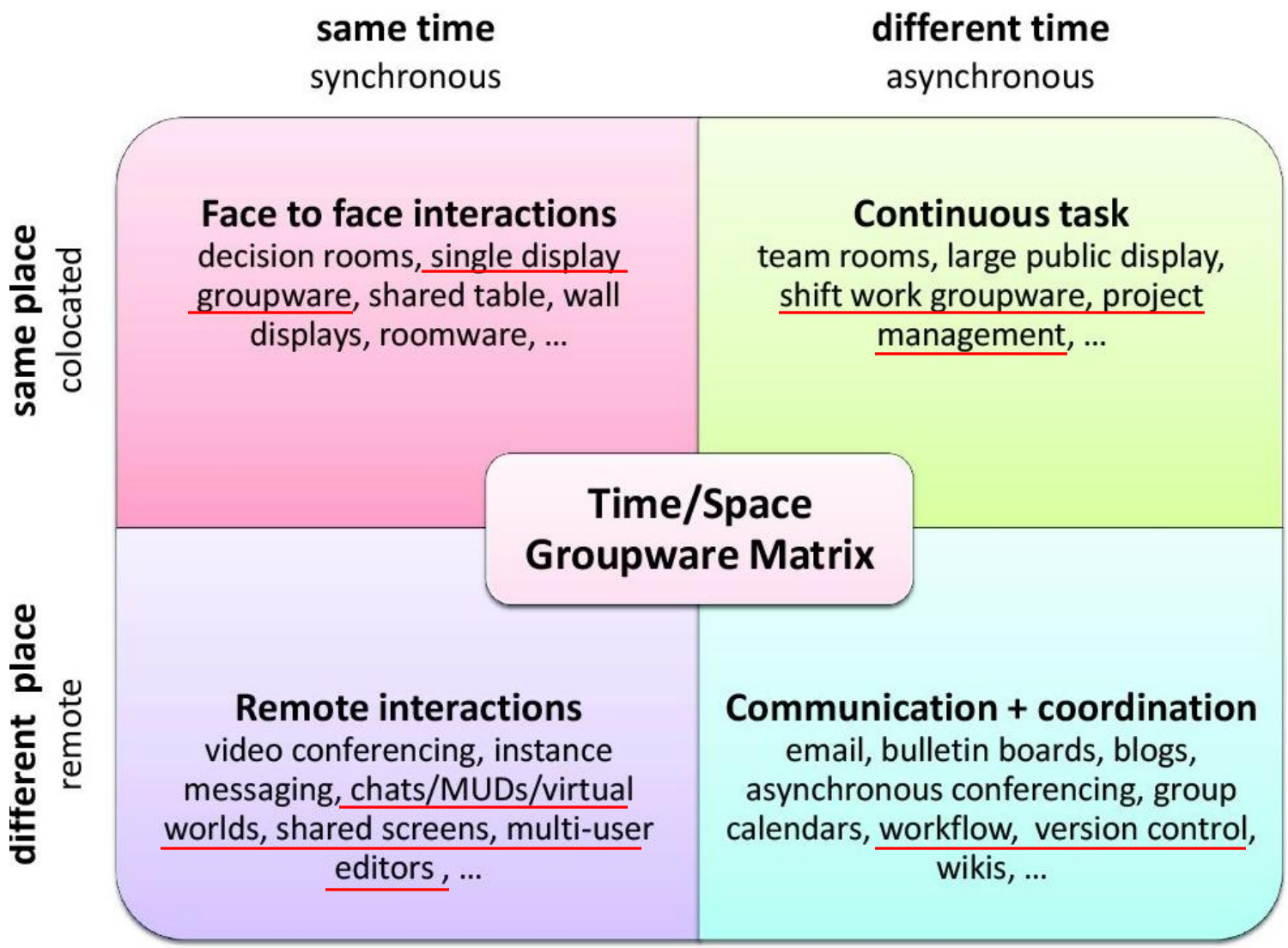
Usage of Conventional Data	Usage of Engineering Data
Isolated work of single users	**Collaborative work** of groups of responsible engineers
Short time required for single tasks (transactions)	**Long sessions (transactions)** to carry out engineering tasks
One-shot read and update accesses	**Interactive and iterative** re-finement of complex objects
One or few application(s) used to access the data	**Diverse applications for different tasks** accessing the same or strongly related data

Collaborative Work

- Members of groups of engineers concurrently and collaboratively working on
  - the same design or
  - different but related aspects of the same design (maybe using different applications/tools)

[Source: The DLR Concurrent Engineering Facility]

- May result in possible conflicts, data loss and inconsistencies
- Resolution mechanisms integrated with management of internal versions and variants, workspaces, check in/check out, etc.



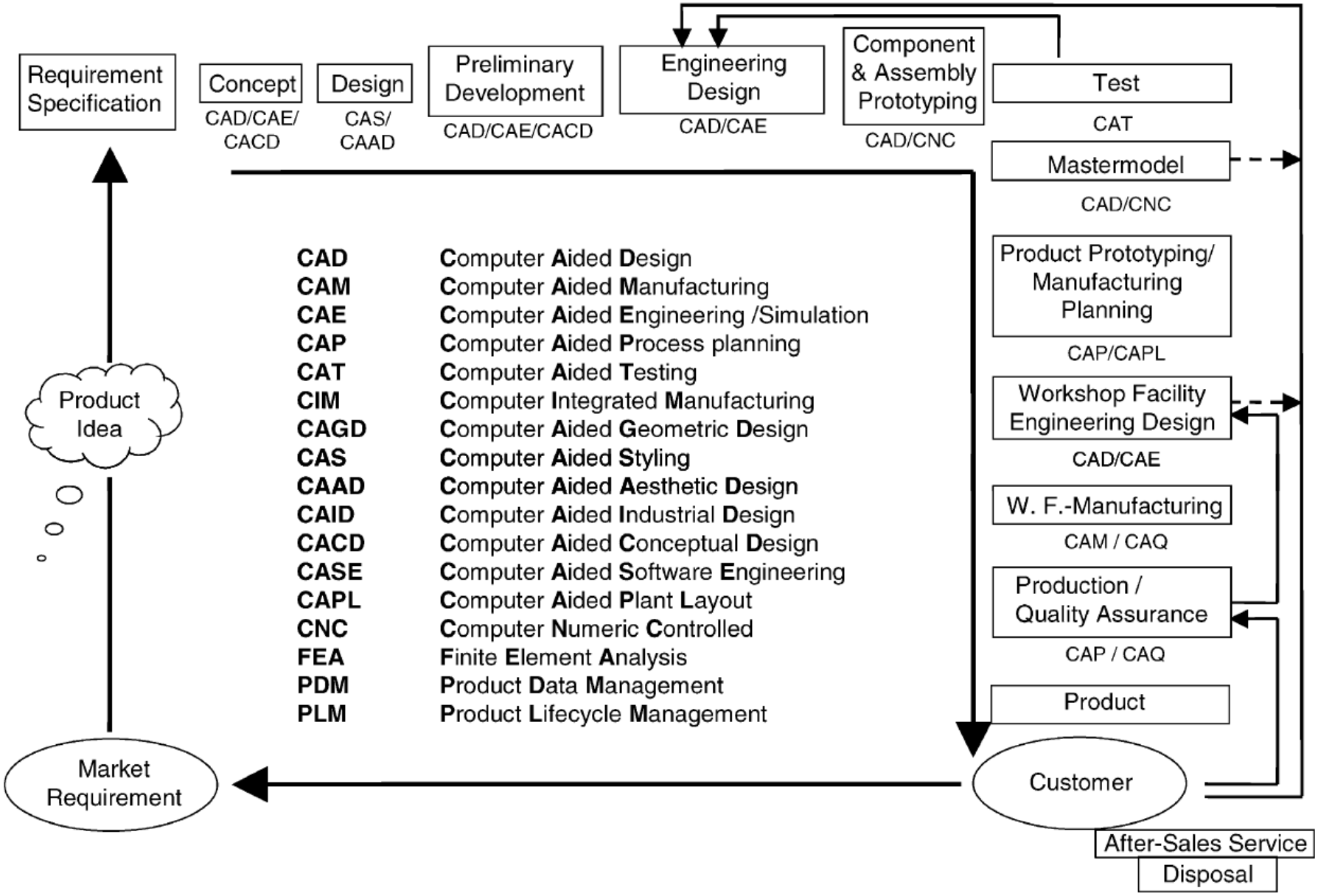
[Source: http://en.wikipedia.org/wiki/Computer-supported_cooperative_work]

Long Transactions

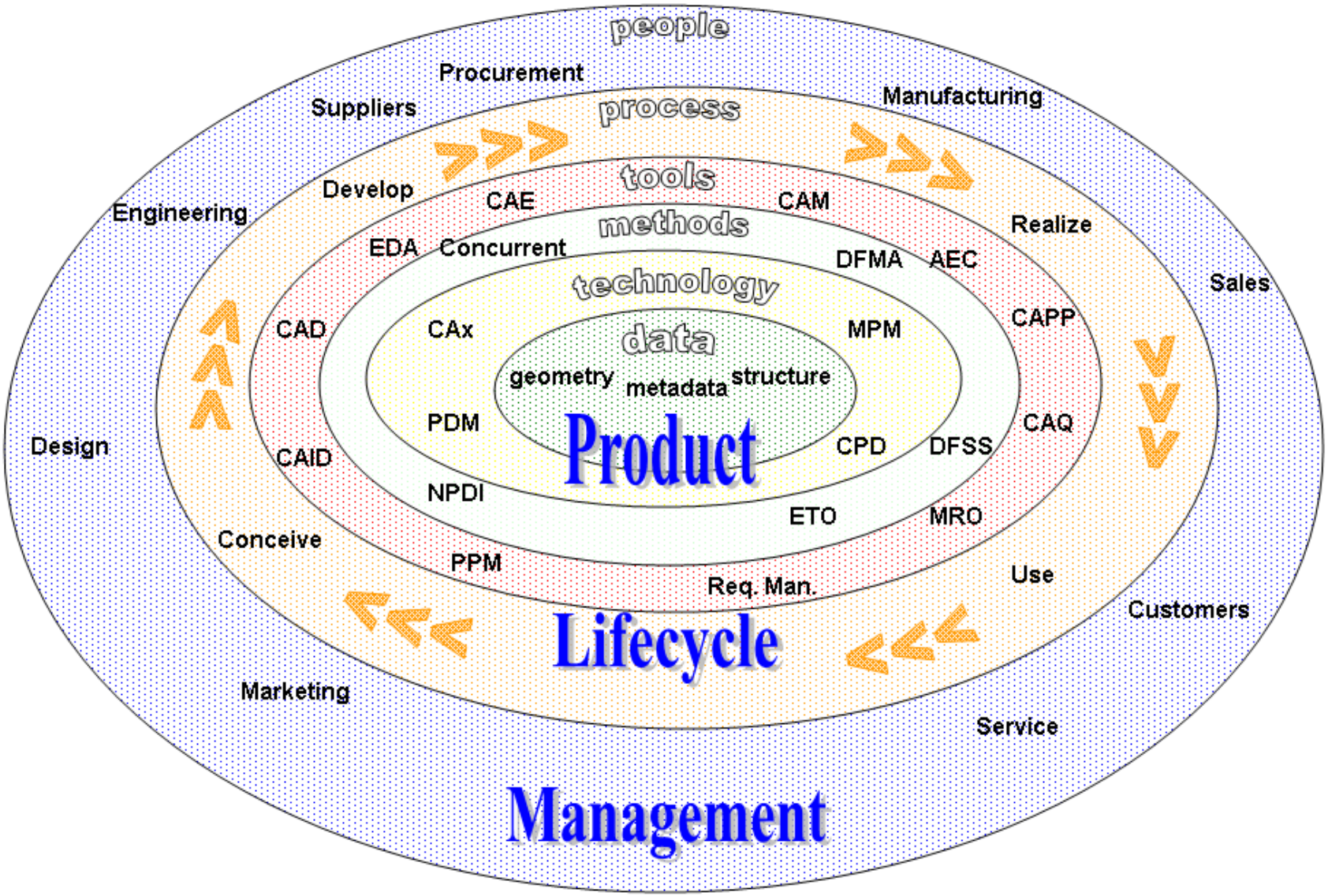
- Product development as creative process: activities typically consistent of long sequences of step-wise and iterative modifications of engineering data
- Processes very loosely structured
- Consistent state may be reached after hours, days, weeks or even longer
- Exclusive access to avoid side-effects data may be prohibitive because of decreased potential for parallel activities

Diverse Applications

- Along product life cycle (including product development phases) engineers may use many different applications with slightly different requirements
- Focus here on
  - CAD (- Design)
  - CAM (- Manufacturing)
  - CAE (- Engineering)
  - PDM (Product Data Management)
  - PLM (Product Lifecycle Management)
- Collaboration (within phases) and processes (across phases) requires interoperability
  - Integration of data (e.g. in one database system)
  - Formats/standards suitable for da excahnge



[Source: Engineers' CAx education—it's not only CAD. Dankwort, Weidlich, Guenther, Blaurock, 2004]



[Source: http://en.wikipedia.org/wiki/Computer-aided_technologies]

Summary (Motivation)

- Engineering applications with very specific requirements regarding data management
  - More complex structures
  - Access patterns focusing on complex objects
  - Usage in creative, interactive and collaborative processes
- Conventional solutions for data management are commonly used in Engineering applications
  - File systems with standardized/proprietary file formats
  - Relational Database Management Systems (RDBMS)
- Advanced data management solutions provide some suitable concepts and are frequently used
  - Object-Relational DBMS
  - Object-Oriented DBMS
  - NoSQL DBMS