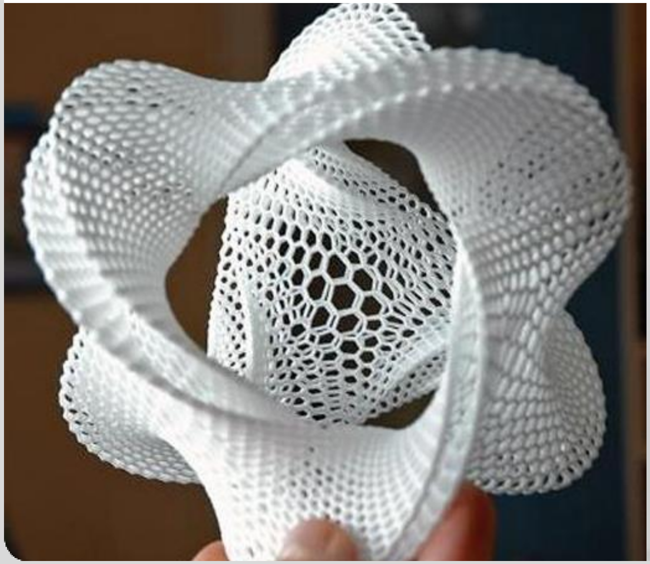
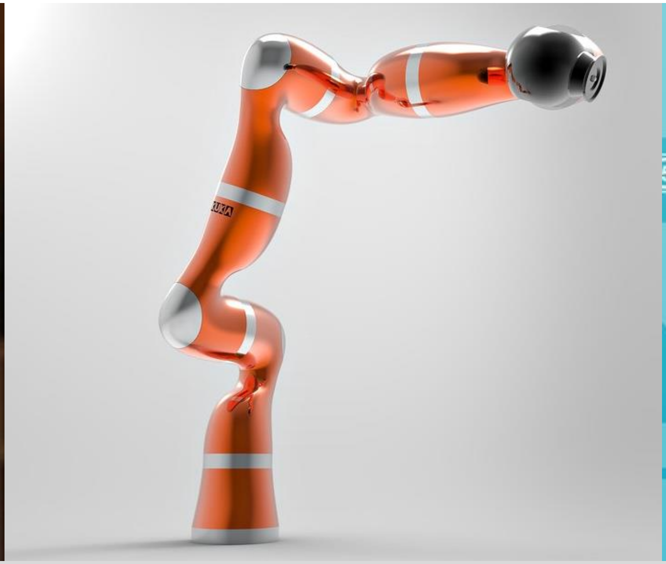
Digital System Integration in the Context of Industry 4.0

Digital Manufacturing **Keynote ACHI 2017**

Dr. Steffen G. Scholz **22.03.2017**

INSTITUTE FOR APPLIED COMPUTER SCIENCE



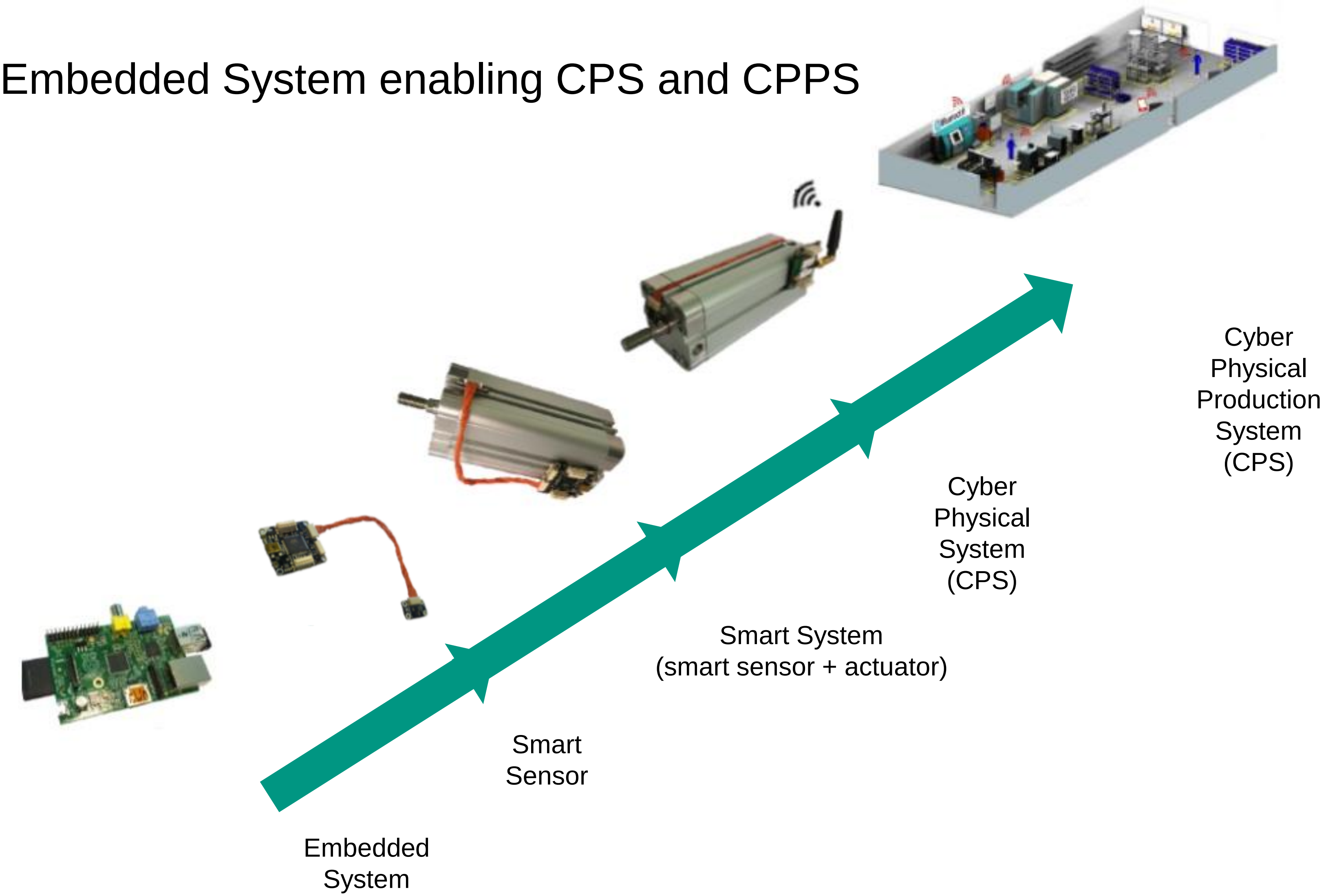


Overview

- Introduction
- Industry 4.0
- Flexible manufacturing
- Digital printing materials
- Tailored applications
- Conclusion

Introduction

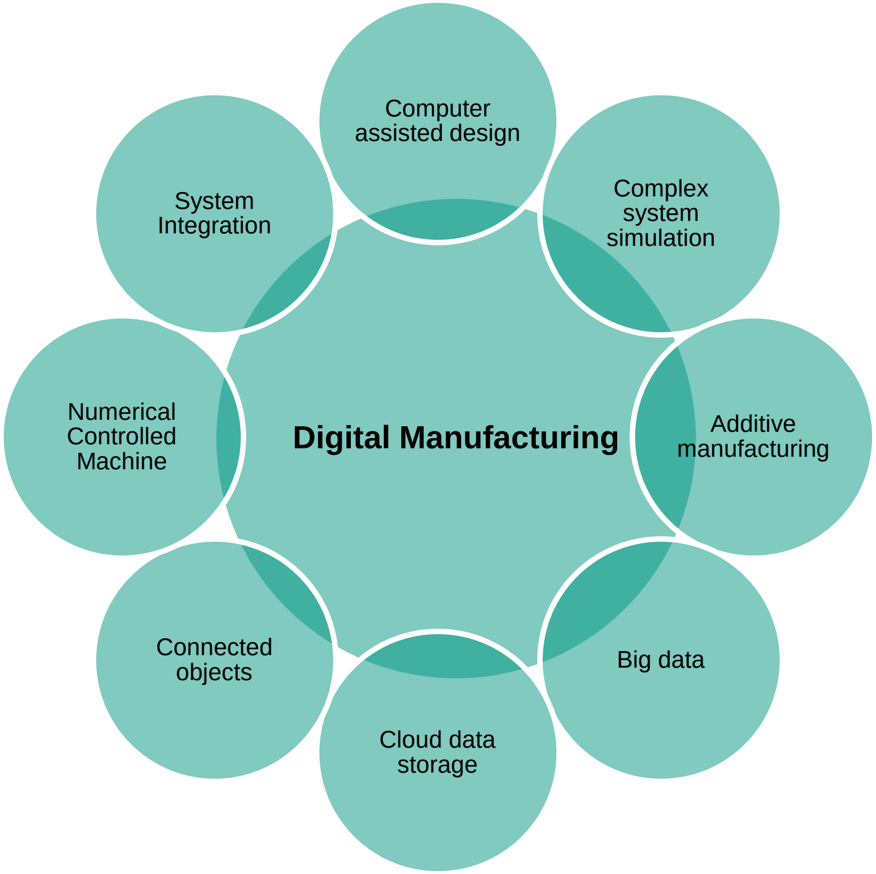
- Embedded System enabling CPS and CPPS



Source: University Darmstadt

Introduction

- Convergence of information and operational technologies



INDUSTRY 4.0
as part of the Internet of thing

The Internet of Thing

" We define the internet of things as sensors and actuators connected by networks to computing systems. These systems can monitor or manage the health and actions of connected objects and machines. Conneted sensors can also monitor the natural worlds, people and animals. "

McKinsey Global Institut

The Mission

Karlsruhe Institute of Technology

A world always more connected

1995
15 million
people with
internet
access

1997
6 million
object with
internet
access

2020
50 billion
objects
connected
to Internet

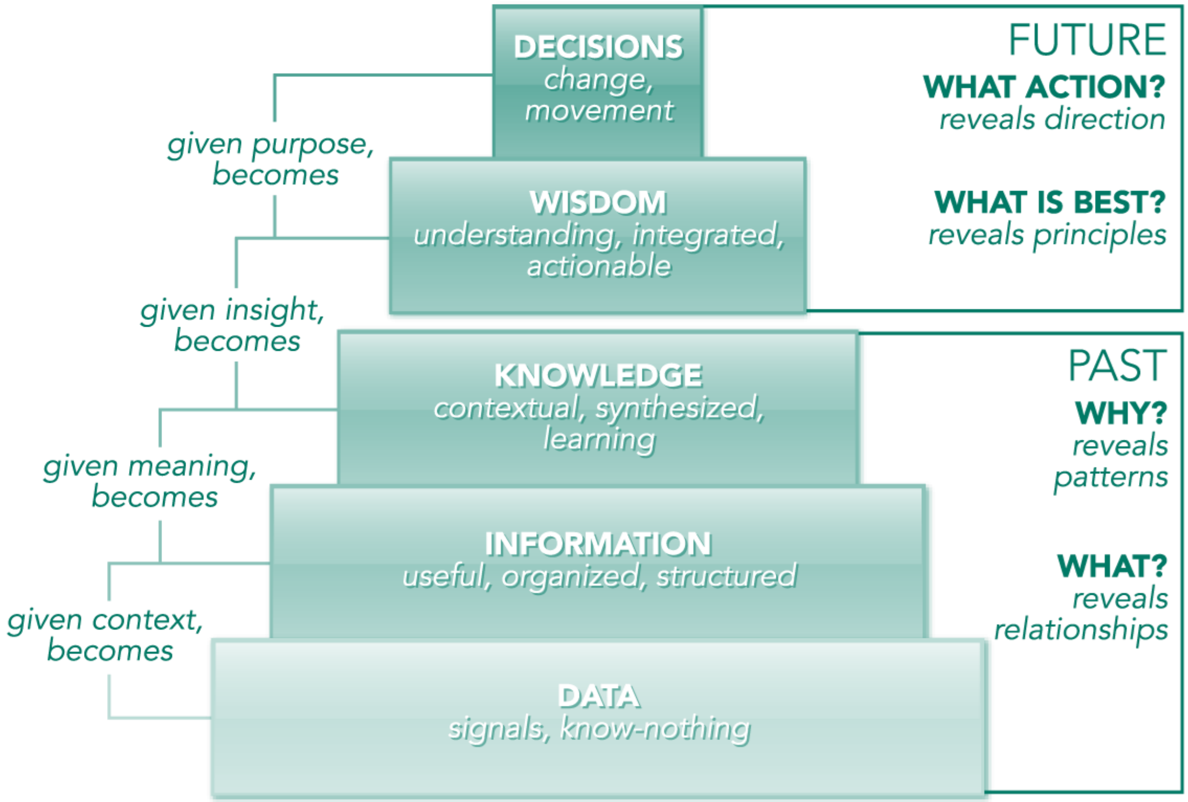
2020
7 billion
with
internet
access

Source: Bosch


Self organised and distributed artificial intelligence
Fast and automatic network integration , highly flexible
Open standards
Virtual real-time image
Digital integrated life-cycle-management
Safe and secure added-value networks
Humans as actors and in the centre

New paradigm

- How to compute the enormous quantity of data comming from sensors and convert it in value creation?

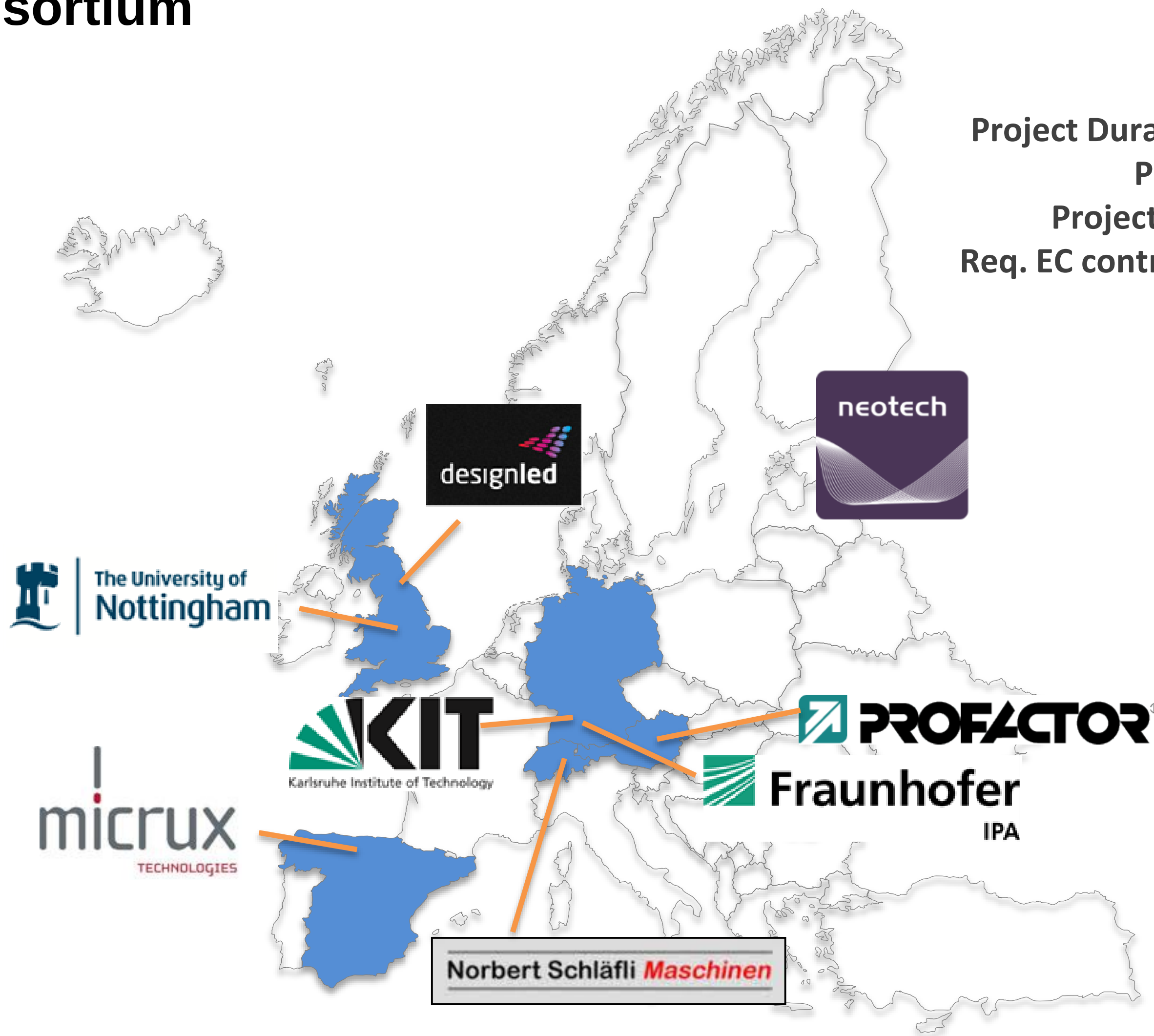


Source: AGT

Flexible Manufacturing Example: Project SMARTLAM

Flexible Manufacturing

The consortium



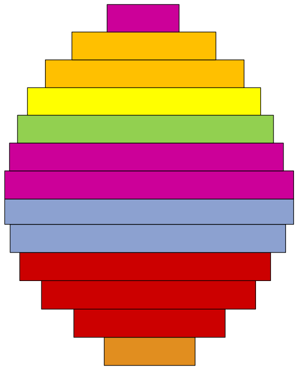
Project Duration: 2012/10-2016/01
Project Number: 314580
Project Volume: 4.1 mio Euro
Req. EC contribution: ca. 3 mio Euro

4 R&D partners
2 Technology partners
2 Reference customers

Flexible Manufacturing

The ambitious vision

Design for traditional fabrication processes



Design for SmartLAM fabrication processes

Stacking of thin polymer films, each with specific properties utilizing advanced film material and surface properties for batteries, wiring, sensors and fluidics (structures and printed components)

Flexible Manufacturing

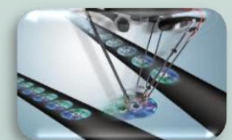
Targets & topics

Project targets

- Capability to rapidly produce 3D mechatronic micro systems
- Increased flexibility and scalability of processes
- Reduced energy consumption
- Reduction of development and sale up time
- Product quality improvement
- Waste reduction and reduced impact on the environment

R&D Topics

3D-I Modelling
& design approach



3D-I compatible
production platform

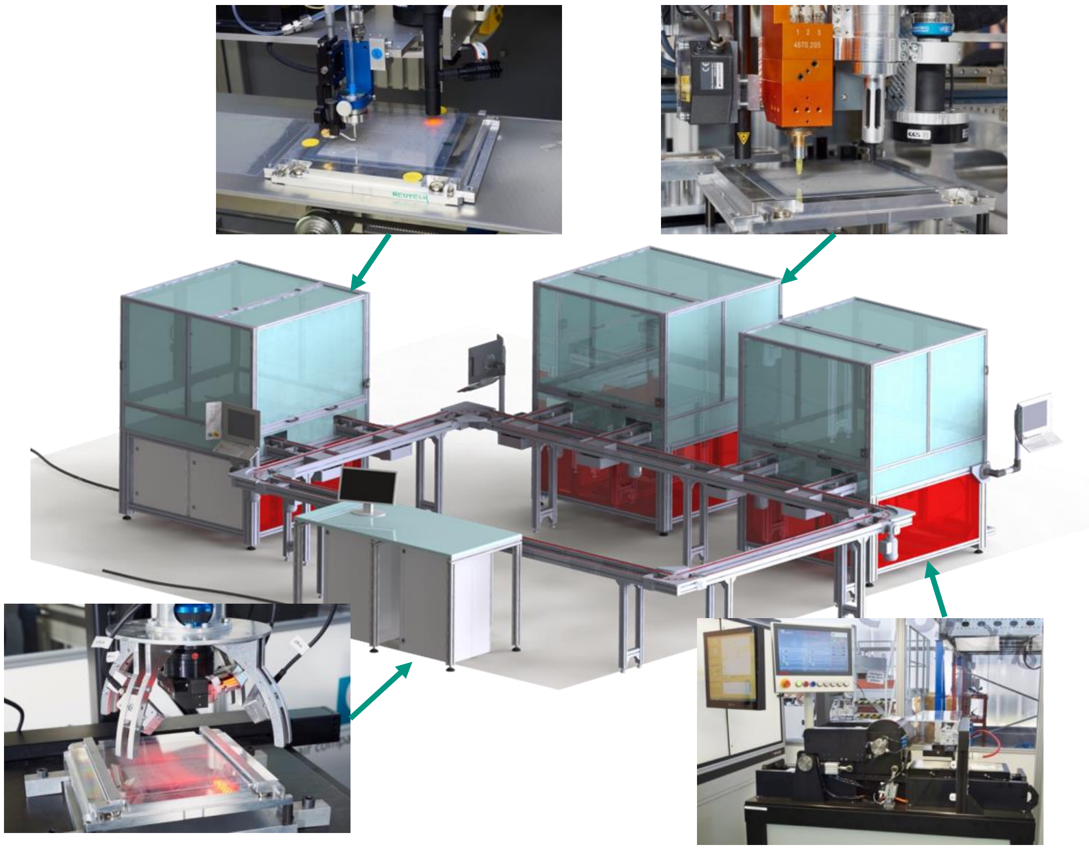
SMARTLAM
adaptive control and
vision inspection

Flexible Manufacturing

SMARTLAM

KIT Karlsruhe Institute of Technology

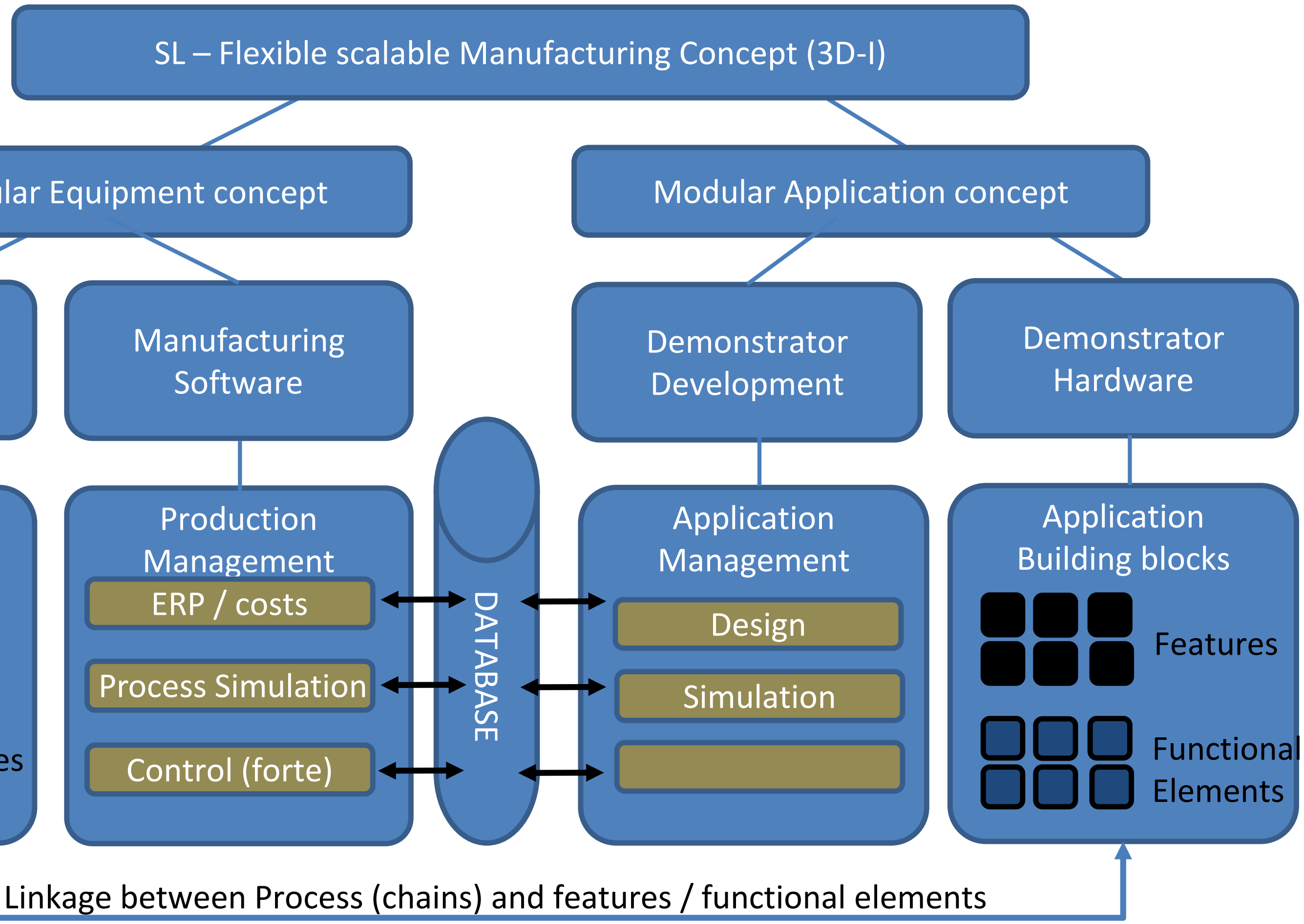
Modularity concept



- SMARTLAM 6 modules
  - Lamination
  - Laser welding
  - Laser structuring
  - Printing module (aerosoljet printing)
  - Assembly
  - Inspection

Flexible Manufacturing

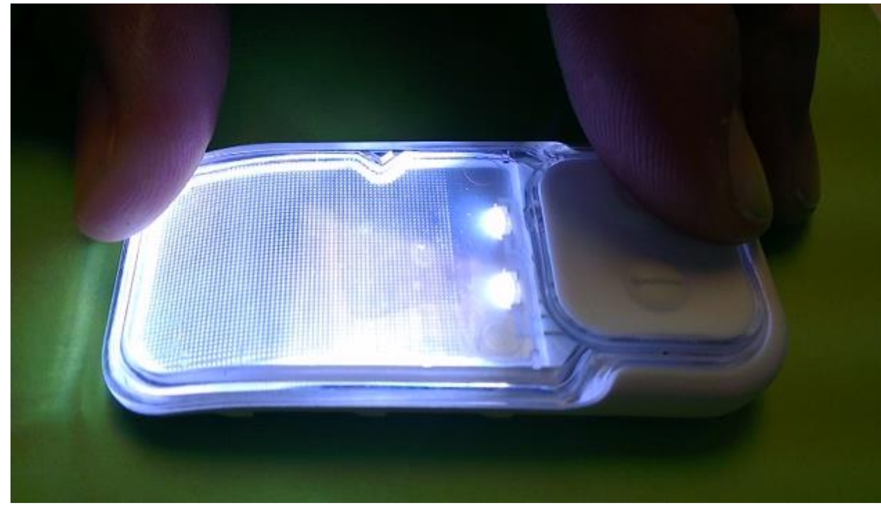
Project overview

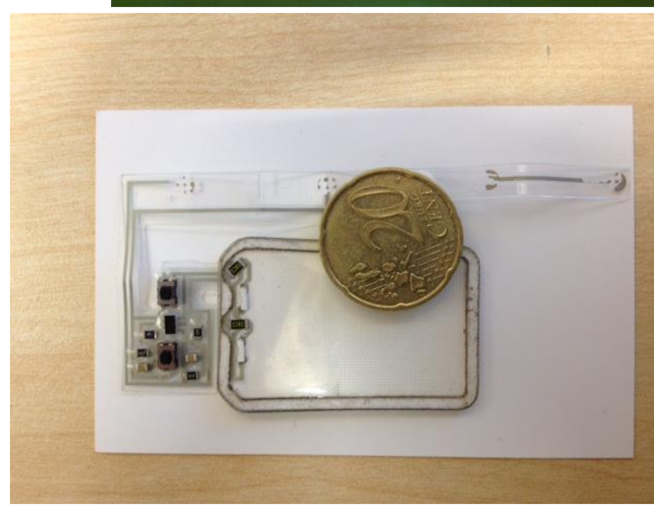


Flexible Manufacturing

Application 1 – LED lighting

- Light source embedded into surgical instrument
- Product includes 1. planar light-guide LED chip source, electronic control, switch and power source
- Sealed and to have high hermiticity for medical accreditation.
- Custom size and light specifications for different surgical procedures
- Specification will evolve over time
- Disposable
- Cost/volume critical – e.g. Veterinary market





Source: DLED

Additive Manufacturing in the context of Industry 4.0

Additive Manufacturing
Definition & Timeline

- Definition of AM:
  - „The process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies, such as traditional machining“[1]

- Typical technologies:
  - Laser/Light Polymerization (e.g. stereolithography)
  - Laser Melting (e.g. selective laser sintering, selective laser melting)
  - Extrusion processes
    (e.g. fused filament fabrication, fused deposition modeling)
  - Material jetting (e.g. inkjet printing or multijet modelling)
  - Adhesive based processes (e.g. laminated object manufacturing)
  - Electron beam manufacturing (EBM)

[1]Source: ASTM Standard. Standard terminology for additive manufacturing technologies, vol 10.04

Additive Manufacturing
Definition & Timeline

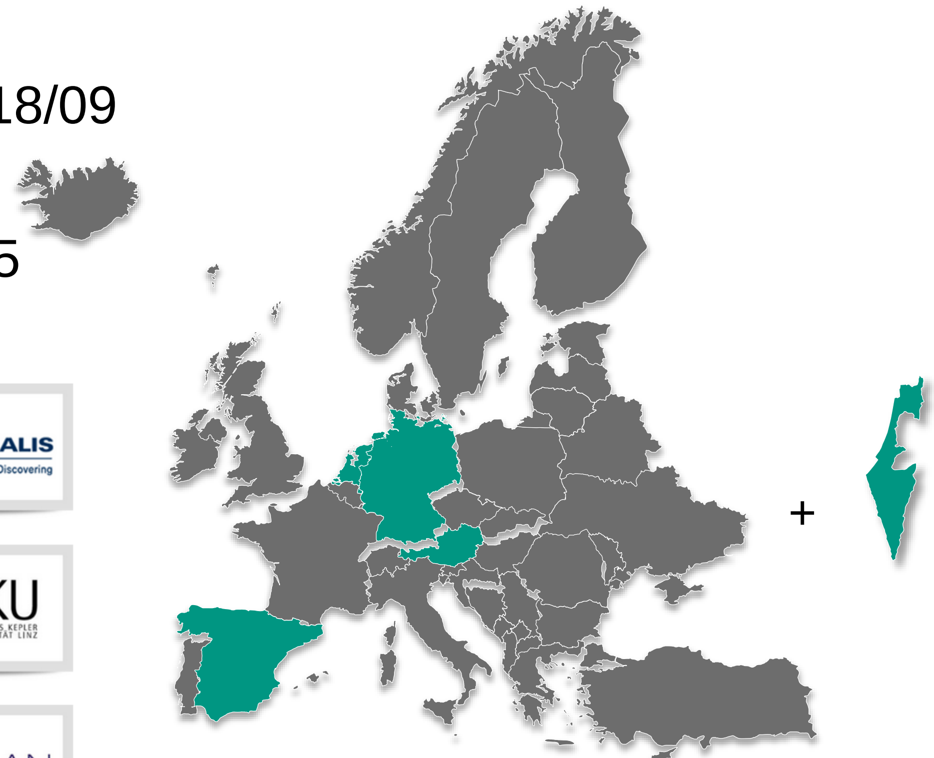
- 2000-2010:
  - Build platforms are getting bigger, resolution is getting better, building time is reduced and prices for machines start to get lower
  - New materials are available: Nanocomposites, high-elongation materials, hight temperature resistant materials, improved mechanical properties and bio-compatible materials
  - Formation of ASTM comittee for producing standards on testing, processes, materials, design and terminology in AM
  - EnvisionTec introduces first stereolithography machine using direct light processing (DLP) technique

- 2010-now:
  - AM is adopted by many industries as a valid production method
  - Capabilities of machines are extended even further (materials, resolution, build sizes)
  - AM is reaching the private sector with affordable FDM, SLA and DLP printers

Additive Manufacturing

The project consortium

- European project und H2020 programme
- 12 partners from 5 countries
- Project duration : 2015/10-2018/09
- Budget : 5M €
- Call: H2020-NMP-PILOT-2015
- Project number : 685937



DiMAP DIGITAL MATERIALS FOR 3D PRINTING

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Polyjet technology

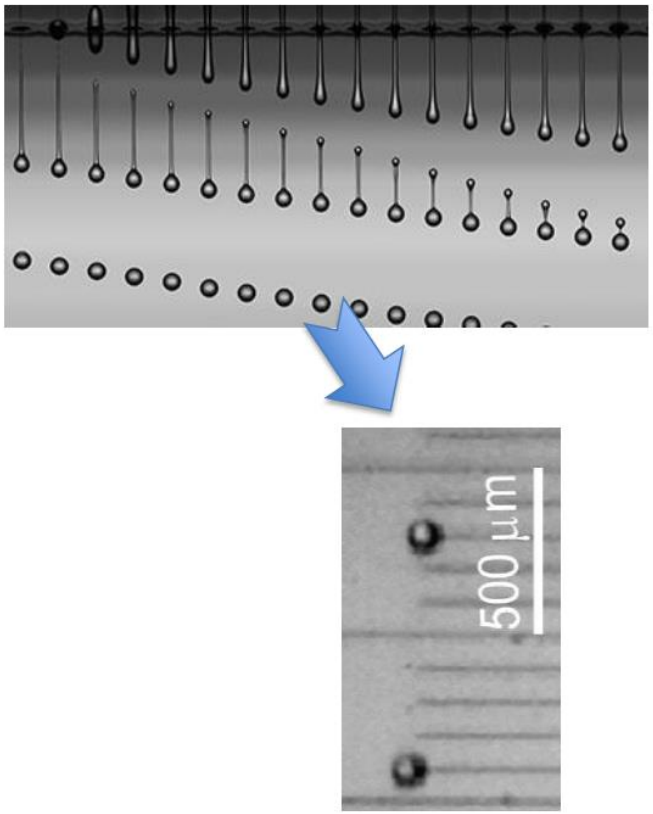
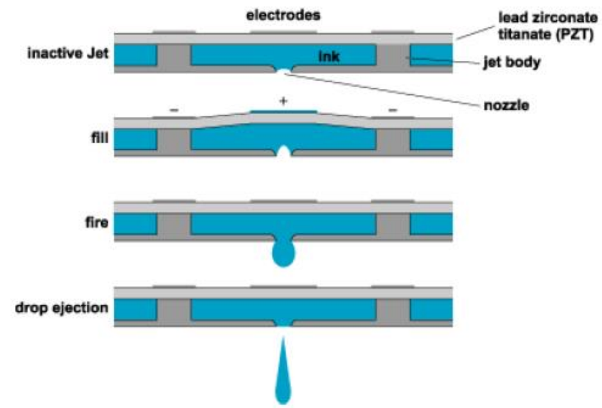


Image Courtesy of Stratasys Ltd



Few numbers….

100’s of jets per head

30-80 nanograms drops

± 10 microns drop accuracy

± 5% drop to drop uniformity

Up to 40 KHz jetting frequency

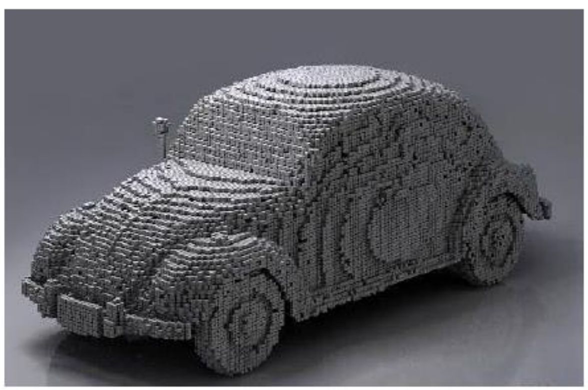
Source: Stratasys

Polyjet technology

Voxel (volumetric pixel):

a volume element representing a value on a regular grid in three dimensional space.

This is analogous to a pixel, which represents 2D image data in a bitmap.



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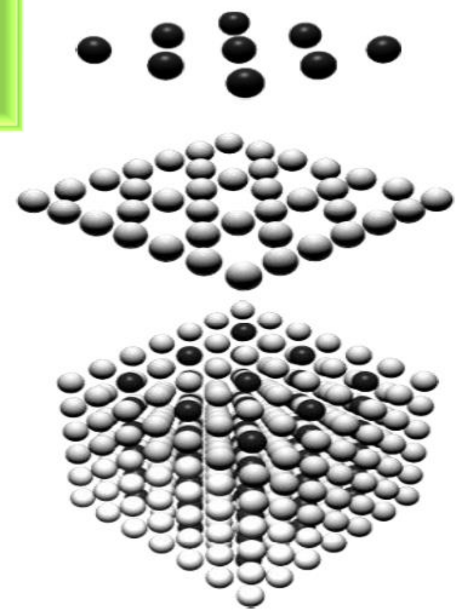
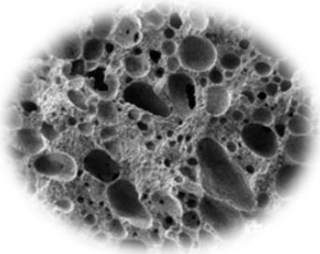


- Black rubbery material (Tango +)
- White rigid material (Vero white)
- ✓ Grey scale
  ✓ Shore hardness scale

Source: Stratasys

Material development

- Ceramic enhanced material
- Lightweight polymer material



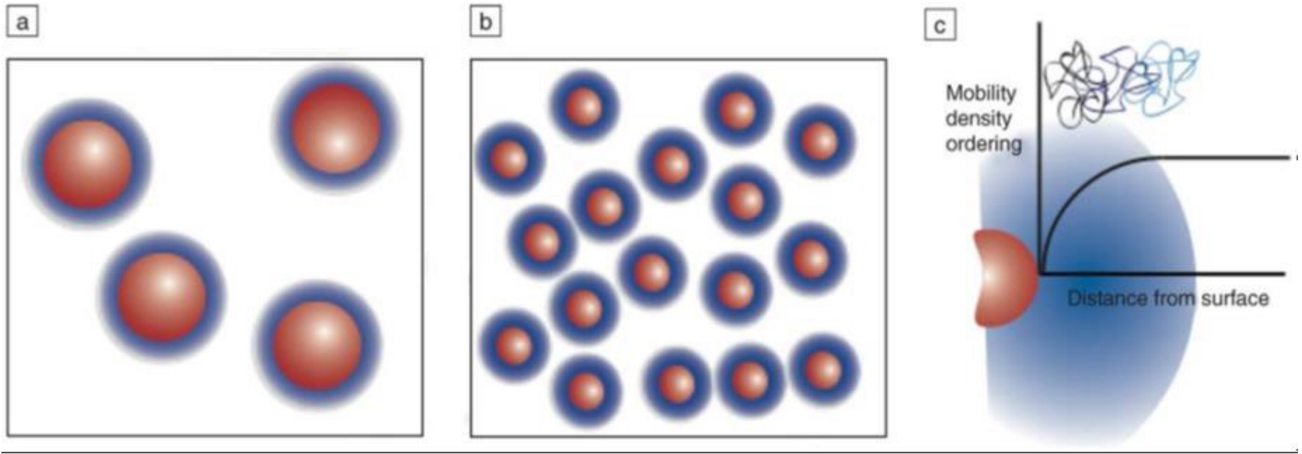
- Electrically conductive material
- High strength polymer material

Ceramic ink

Concept of requirements for ceramic inks

Frame conditions given by the process and the aspired applications:

- Maximum particle defined by printhead's orifice: d100< 500 nm
- Too much NANO is not helpful -> Increased viscosity



Compromise:
"Large" nanoparticle size and small specific surface areas needed

- a) Microsizedparticles, b) nanosizedparticles, c: Change of polymer mobility with distance from **ceramic nanoparticles**, showing a pronounced amount of immobilized polymer in the composite **causing a pronounced viscosity increase**.

Additive Manufacturing

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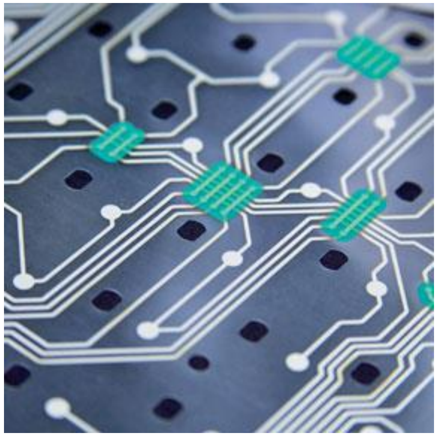
Conductive ink



Classic:

- Screen Printing and Photolithography

3D Printing:

- No material yet available

-> Polymer with silver nanoparticle

-> concurrent properties:

  - Low Viscosity
  - Low resistivity (High metal content)
  - Surface tension
  - Small non agglomerate particles

Parameter	Requirement	Description
Solids %	≤50% w/w (as starting points)	
Particle size	D(50) = 75-90 nm d(90) = 95-130 nm	
Viscosity	12-20cP at printing temperature (<60°C)	It is not recommended to heat PVN inks above 60°C
Surface tension	25-35 dyn/cm	
Stability test at room temperature (1 month) (Shelf life test)	Viscosity change ≤5% Particle size change ≤5%	Re-dispersible by mild shaking
Stability test at 60°C (8, 24 hours) (Stability during printing time)	Viscosity change ≤5% Particle size change ≤5%	
Accelerated sedimentation rate	<0.38 µm/sec @T=10% transmission	Tested with Lumisizer centrifuge
Jetting test	Jetting latency > 10min	

DIGITAL MATERIALS FOR 3D PRINTING

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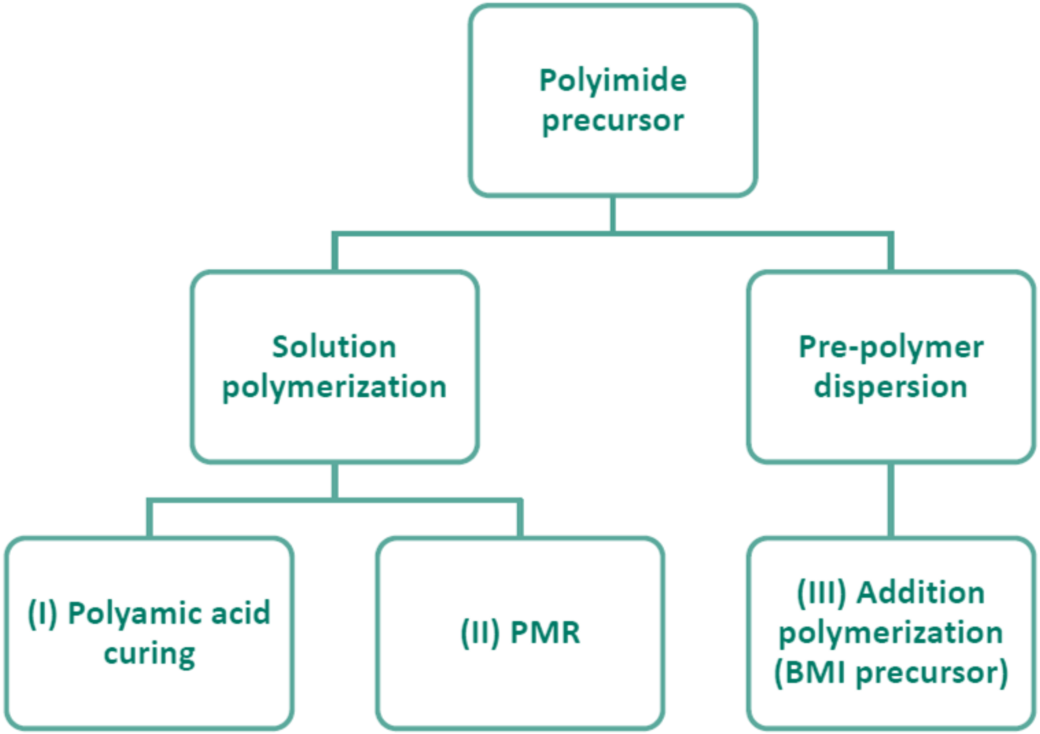
High strength ink



- High viscosity of polyimide precursors
- Slow kinetics
- High temperature tolerance needed
- Solution polymerization is a challenging process for inkjet formulation

Initial ink requirement (STR) reveal basic limitations of solution polymerization approach

Novel approach to be studied

Additive Manufacturing - Applications

Multi material

- Creation of parts with functionally graded materials:
  - Hardness
  - Flexibility
  - Adhesive properties
  - Stiffness
  - Color

Image Courtesy of Kiril Vidimce

Image Courtesy of Synthesis Design + Architecture

Images Courtesy of Massachusetts Institute of Technology

- Possible Applications:
  - Compliant joints
  - Artistic sculptures
  - Heat Dissipation

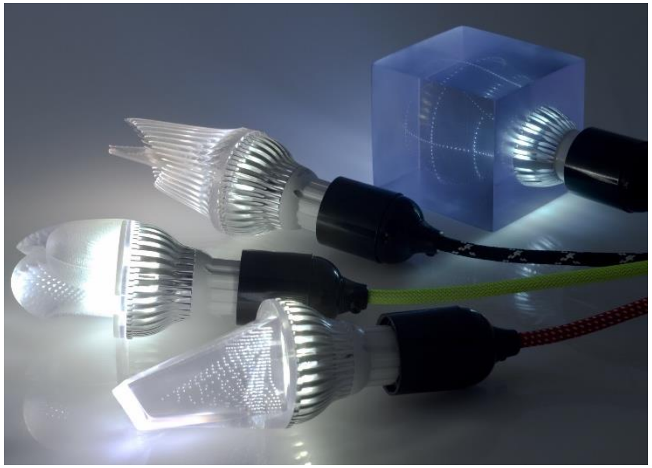
Image Courtesy of Stratasys Inc.

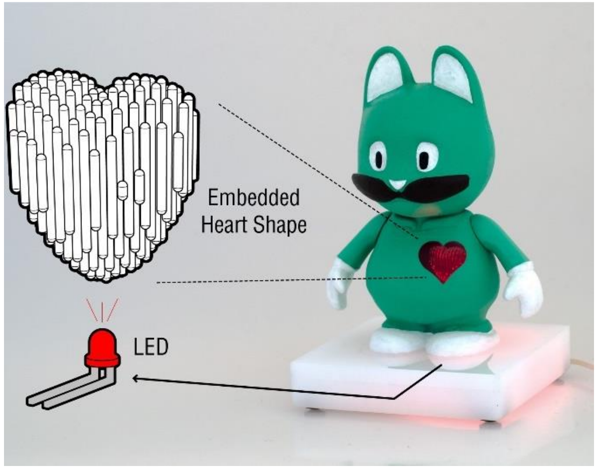
Additive Manufacturing - Applications

Embedded components

- Objects can be embedded due to layer-by-layer build-up
  - Circuits
  - Sensors
  - Monitors
  - Threaded rods
  - Etc.

Image Courtesy of Berkeley University





Images Courtesy of Disney Research

- Possible Applications:
  - Toys
  - Lighting devices
  - Food monitors

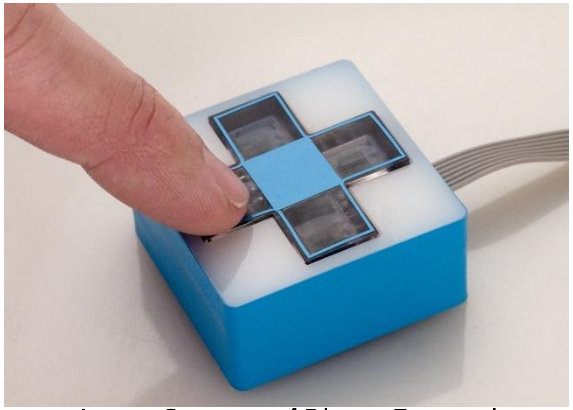


Image Courtesy of Disney Research

Additive Manufacturing - Applications

Printed electronics

- Pre-Assembled Parts directly printed
  - Use of sacrificial support material
  - Gaps of few hundreths µm between parts
  - Removal of support leaves captive assembled linkage
- Possible Applications:
  - Physical Working models
  - Locomotive robots
  - Articulated Models
  - Prosthetics

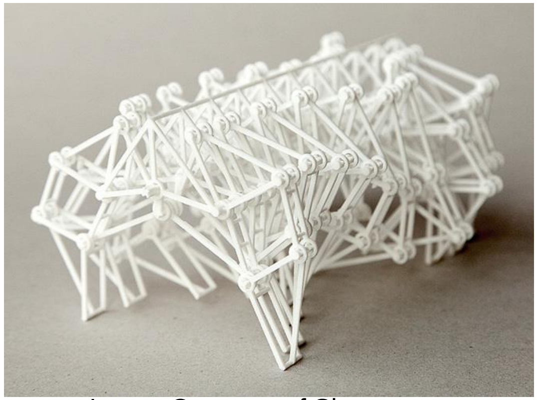
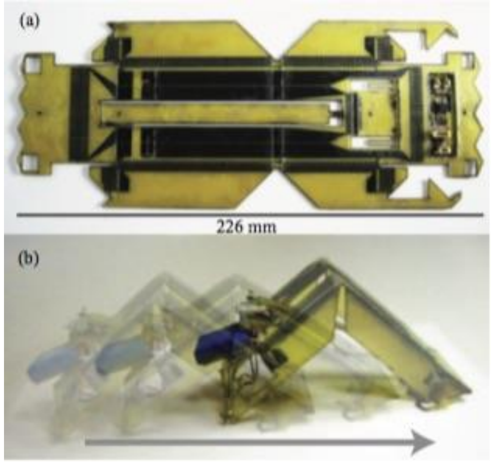


Image Courtesy of Shapeways

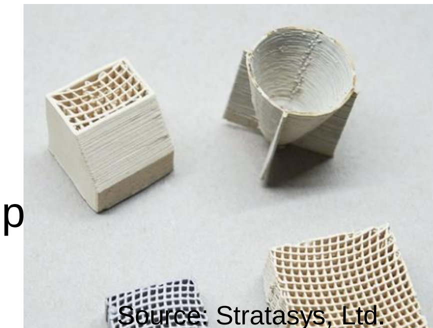


S.M. Felton et al. „Robot Self-Assembly by Folding: A Printed Inchworm Robot“, ICRA Conference 2013

M. Bächer et al. „Fabricating Articulated Characters from Skinned Meshes“, ACM Trans Graph, 31 (4), 2012

Additive Manufacturing – Trends & Challenges

- Materials:
  - Broadening of available materials; solid loaded inks & polymers
  - Digital materials & integration of discrete parts
  - Biomaterials (tissue scaffolds, organs)
- Design:
  - Specific tool representing AM functions & interactions; simp designing complex shapes
- High throughput & build size
  - Multinozzle array print hea
  - Integration of additional pr g)
  - Large scale parts
- Modeling, Sensing and Proc
  - Transport phenomena, ten od
  - Access to build chamber fo
  - Integration of control algor ts of building process



Source: Stratasys, Ltd.

Image Courtesy of Shapeways

Conclusion

- A New Industrial Revolution of connected objects is happening
  - IT Advances:
    - Cloud storage
    - Calculation capacities
  - Operation Technologies advances:
    - Digital system Integration
    - AM processes
    - Materials
- Changes to come:
  - Mass customisation
  - Higher productivity (predictive maintenance, automatization, …)
- It is up to us to make this revolution Human-Centred
  - Improvement of Human-machine interface
  - Telepresence
  - Training

Acknowledgements

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SMARTLAM FP7 FOF.NMP.2012-5; GA-Number 314580

DiMAP DIGITAL MATERIALS FOR 3D PRINTING H2020-NMP-PILOTS-2015; GA-Number 685937