Universitetet i Stavanger

Hirpa G Lemu, Professor,
Institutt for maskin, bygg og materialteknologi

Development progresses of AM Technology and Facilities/ Activities at UiS

AM dagen, UiS

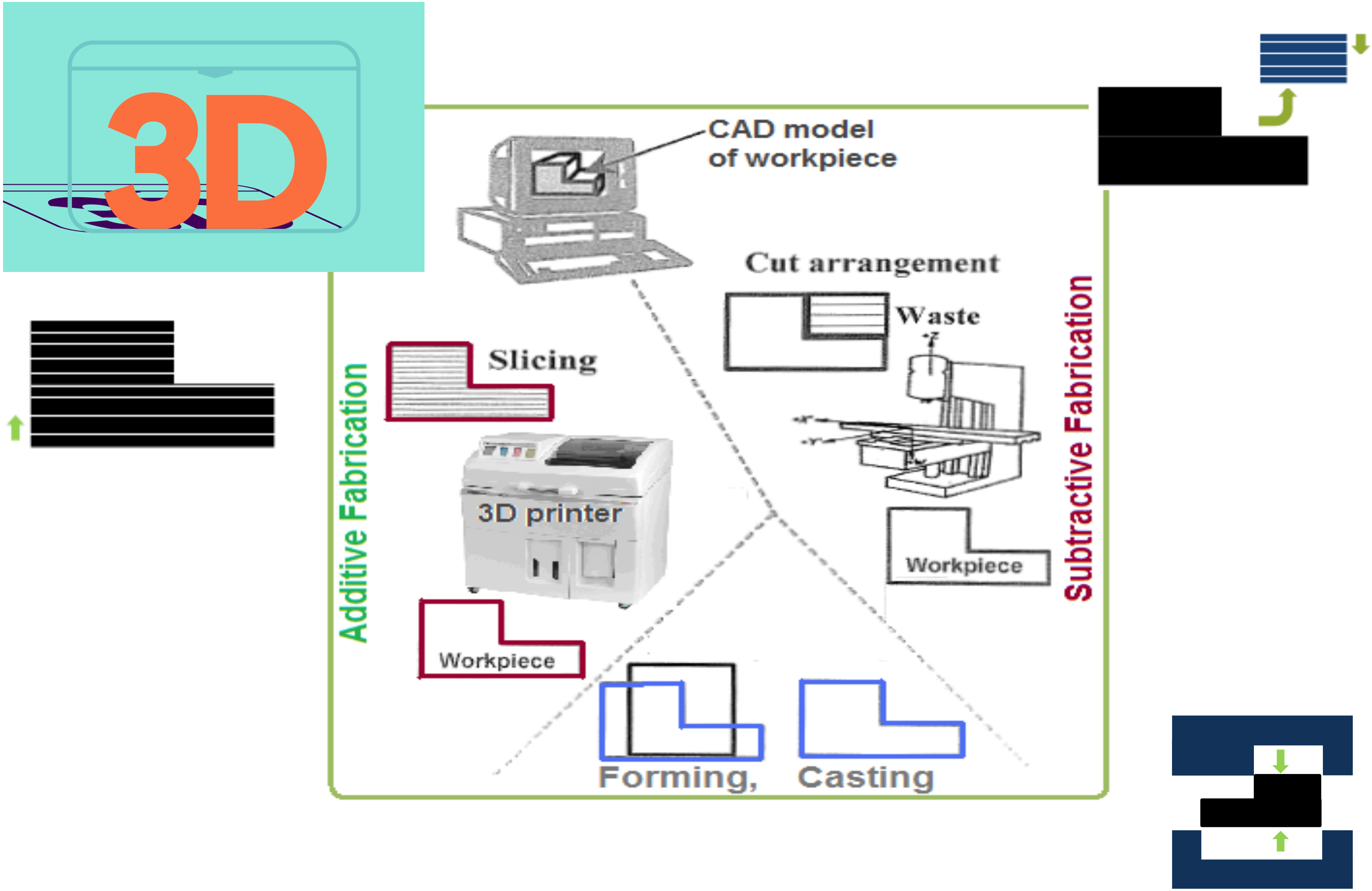
12.09.2019

NÆRINGS FORENINGEN
Gir kraft til vekst

Universitetet i Stavanger

equinor

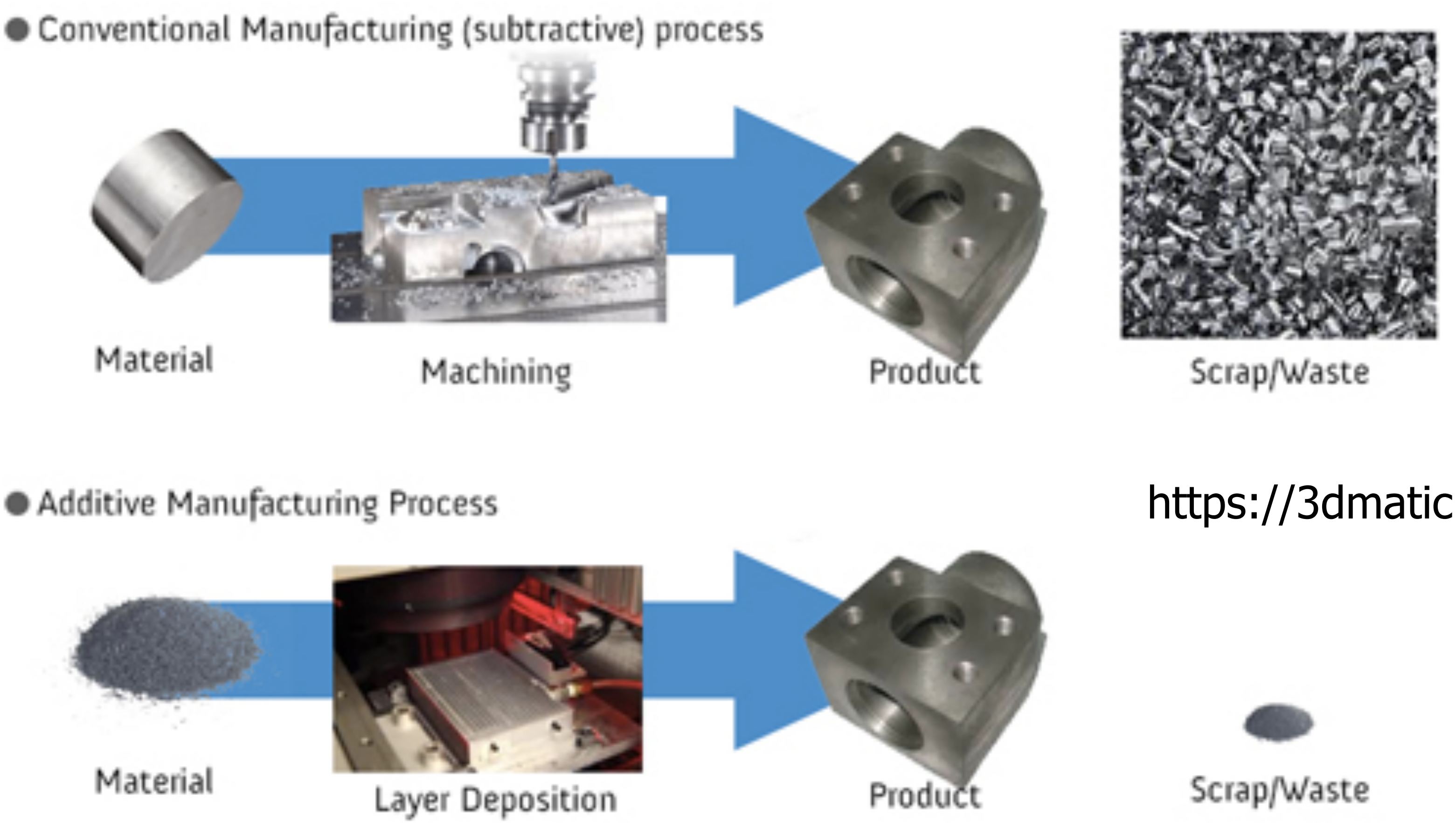
The Concept



3D
CAD model
of workpiece
Cut arrangement
Waste
Slicing
3D printer
Workpiece
Workpiece
Additive Fabrication
Subtractive Fabrication
Forming,
Casting

Additive vs. subtractive

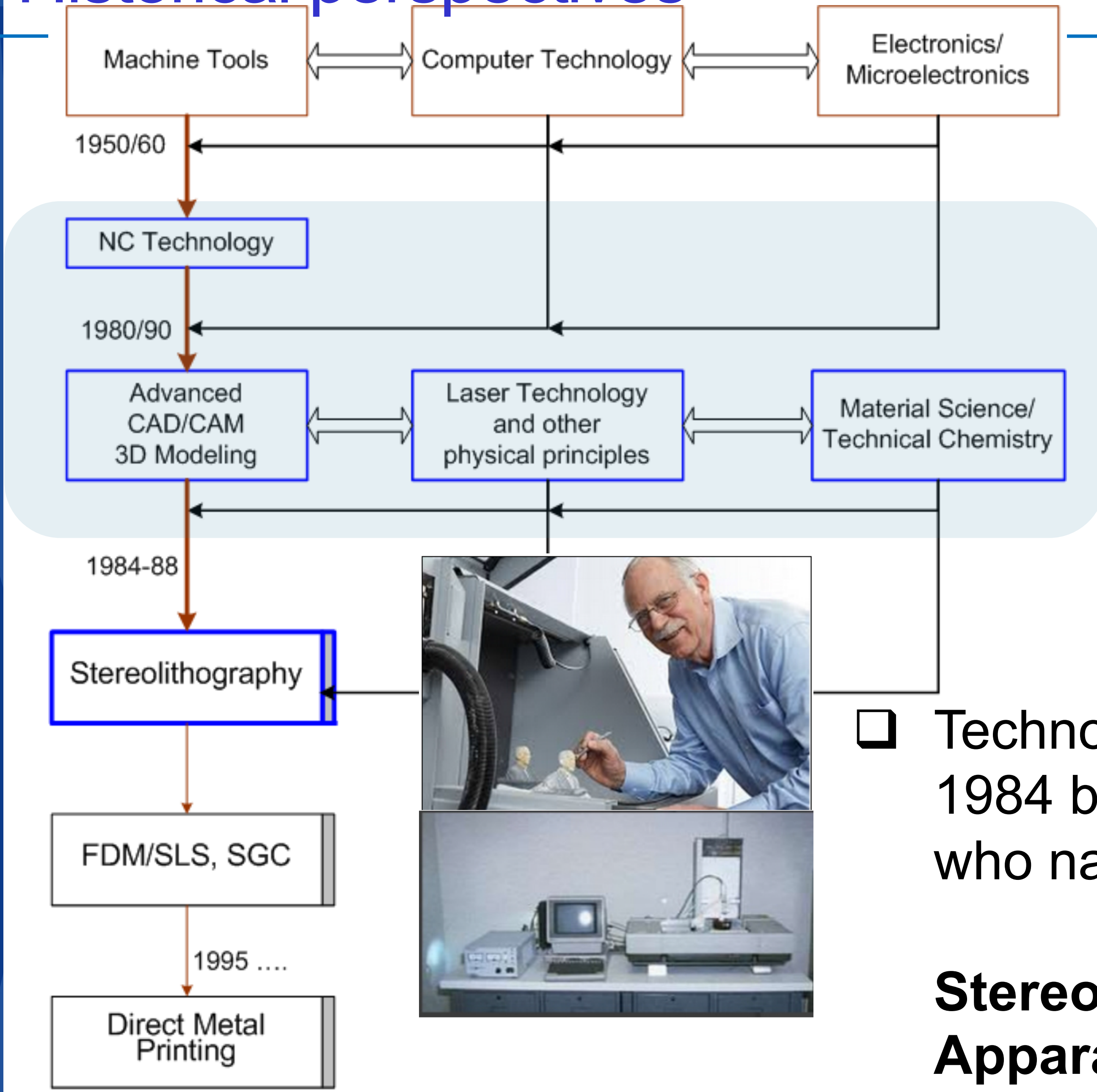
- AM processes, particularly that of polymer materials, lead to a no/very low waste manufacturing system.



https://3dmatic.com.au/

More green manufacturing

Historical perspectives



- Technology invented in 1984 by Charles Hull, who named it

Stereo lithography Apparatus (SLA)

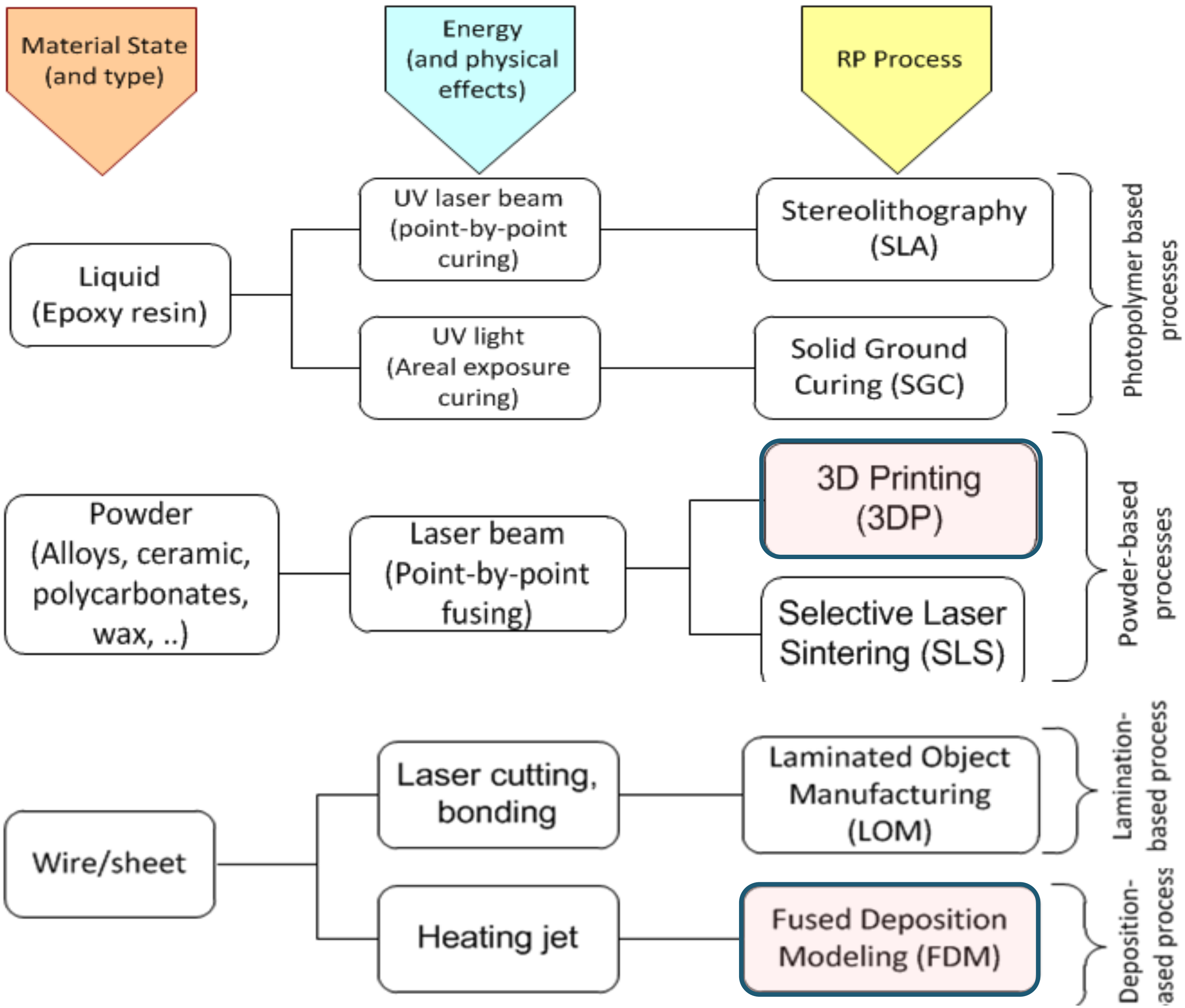
Many technologies/companies are appearing

1. 3D Systems Inc., USA
2. 3D-Micromac AG, Germany
3. Arcam AB, Sweden
4. Aeromet Corp., USA
5. Alpha Products and Systems Pte Ltd, Singapore
6. Blizzident, USA
7. CAM-LEM Inc., USA
8. Carl Zeiss Pte Ltd, Singapore
9. Champion Machine Tools Pte Ltd, Singapore
10. CMET Inc., Japan
11. Concept Laser GmbH, Germany
12 Creatz3d Pte Ltd, Singapore
13. Cubic Technologies Inc., USA
14. Cubital Ltd., Israel
15. Cybron Technology (S) Pte Ltd, Singapore
16. Defense Distributed, USA
17. EnvisionTec., Germany
18. Ennex Corporation, USA
19. EOS GmbH, Germany
20. Festo, Germany
21. Fraunhofer-Institute for Applied Materials Research, Germany
22. Fraunhofer-Institute for Manufacturing Engineering and Automation, Germany
23. Innomation Systems and Technologies Pte Ltd, Singapore
24. Kira Corporation, Japan
25. MCOR Technologies, Ireland
26. Meiko's RPS Co., Ltd., Japan
27. MIT, USA
28. Materialise, Belgium
29. Optomec Inc., USA
30. RegenHU Ltd, Switzerland
31. SLM Solutions, Germany
32. Solid Concepts, USA
33. Solidimension Ltd., Israel
34. Solidscape Inc., USA
35. Soligen Inc., USA
36. Stratasys Inc., USA
37. Teijin Seiki Co. Ltd, Japan
38. The ExOne Company, USA
39. ThreeASFOUR, USA
40. voxeljet AG, Germany
41. Zugo Technology Pte Ltd, Singapore

Source

Chee Kai Chua and Kah Fai Leong
3D PRINTING and ADDITIVE MANUFACTURING
PRINCIPLES AND APPLICATIONS
(The 4th edition of Rapid Prototyping: Principles and Applications)

The process



Material State (and type)
Energy (and physical effects)
RP Process
Liquid (Epoxy resin)
UV laser beam (point-by-point curing)
UV light (Areal exposure curing)
Stereolithography (SLA)
Solid Ground Curing (SGC)
Photopolymer based processes
Powder (Alloys, ceramic, polycarbonates, wax, ..)
Laser beam (Point-by-point fusing)
3D Printing (3DP)
Selective Laser Sintering (SLS)
Powder-based processes
Wire/sheet
Laser cutting, bonding
Heating jet
Laminated Object Manufacturing (LOM)
Fused Deposition Modeling (FDM)
Lamination-based process
Deposition-

Process Classification

Seven major material processing categories:
American Society for Testing and Materials (ASTM)

	Binder jetting	Direct energy deposition	Material jetting	Material extrusion	Powder bed fusion	Polymerization	Sheet lamination
Polymers	Commercially available	Not yet developed	Commercially available	Commercially available	Commercially available	Commercially available	Not yet developed
Metals	Commercially available	Commercially available	In R&D stage	In R&D stage	Commercially available	Not yet developed	In R&D stage
Composites	Not yet developed	Not yet developed	Not yet developed	Commercially available	Commercially available	Not yet developed	Commercially available
Ceramics	Commercially available	Not yet developed	In R&D stage	Commercially available	Not yet developed	In R&D stage	Not yet developed
Biological	Not yet developed	Not yet developed	Not yet developed	In R&D stage	Not yet developed	Not yet developed	Not yet developed

Commercially available	(green)
In R&D stage	(red)
Not yet developed	(grey)

Polymer materials are the most developed due to the ease of manufacturing.

Source: Landscape of AM Research by Imperial College Network (2016): https://core.ac.uk/download/pdf/77018324.pdf

Global Trends 2025: A Transformed World,

Universitetet i Stavanger

ATLANTIC COUNCIL

IDEAS. INFLUENCE. IMPACT.

STRATEGIC FORESIGHT REPORT

Thomas Campbell
Christopher Williams
Olga Ivanova
Banning Garrett

Worked with US National Intelligence Council

ORESIGHT INITIATIVE

OCTOBER 2011

Could 3D Printing Change the World?

Technologies, Potential, and Implications of Additive Manufacturing

Transformative technologies are the stuff of history. The steam engine, the light bulb, atomic energy, the microchip—to name a few—unalterably changed our world. Such breakthroughs often take decades from initial invention to changing the way we do things and their potential impact can be nearly unimaginable early in the process. It is doubtful that even Tim Berners-Lee in his wildest dreams imagined what the World Wide Web would do to our global "operating system" when he invented it 20 years ago.

Now another new technology is gaining traction that may change the world. 3D Printing/Additive Manufacturing (AM) is a revolutionary emerging technology that could up-end the last two centuries of approaches to design and

THE STRATEGIC FORESIGHT INITIATIVE

The Strategic Foresight Initiative seeks to enhance understanding of the potential impact and policy implications of long-term global trends, disruptive change, and strategic shocks. The Initiative publishes articles, blogs, and reports and convenes workshops that bring together policymakers, academic and think tank specialists, and business leaders to analyze long-term threats and challenges ranging from climate change, water and food shortages, and resource scarcities to the impact of urbanization and new technologies. It also analyzes how these trends interact with social, political, economic, and security

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The **Foresight, Strategy, and Risks Initiative** (FSR) provides actionable foresight and innovative strategies to a global community of policymakers, business leaders, and citizens.

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Although still in its infancy, the 3D printing revolution has already transformed our daily lives—from 3D-printed shoes and clothes to custom-printed exteriors and interiors for green, low-energy cars

.. there is now a capacity to *print living tissues* and some kinds of replacement *organs.*

Bioprinting

3D PRINTING: REVOLUTIONIZING MEDICINE

Oliker, Aaron. **Americas Quarterly** 9.2 (Spring 2015): 46-47.

3D PRINTING: REVOLUTIONIZING MEDICINE

By Aaron Oliker

ADVANCEMENTS IN 3D PRINTING ARE CHANGING HEALTHCARE

With its recent transformation from fringe technology to mainstream commodity, 3D printing has been hailed as the next Industrial Revolution. The ability to design and manufacture goods at low costs could fundamentally change the way we produce and consume.

Although still in its infancy, the 3D printing revolution has already transformed our daily lives—from 3D-printed shoes and clothes to custom-printed exteriors and interiors for green, low-energy cars such as the Urbee. But some of its most transformative applications have been

thousands of free, community-generated models for download. Once a model has been loaded into special software—Cura and Repetier are two of the most popular, and are also free—the user just has to press print and watch as the 3D printer slowly builds the model one thin layer at a time. The object is created with

technology has been around for 30 years, it has only recently become accessible and affordable enough for true innovation. Just seven years ago, a printer could cost as much as $250,000; today, it is possible to purchase a fully assembled and calibrated printer for less than the cost of a laptop.

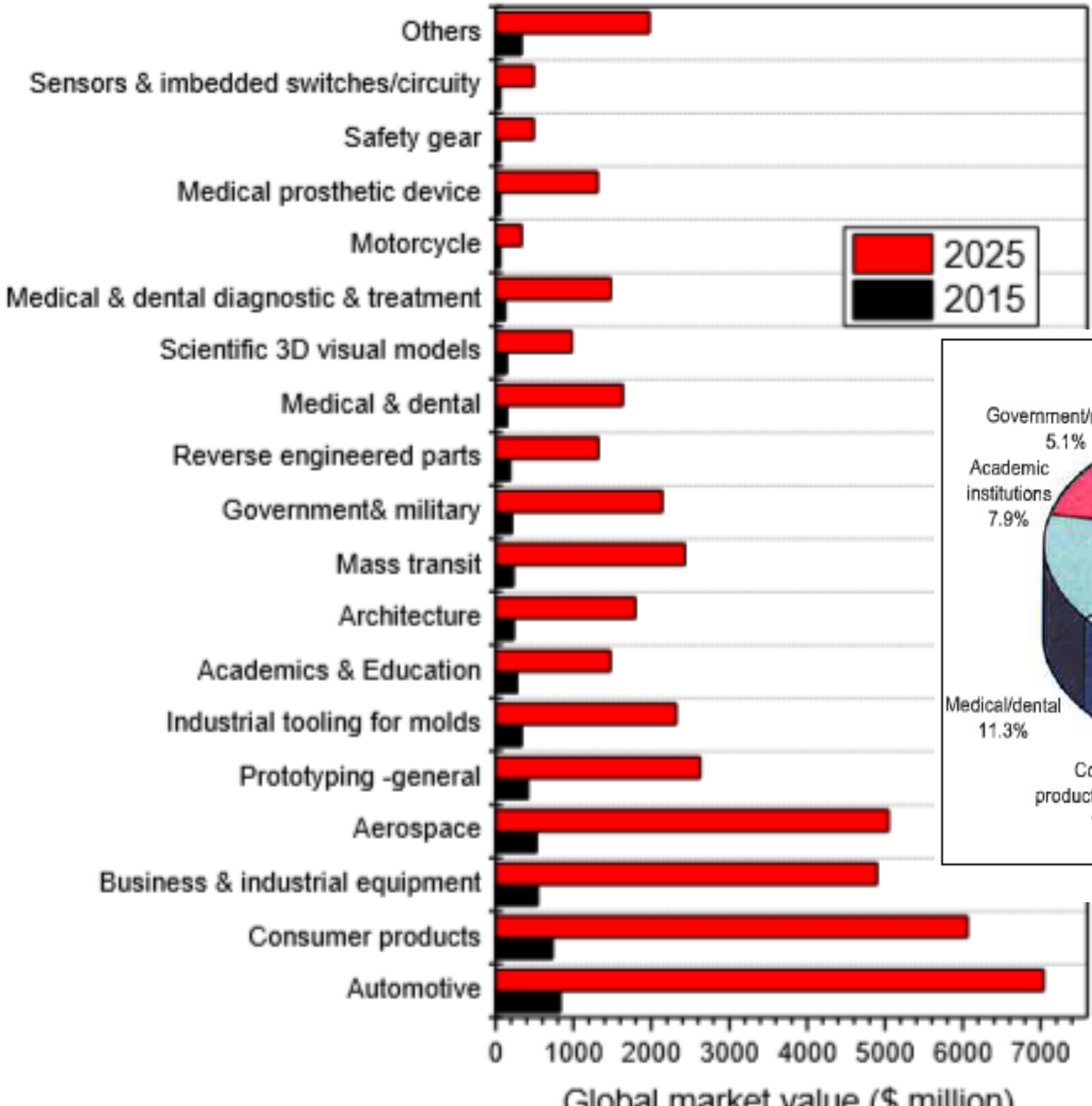
Medicine is one area

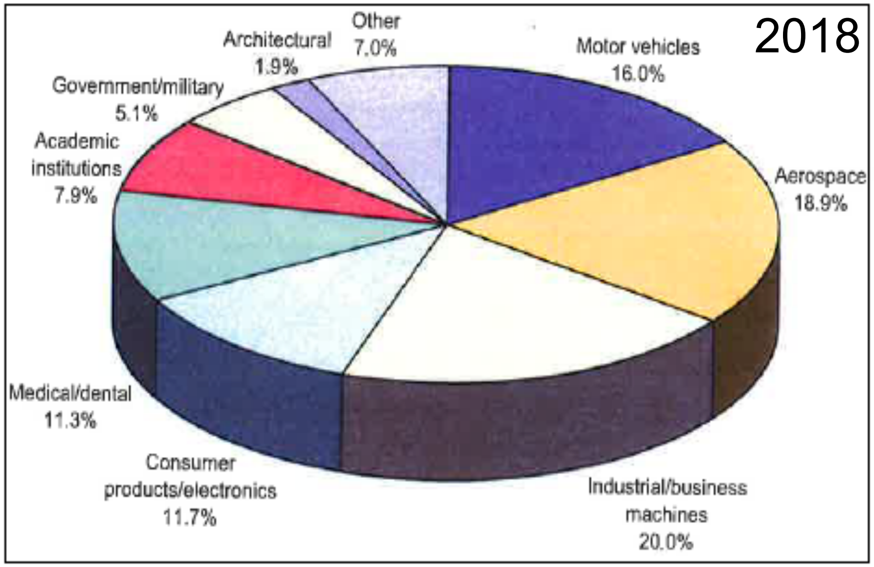
3D PRINTING IN MEDICINE IS EXPECTED TO CREATE CUSTOMIZED SOLUTIONS FOR INDIVIUAL PATIENTS.

been using higher-end 3D printers in the U.S. for education and surgical planning since the late 1990s, surgeons have begun printing custom-designed implants for their patients in the past decade.

3D printers have also been used to produce artificial limbs. Robohand—a South Africa-based charitable organization that creates 3D limb models and offers free downloads of their instructions and designs—uses 3D printers to generate featherweight custom arms, hands and fingers at lower costs than traditional prostheses: $500 to $2,000 instead of $10,000. As an added bonus, their designs work with the motion of exist-

Industrial AM market growth, projected 2015 - 2025

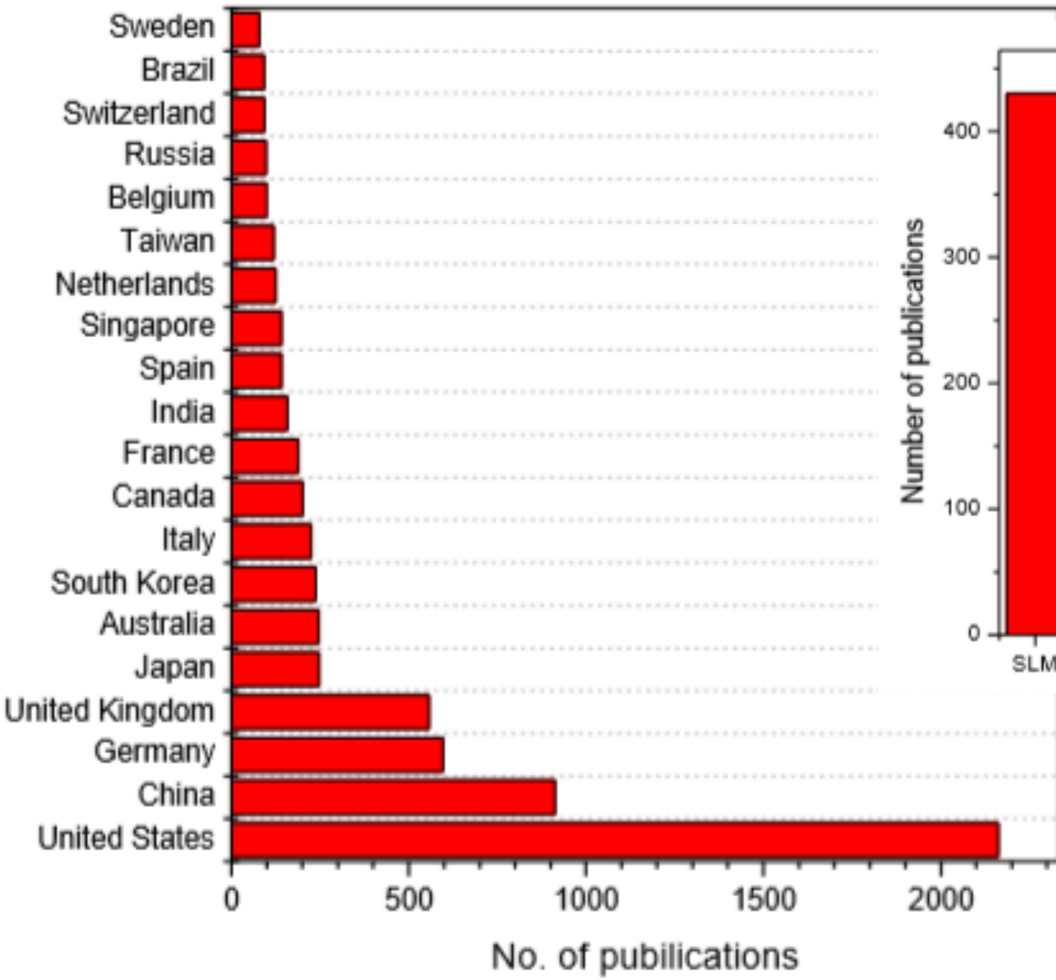


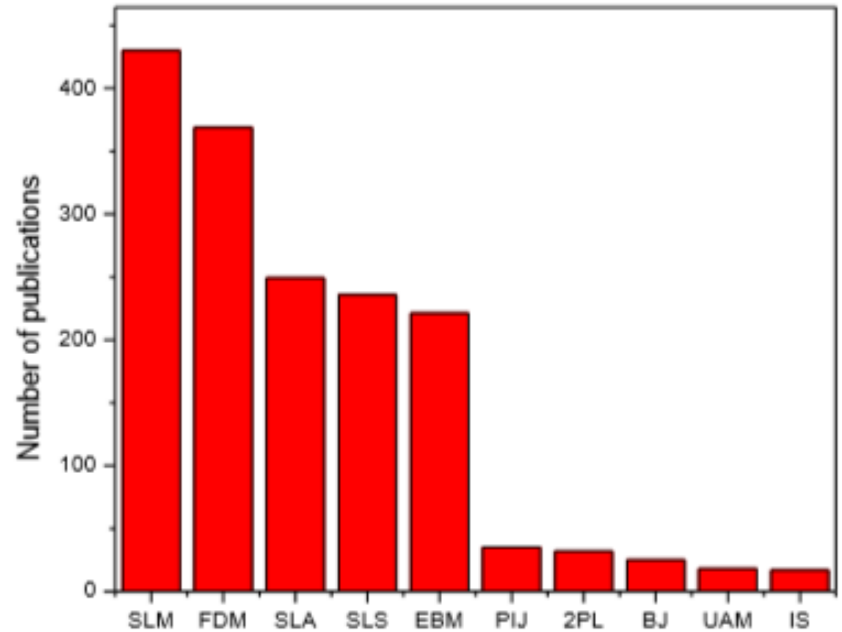


Source: Wohlers Associates, Inc.

H. Blum, The future of 3D printing to 2025, (2015). http://www.smitherspira.com/news/2015/june/3d-print-market-expected-to-reach$49b-by-2025.

Top 20 Countries Working on AM Research

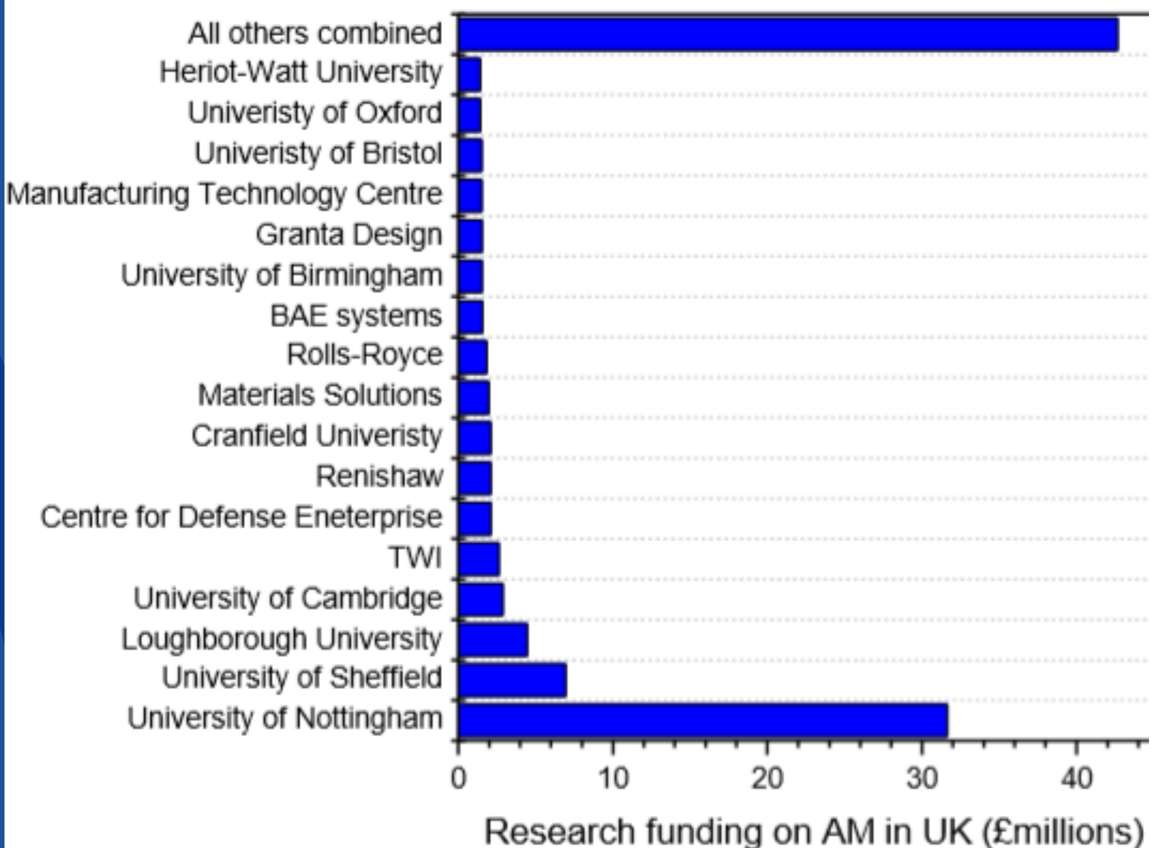




Total number of publications worldwide of various AM techniques

Landscape of AM Research by Imperial College Network (2016):
https://core.ac.uk/download/pdf/77018324.pdf

Research funding (received in UK organizations)



Production of publications

3DP LAB AND FACILITIES

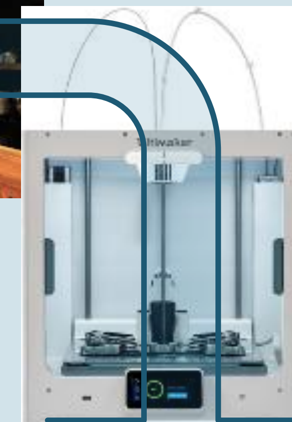
3DP Lab

Design modeler, 2008

Prototyping, 2012

Functional part fabrication, 2016

3D Scanning



3D Printing in Education, 2018

Markforged Mark Two
nylon with continuous fiber of karbon, glass fiber or kevlar

Markforged Metal X
Stainless steel, Al., Inconel, Tool Steel and Titanium

Education

MSK 550 Computer-aided Engineering

- Rapid prototyping and additive manufacturing technologies (lectures 2 x 4 hrs)

- Practical exercises on 3D printing

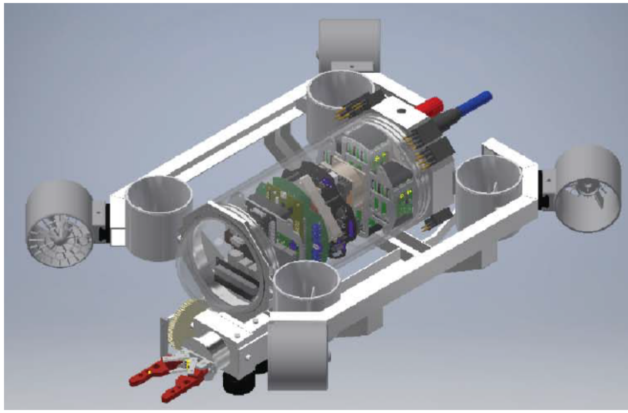
- Semester projects
  – literature review
    - *Medical applications*
    - *Functional part fabrication*

Introductory lectures and demos in other courses

Education: Student projects

Examples

- ***Functionality risks associated with Dimensional, Geometrical and Strength deviations in 3D printed parts, MSc 2016***
- Design of Propeller and Shroud for Remotely Operated Underwater Vehicle using Additive Manufacturing Processes, BSc 2016



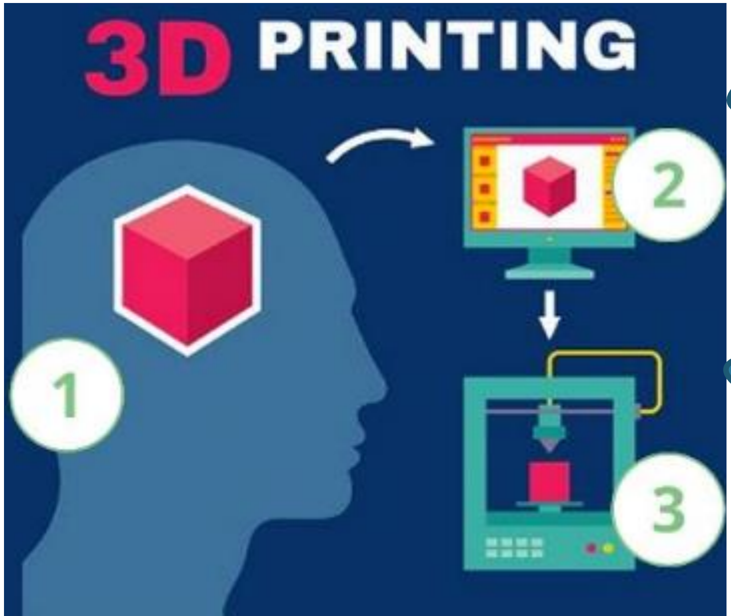
- Comparative study of material properties of 3D printed parts using FDM technology, BSc 2017
- Investigation of design solutions for additive manifactured thruster for ROV, BSc 2018

3D Printing for Education project (2018 -2019)

Under3DP

Funded by Faculty of Science and Technology, UiS

NOK 300 000



- Stimulating innovation
- Problem-based learning

Why 3D Printing Technology in Education?

Primary objective

Improve the *educating and learning process* in the Mechanical Engineering program at UiS using 3D printing technology.

- 3D print difficult-to-grasp objects for use in class examples/demonstrations/ explanations
- Allow students to fabricate their design concepts, evaluate and present
- Support learning by doing → hands-on experience

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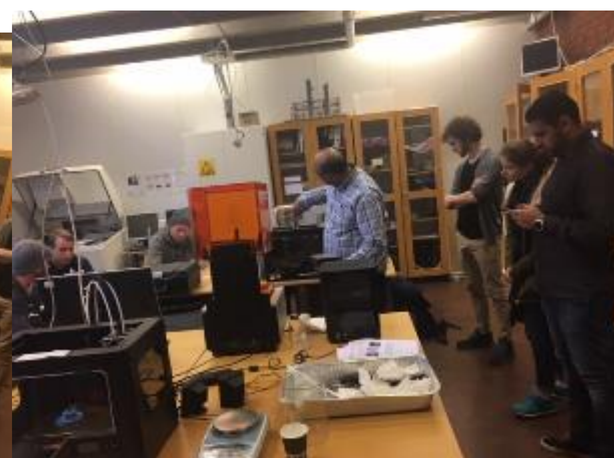
Why 3D Printing Technology in Education?

Additional objectives

- Contribute in **stimulating students for STEM education**
- Contribute in creating better awareness about the technology in local industry
  → Transform to **digital manufacturing**



Local/national initiatives and creating awareness in the industry

Organized a number of seminars and demos in the period 2015 - 2018

Nov. 2015 — June 2016 — Aug. 2016 — Sept. 2017 — June 2018

Seminar for local industries (CIAM)

Participation in Gjøvik national initiative for pilot project

Attempt to organize AM course for industries(CIAM)

A Study Tour fo

With the initiative of CIAM, Indu
a very interesting study tour la
Gelgele Lemu and Professor Vi
Department of Structural and M

Del artikkel: f in

3D Printing Study Tour organized by CIA

3D Printing technology has been ar
recently has the Universityof Stavan
technology. We have some 3D mach
research and further studies.

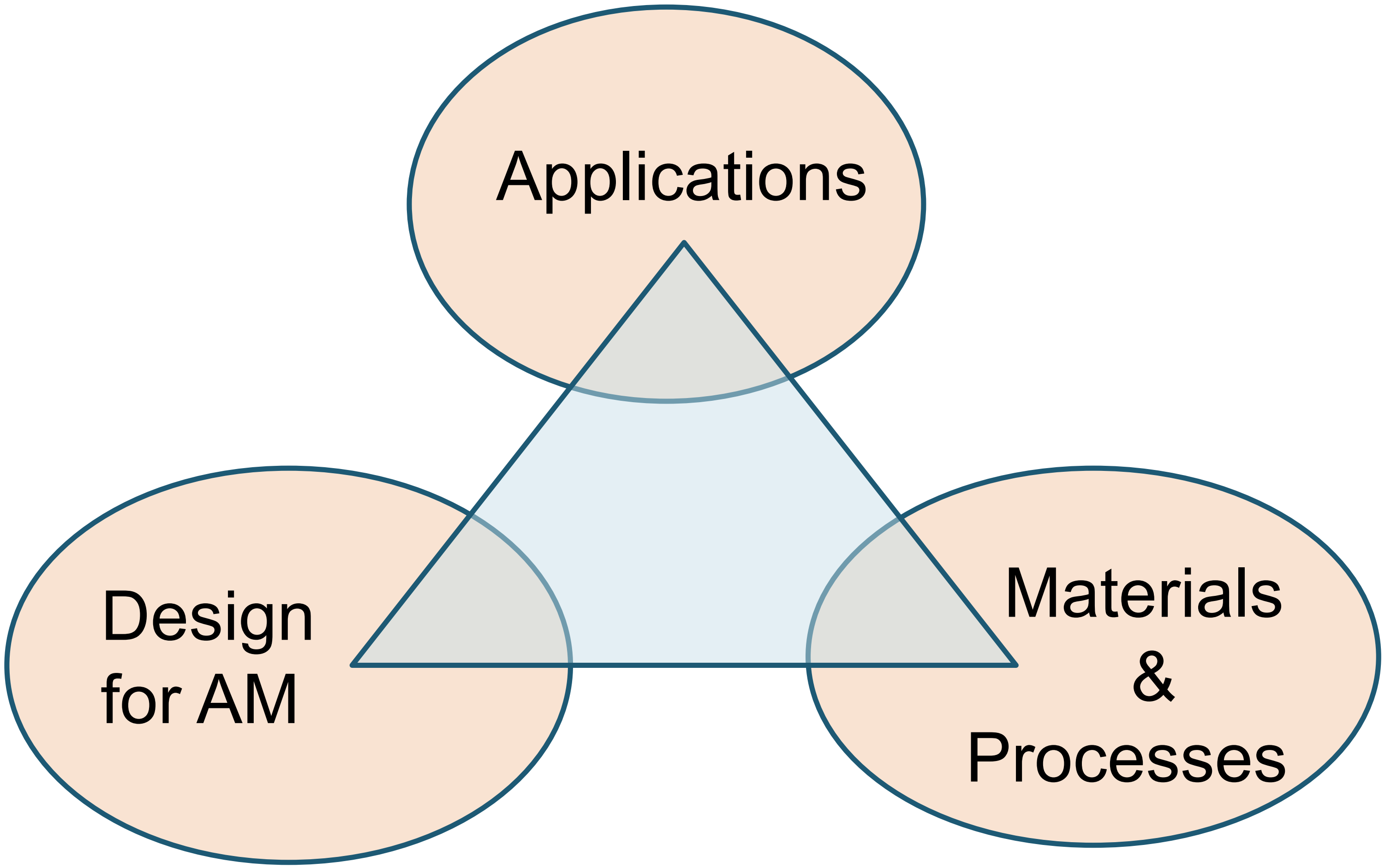
Project on 3D Printing

Participants from all over the region, came in for a one day event on a possible joint project on additive manufacturing/3D printing.

3D Printing Event in Stavanger

It was a nice day in Stavanger, when over 40 participants from all over Norway gathered in Måltidetshus for a historical meeting on additive manufacturing (3D Printing).

Research related activities



Focus areas for research

(1) **Design for AM or design to print (procedures, standards ...), benchmarking the process, …**

- *Design optimization – real topology optimized design*

- *Geometry considerations*
  – which parameters/changes give impact on productivity?

- *Manufacturing digitalization and digital control*:
  - position, motion and orientation of part and the nozzle,
  - rate of material deposition/speed of nozzle
  - sharing digitalized product data …

Focus areas for research …

(2) *Materials*:

Material behavior characterization (modeling, testing), influence of parameters, multimaterial printing

(3) Process *simulation and numerical analysis*:

use of computational methods to predict behavior

(4) *Process control and monitoring*:

achievable accuracy, surface quality, … how to influence

(5) *Structural integrity*: friction, lubrication, fatigue life, ….

(6) Others:

Economic impact for companies, environmental impact of the process …

R&D Focus … Application Areas

Offshore applications

Consumable products, Jigs & fixtures

Medical sector

- ❑ on-demand production
- ❑ Lower downtime
- ❑ Simplification of offshore logistic – raw materials are transported, not parts - reduced rework and transport costs

Particularly one-of-a-kind products

- On-demand production – easily customized to patient needs
- No limitation of geometry complexity
- Applicable technologies: SLS/SLM, FDM, Polyjet and SLA (transparent)

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International collaborations

Erasmus+

European Commission
Research & Innovation - Participant Portal
Proposal Submission Forms

European Commission

Horizon 2020

Call: H2020-MSCA-RISE-2018

(Marie Skłodowska-Curie Research and Innovation Staff Exchange)

In summary,

Our ambition has been

- ❑ to develop sufficient knowledge, competence and facilities within AM to support the technological development at regional and national level
- ❑ to contribute in the potential transition of industries from subtractive to additive manufacturing business

Thank you for your attention!