3D Construction Printing

A Worldwide overview

The Danish Partnership for 3D Construction Printing

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GRØN
OMSTILLINGSFOND

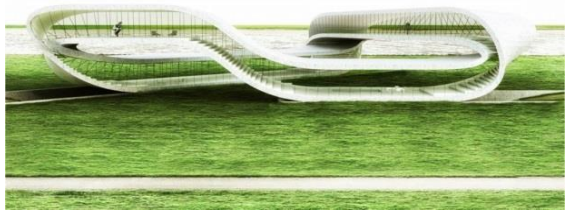
Danish Partnership for 3D Construction Printing

- 3D Printhuset, NCC Denmark, Force Institute and Gypsum Recycling int., working together based on a grant from the Danish Green Transition Fond
- Visited and analysed +35 3D Printing projects worldwide over 2 year period
- Build own mini test concrete printer and applied even bigger version to test materials
- Tested and measured various 3D concrete printing materials
- Assisted 3D Printhuset with the BOD, Europe's first 3D printed building

Why is 3D Construction Printing interesting ?

4 main potential advantages:

- Design freedom (complexity is free)
- Automatisation
  - Lower cost/higher productivity
  - Zero mistakes
  - Better safety
  - More precision
- Reduction of waste
- New materials (recycled)



The Landscape house

Contour Crafting Corp.

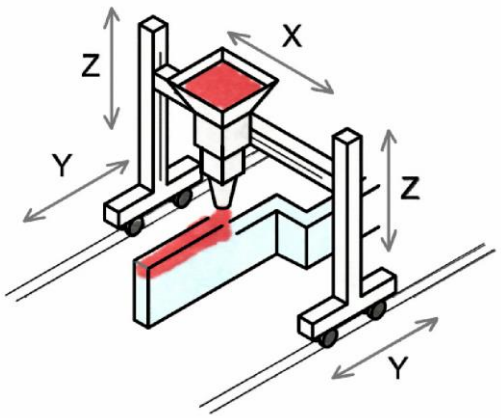
3D Printhuset

Agenda

- Why is 3D construction printing interesting
- 3D construction printing technologies
- Worldwide overview
- Perspectives on the development of 3D Construction printing
- Conclusion

3D Construction printing technologies :

Gantry printer type



Generic

Technical Univerisity Eindhoven

3D Printhuset

Concept

The printhead is moved in X, Y and Z direction with a gantry system. Printing occurs within the boundries of the system

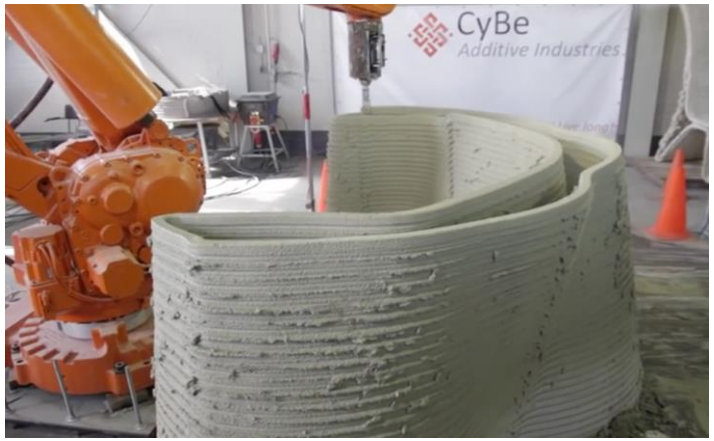
Pros & Cons

- + Stable and secure construction
- + Simple and cheap construction
- - Flexibility
  - Hard to move from place to place
  - Takes up a lot of space

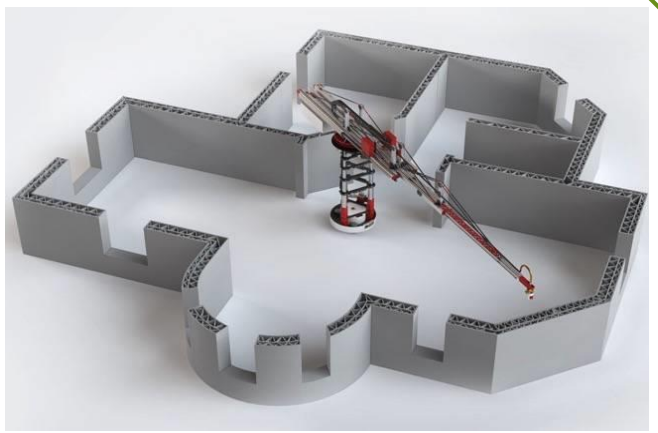
3D Construction printing technologies :

Robotic arm / crane printer type

Batiprint (Nantes University)



Cybe Construction



Apis Cor

Concept

This platform is rooted in the center of the print area.The nozzle is fixed on a robotic arm or a computer driven crane system.

Pros & Cons

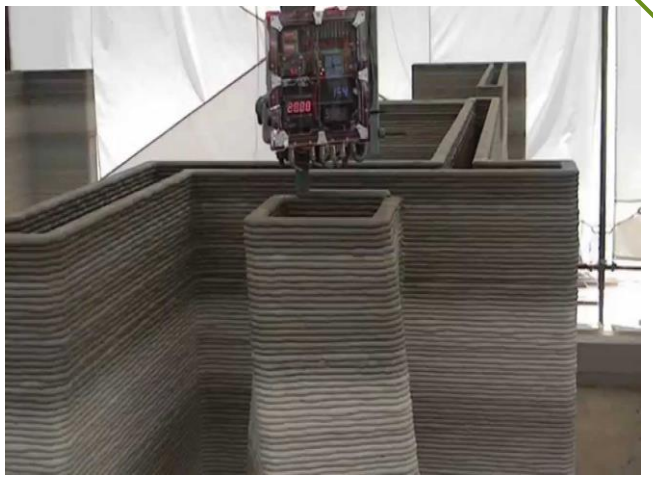
- + Smaller mechanical system
- + Easy movable
- - Price and stability
- - Print Area/limited reach (unless mounted on a moving platform)

3D Construction Printing technologies

In Situ printing

Apis Cor

3D Printhuset



Total Kustom

Concept

The Construction is built on site.

Pros & Cons

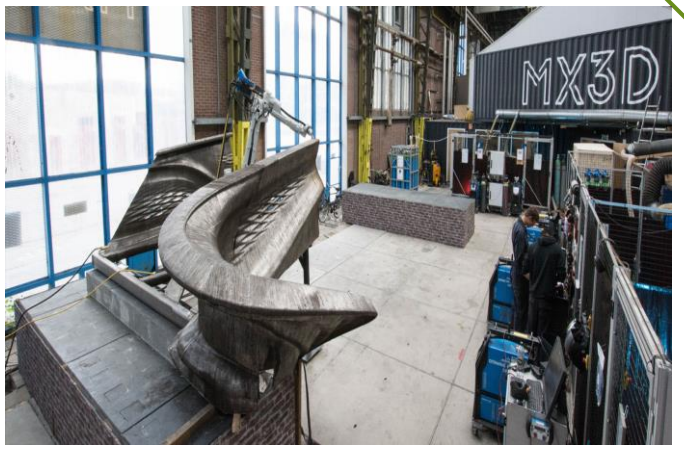
- + Full construction in one go; no assembly
- + Less freight of elements
- - Varying weather parameters, unless printer is kept in a tent (costs)

3D Construction Printing technologies:

Off Site (Prefab Construction)

Winsun

Winsun



MX3D (steel)

Concept

Prefab elements are 3D Printed in a production area where the 3D Printer is stationary. After production the elements are shipped to the construction site and assembled on site.

Pros & Cons

- + Stabilitet in a stationary system
- + Stable weather parameters (indoor)
- - Shipping of elements
- - More manual labour required on the construction site

Other printer types/technologies :

Nantes University/Batiprint and MIT

Concept

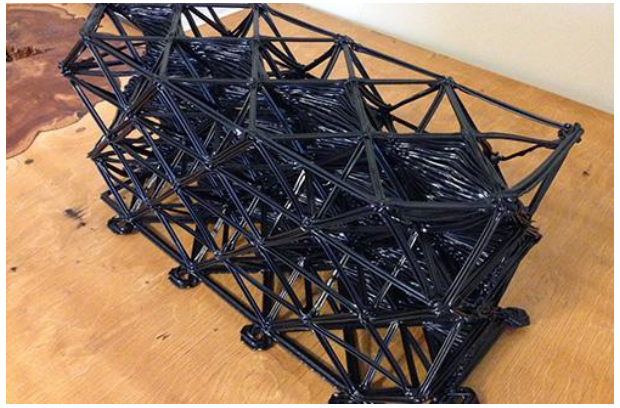
3D printing of insulation foam (EPS) formworks – concrete poured in afterwards

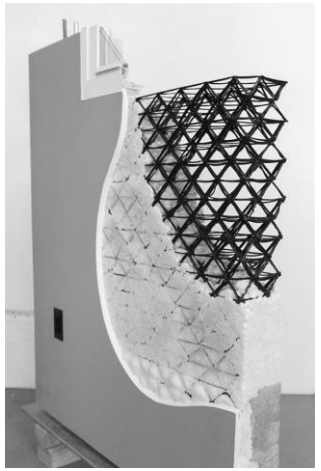
Pros & Cons

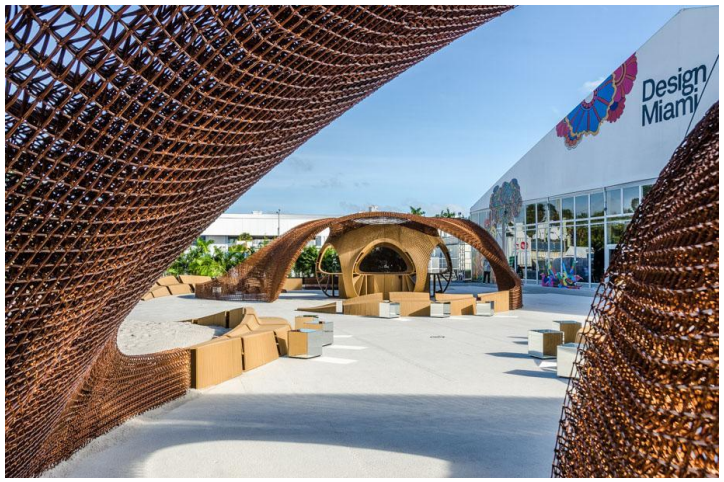
- + Fast printing
- + Integrated (and solved) insulation issue
- - Complex connections required to interior
- - Fire code regulations

Other printer types/technologies :

Branch Technology







Concept

Freeform 3D Printinting of grid-structure in plastics. After the print the insulation, concrete, plaster or other building materials can be added/sprayed on.

Pros & Cons

- + Freeform structures (real 3D) and “prefab” method
- + The plastic grid is easy to ship (lightweight)
- - More manual labour on the the site.

Powder bed printing

- D-Shape/Enrico Dini
- First 3D printed bridge (Acciona, Spain)

Concept

Powder bed printing.
Off site construction of elements
Assembled on site

Pros & Cons

- + Advance shape/form – real 3D
- - Complex/cumbersome production process
- - Reinforcement required on site

3D Construction Printing technologies/places:

The printer technologies and printing places combined, and some of the most interesting projects using them

Place Printer type	In situ	Off site
Robot/crane printer	• Batiprint (Nantes) (foam) • MIT (foam) • Cybe (components) • Cazza • Apis Cor	• Xtreee • MX3D (steel) • Branch Technology (plastic)
Gantry printer	• TotalKustom • 3D Printhuset • Contour Crafting	• Technical Univ. Eindhoven • Winsun • D-Shape (Enrico Dini)

Agenda

- Why is 3D construction printing interesting
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Worldwide Overview – 3D Construction Printing

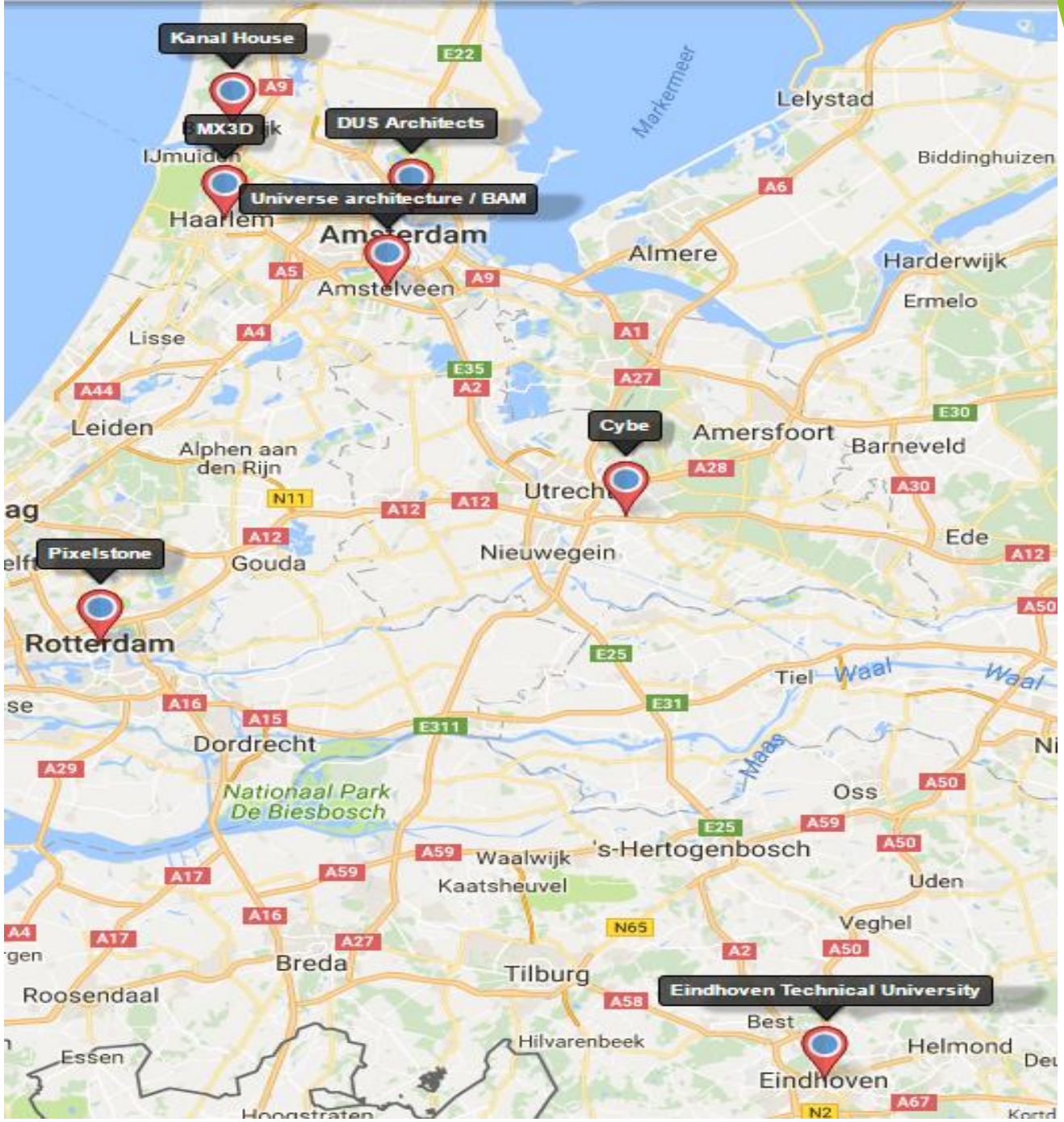
- **Very hard to make –**
  - New projects every month / week.
  - Many projects in ”stealth” mode – hiding project until they have something good to show.
  - Quick Snapshot
- **66 identified projects worldwide**
- **Europe:** 34 significant projects
- **US (North and south America):** 17 significant projects
- **Asia:** 15 significant projects

Europe

(excl. Russia)

- Most projects; 34, but still today very little actually build in real life, except for two bridges (Spain+Holland) and 2 buildings being done (Denmark+France)
- High labour costs makes automation a huge plus.
- Conventinal construction industry is becoming involved
- Environmental aspects also in focus
- Universities involved a lot cooperating closely with businesses (TUE, Lille, Lund, ETH, Dresden, Loughborrough and more)
- **Holland** is dominating with 7 projects.

Holland


Kanal House
MX3D
DUS Architects
Universe architecture / BAM
Cybe
Pixelstone
Eindhoven Technical University
Rotterdam
Amsterdam
Haarlem
IJmuiden
Amstelveen
Lelystad
Markermeer
Biddinghuizen
Almere
Harderwijk
Ermelo
Lisse
Leiden
Alphen aan den Rijn
Amersfoort
Barneveld
Utrecht
Nieuwegein
Ede
Gouda
Dordrecht
Tiel
Waal
Maas
Oss
's-Hertogenbosch
Waalwijk
Kaatsheuvel
Uden
Veghel
Breda
Tilburg
Roosendaal
Best
Helmond
Eindhoven
Hilvarenbeek
Essen
Nationaal Park De Biesbosch
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A30
N11
A12
E25
E31
E311
A15
A16
A29
A59
A50
A17
N65
A58
A67
N2

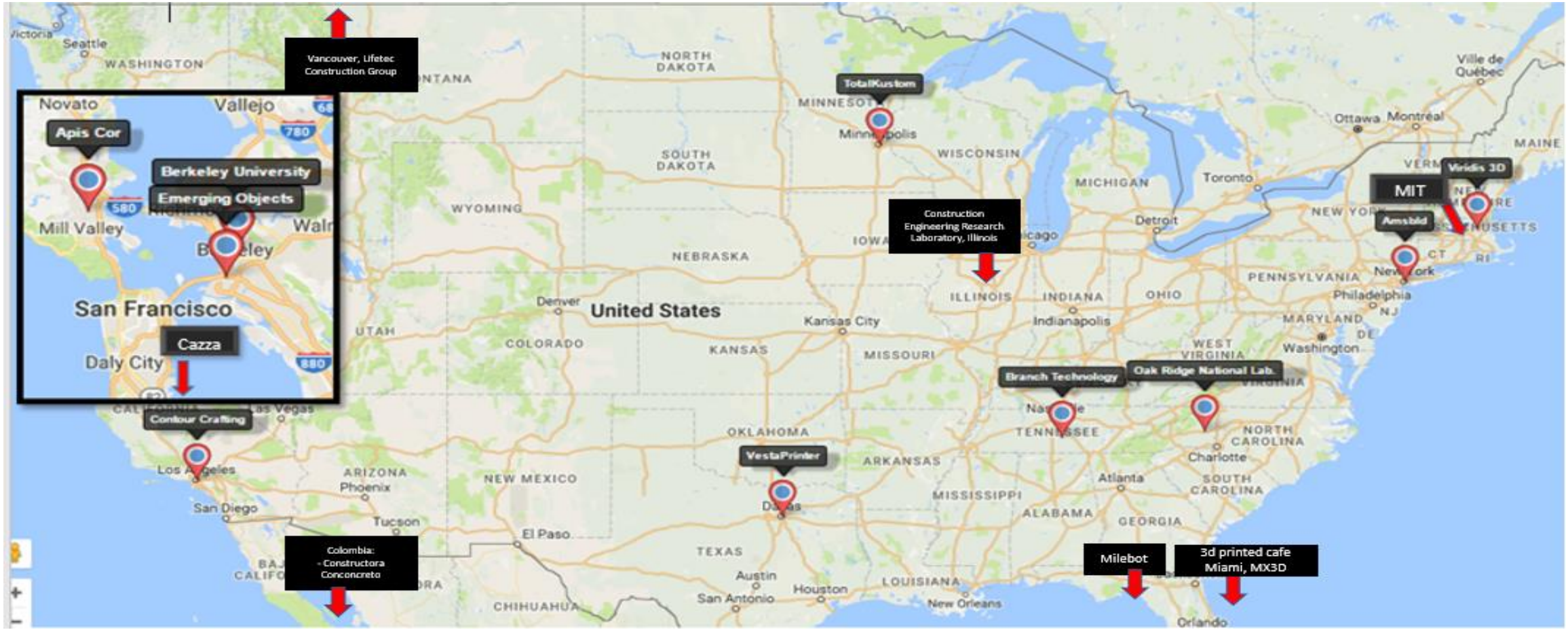
Asia

(Incl. Russia and Australia)

- Relatively few projects (15) but **leading on buildings actually made** with 3D Printing (made in Russia, China and Dubai);
- Maybe because regulations are easier to live up to (??)
- Most Known: Winsun (China) and Apis Cor (Russia).
- All Projects are commercial projects – almost no universities involved (only Singapore)
- Limited involvement from conventional construction industry

US (North and South America)

- Founding fathers of the concept – 3D construction printing (Khoshnevis)
- 17 projects, but very few buildings – maybe because of patents or legal issues (??)
- Some universities involved (UCSC, Berkeley, Oak Ridge)
- Virtually no involvement from conventional construction industry



Worldwide Overview – 3D Construction Printing

Global status (conclusion) and prediction (subjective):

Europe:

- Leading in number of projects being developed
- Leading in terms of cooperation between academia and business
- Presently lagging in terms of realized projects, but will catch up
- Destined to take the lead in the future (if funding is secured and conventional construction industry continue to become involved)

Asia:

- Presently leading in terms of projects and is likely to continue to lead in number of buildings done due to The Middle East
- Not leading in terms of innovation height and scope; lack of involvement of academic and industrial resources

US:

- Leading only in terms of claims for what 3D printing can do for the construction industry
- Something needs to change for the US to play a bigger role going forward

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A historical view – The pioneers

1995:
Professor Berok Khoshnevis of University of Southern California in LA takes out patent on ceramic extrusion

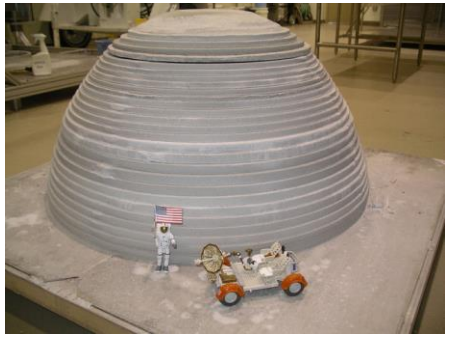
Loughborough University

2000:
Khoshnevis focuses on 3D construction printing and makes the concept **Contour Crafting**

2003:
Ruper Soar, Loughborough University gets funded for upscaling 3D printing to construction purposes

2008:
Loughborough begins to 3D print concrete (Skanska) – and Khoshnevis got funding for NASA project.

USC University of Southern California **CONTOUR CRAFTING** Robotic Construction System USC Viterbi School of Engineering

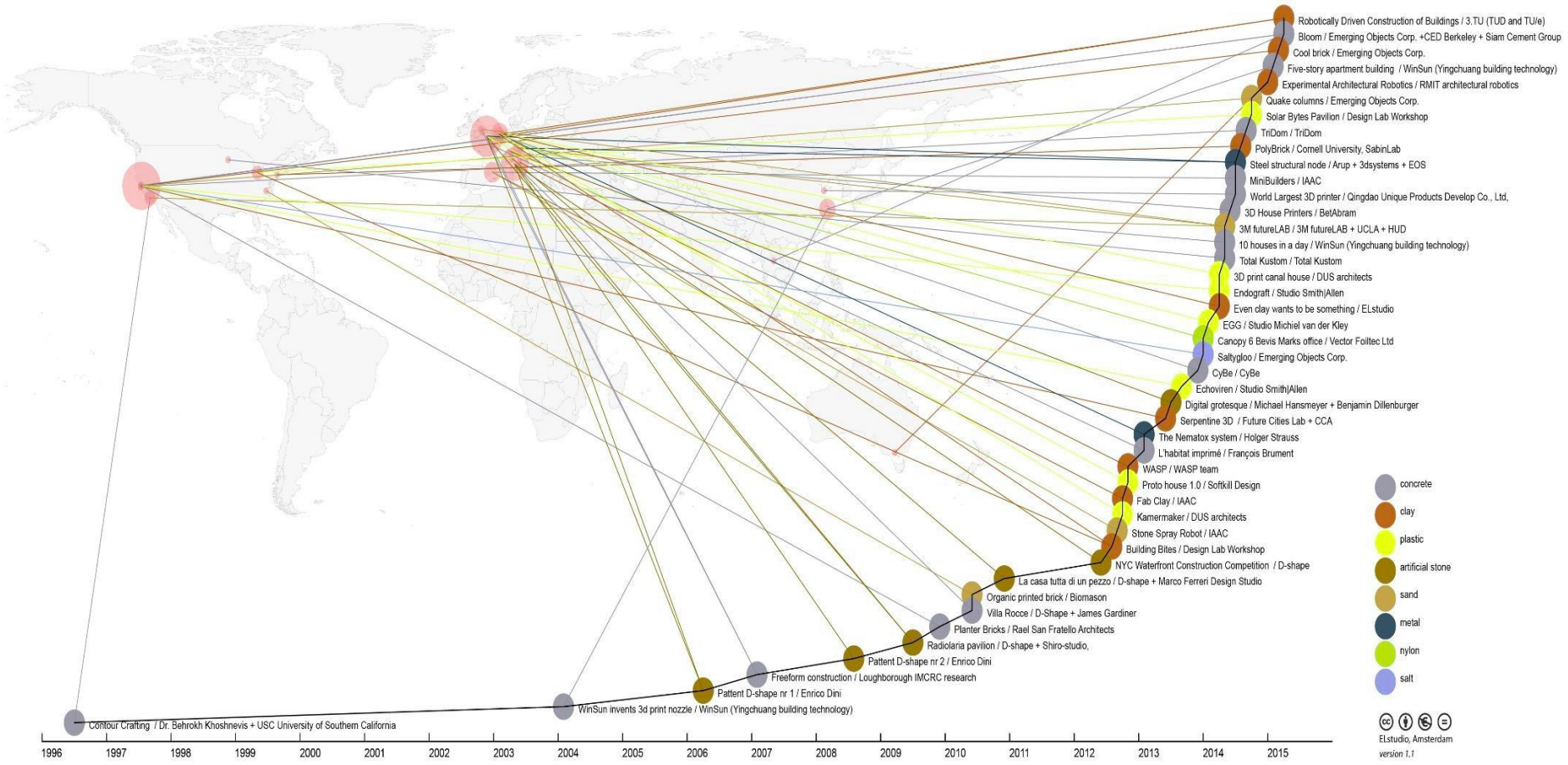


2005:
Enrico Dini, Pisa, Italy, takes out patent for the D-Shape technology (binder jetting)

d-shape

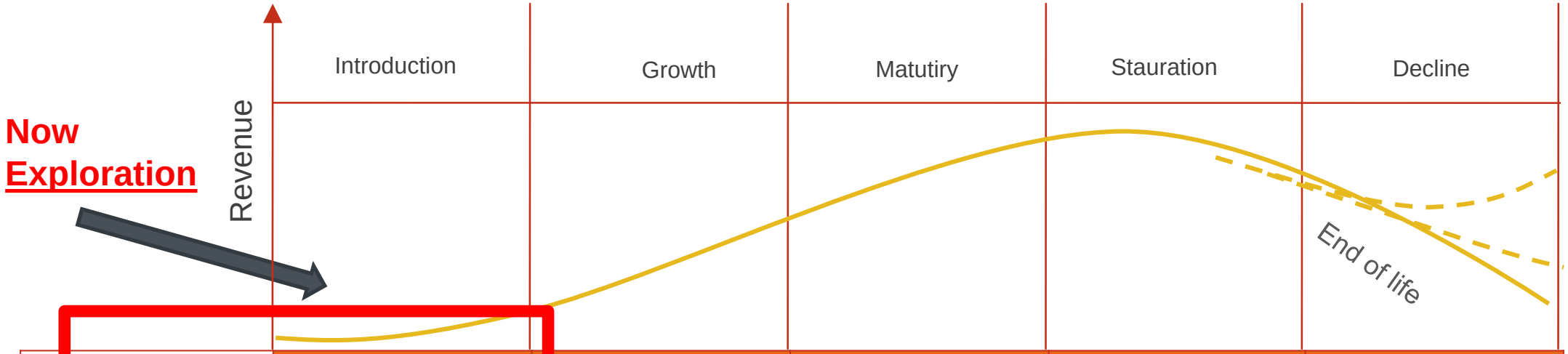
3D Construction Printing - Status

Exponential growth in projects/concepts last few years



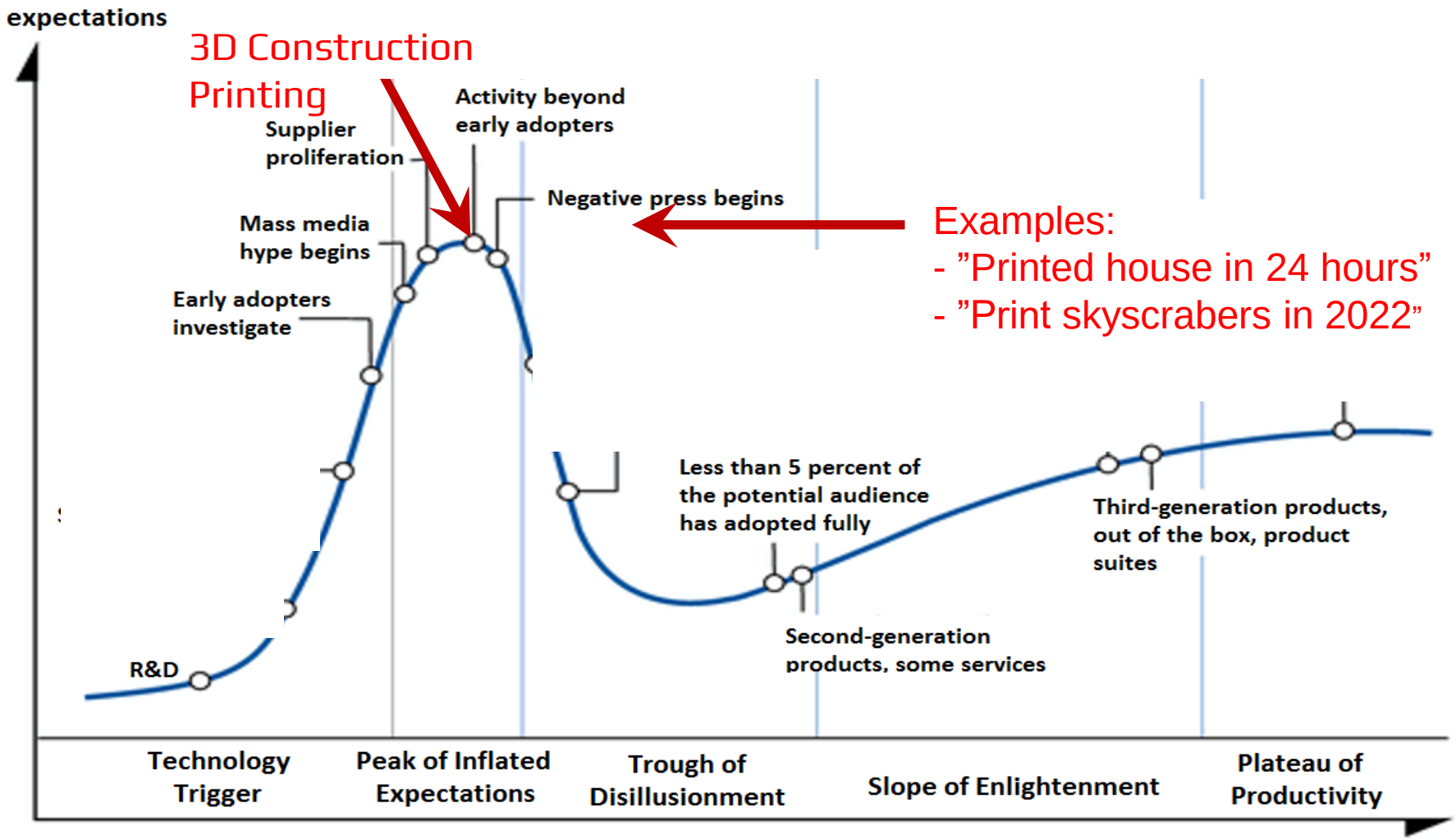
3D Construction Printing - Status

Market matureness



	Audience	Market	Price	Sales	Competition	Business Focus
Innovators	Innovators	Small	Very High	Low	Low	Awareness
Early Adopter	Early Adopter	Expanding	High	Expanding	Increasing	Growth
Every Majority	Every Majority	High	High	High	Moderate	Market share
Late Majority	Late Majority	Peaked	Medium	Flattening	High	Customer Retention
Laggard	Laggard	Contracting	Low	Moderate	Moderate	Transition

Gartners hype cycle – Expectations; a prediction !



Explanation:

A potential technological breakthrough Starts things off

Early publicity produces a Number of success stories

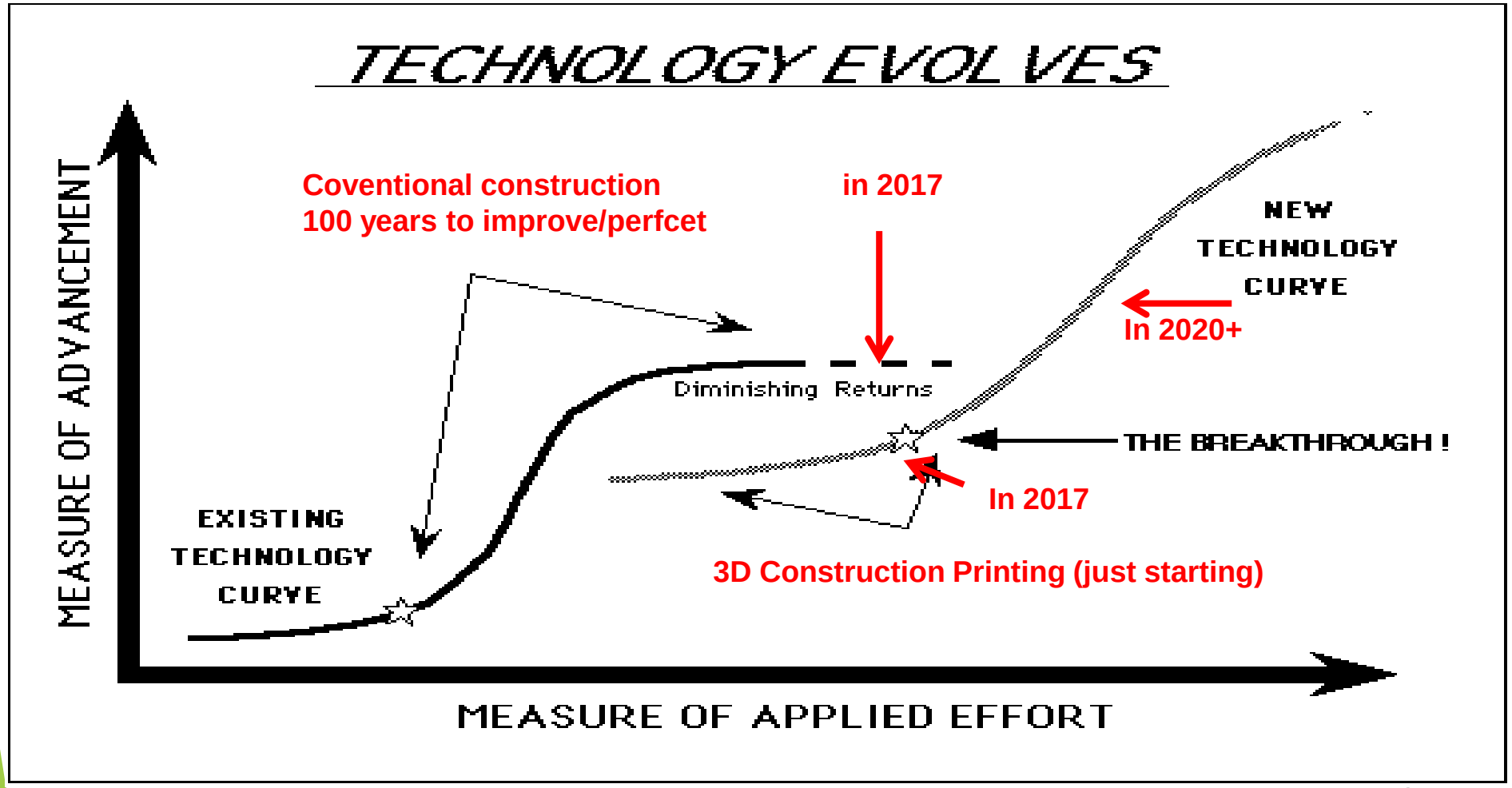
Reduced interst as experiments and projects fail to deliver

More instances of how the technology can benefit start to crystalize and become more wiedely understood

Mainstream adaptation starts to take off

3D Construction Printing - Status

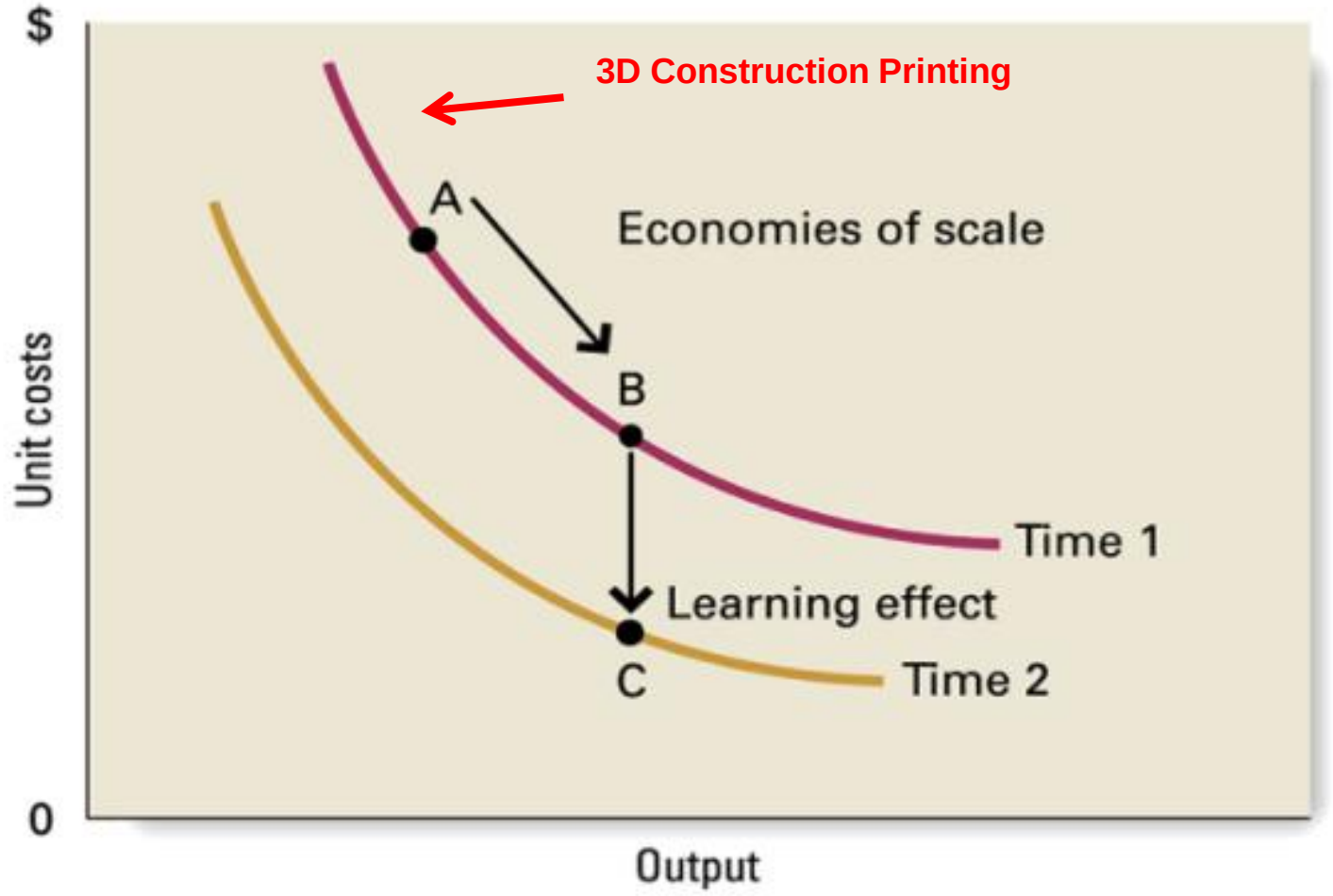
The technology S-curve



3D Construction Printing - Status

The reasons for low present competitiveness;

- No learning curve effect yet (still on Time curve 1)
- No scale advantages yet (still on the start of the Time curve 1)



3D Construction printing – the “Truth”

- None of the completed 3D construction printing projects have been competitive so far !!!
- There might have been saving here and there, but overall when all costs are calculated the application of 3D printing has not been competitive
- Why: It is very difficult to do something right and efficiently the first time
- There is still a lot to be learned !!
- But the technology has proven it’s potential and will become competitive if resources continue to be applied

3D Construction Printing

A reminder:

”Portable” laptop 1983

Laptop 2013

”Portable” mobile phone 1990

Mobile phone 1996 and 2007

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3D Construction printing – conclusion

- The technology/emergent industry needs more resources to develop faster;
  - Cooperation with academia (begun, more needed)
  - Cooperation with conventional suppliers (initiated, more needed)
  - Capital; starting, but very positive and needed;
    - Multiple conventional construction companies have begun investing in own or external 3D construction printing:
      - Skanska (S), Sika (CH), Bougues (FR), Zublin-Strabag etc. have invested in development of own 3D construction printing competence
      - Vinci (F), Doka (AT), Caterpillar (US) etc. have invested in new 3D construction printing start ups

3D Construction printing – conclusion

When the conventional construction companies have started showing **with their money** that they believe in the technology ……..

isn’t time you do also !!!