Direct Digital Manufacturing: applications in construction

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Why consider Direct Digital Manufacturing?

- Technology developing towards maturity
- Industry has started to adopt
- … but, opportunity not yet fully understood

Outline

- What is direct digital manufacturing?
- Impact on manufacturing and supply chains
- Future applications in construction

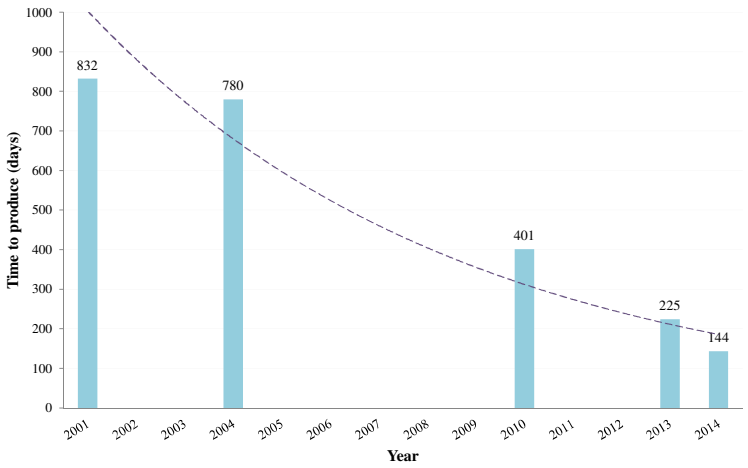
Direct digital manufacturing

- Manufacture of parts from an original digital design (or physical scan) without tooling and set-up
  - 2D example: laser printers producing a document directly from a manuscript without typsetting
  - 3D example: laser sintering a spare part from a 3D model without tooling

3D printing technologies

	Description of process	Materials used	Typical applications	Equipment cost (USD)
Material extrusion (Fused deposition modelling, FDM)	Solid material is heated up and selectively extruded in liquid form through a nozzle to produce thin layers of object upon cooling down and solidification	Plastics and also biocompatible plastics	R&D prototypes, investment casting pattern production	~ 30,000 (10,000-380,000)
Material jetting	The droplets of raw material (e.g.: photopolymer or wax) are selectively deposited to form the object, layer by layer	Plastics, metals	Marketing prototypes, investment casting pattern production	~ 100,000 (20,000-700,000)
Binder jetting	A liquid binder is selectively deposited to join the raw powder	Metals, glass, plaster-based powder	Marketing prototypes, moulds for casting	~ 200,000 (16,000-1,800,000)
Sheet lamination	The sheets of raw material being cut (e.g.: by LASER or blade) to shape the layers and then bonded together	Metals , paper	Prototyping for simple parts	~ 40,000 (36,000-73,000)
Stereo-lithography, SLA	The vat of liquid photopolymer is cured selectively and layer by layer through the exposure to light	Plastics, photopolymers, ceramics	Prototyping and demonstration products, tool-making and pattern production	~ 300,000 (4,000-800,000)
Powder-bed fusion (Selective laser sintering, SLS)	A source of thermal energy (usually LASER) is used to selectively fuse the raw material powder to form the layers of final part	Plastics, metals , ceramics	Industrial final parts production, tool-making, orthopedic and dental implants manufacturing	~ 500,000 (85,000-2,000,000)
Direct energy deposition	A flow of raw material powder is being melted before selective deposition through the use of a focused thermal energy (e.g.: LASER, electron beam or plasma arc)	Metals	Full density near shape final parts	~ 500,000 (300,000-5,000,000)

Example: Time to print the body of a mid-size car



https://www.youtube.com/watch?v=OnhJ5h7dpKc

Direct Digital Manufacturing in construction

- Configurator and CNC based
  - Log house kits produced from set of ArchiCad model objects (ArchiLogs)
    - See http://vanha.mad.fi/mad/logs.html
  - Kitchens, windows produced from configurator based models
- From 3D model to 3D printing
  - 3D printing of concrete
    - https://www.youtube.com/watch?v=EfbhdZKPHro

Not ”Digital construction”,
but
”Direct Digital Construction”

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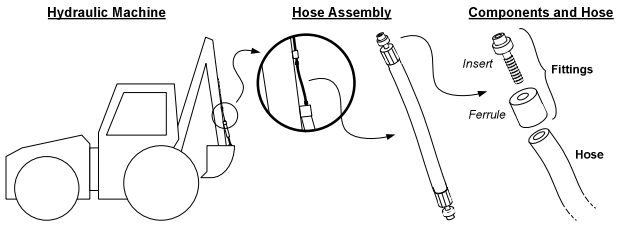
Impact on manufacturing

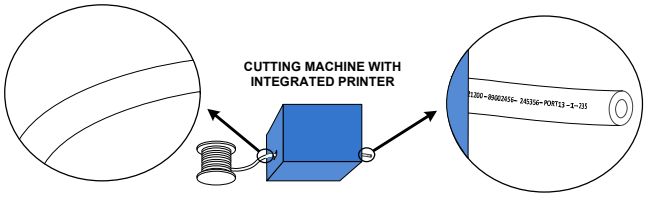
	Tool-based manufacturing	Direct digital manufacturing
Production technology	Tooling and process based	Digital model based
Material flow	Production batches flow through production stages	Kits on demand to on-site assembly
Planning structures	Stock keeping units (SKUs) Bill of materials (BOM)	Product level, assembly kits
Production planning	Lot size, load profiles per process, production schedule	Total load

Example: Customized Machines



Source: Jouni Lyly-Yrjänäinen

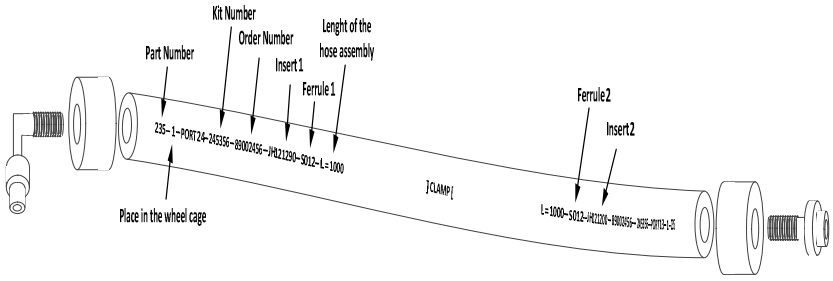
1D - Direct digital manufacuting



- Hoses cut according to specification in order (product model sent with order)
- Each hose cut without set-up or tooling

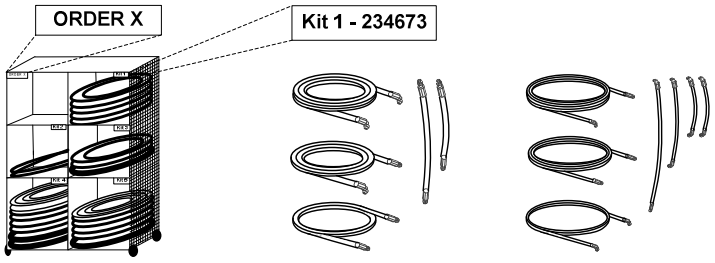
Source: Jouni Lyly-Yrjänäinen

Embedded control



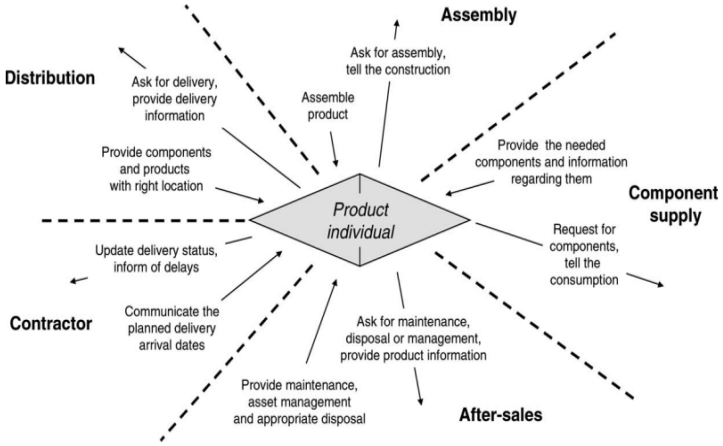
Source: Jouni Lyly-Yrjänäinen

Hose directly manufactured for kit



Source: Jouni Lyly-Yrjänäinen

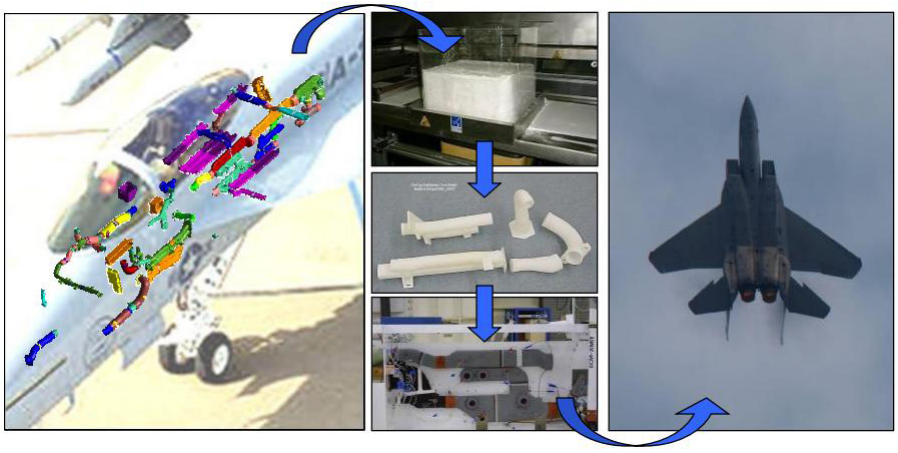
No planning – instead product centric control



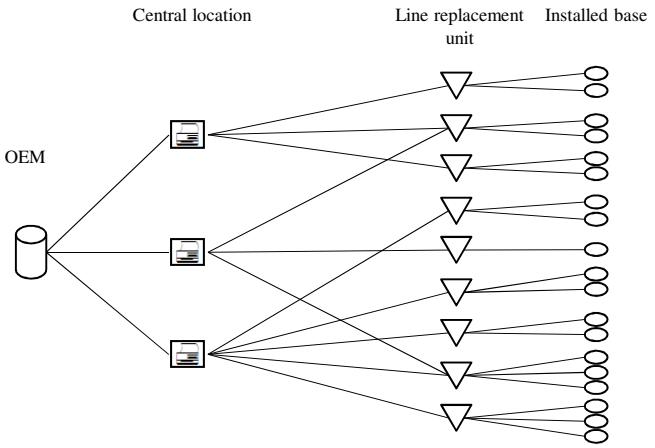
Impact on supply chains

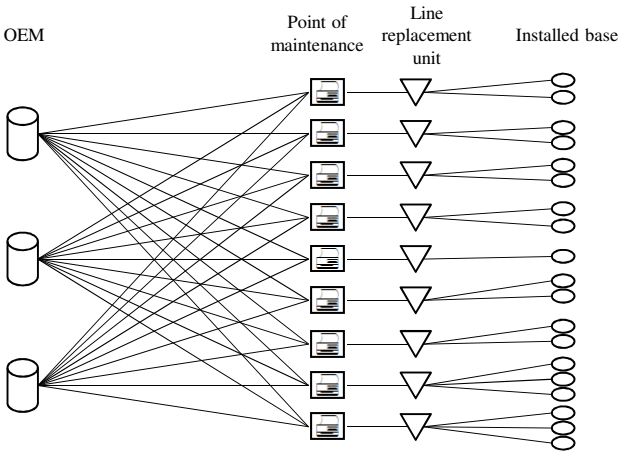
	Tool-based manufacturing	Direct digital manufacturing
Economies of scale and scope	Specialized suppliers in global supply chains	Pools of local (generalized) service providers
Product improvement	Replacement: develop new models	Upgrade/ refurbish: ability to improve products-in-use
Intellectual property rights (IPR)	Controlled designs and tools	Global distribution of design models required for localized direct digital manufacturing

Example: F18 Super Hornet



Current spare parts supply chain


Central location
Line replacement unit
Installed base
OEM


OEM
Point of maintenance
Line replacement unit
Installed base

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Extend principle to operations in general?

- Basic principle of direct digital manufacturing: *The design model directly controls manufacturing*
- Opportunity to extend control principle
- *Direct digital X: manage ops without transactional IT*
  - Add handling instructions to model?
  - Specify how to install?
    - http://video.mit.edu/watch/small-cubes-that-self-assemble-25913/
  - Link performance history to objects directly?
  - Forecast performance of individual?

Potential benefits of extending principe

- Product centric as enabler of lean, high precision manufacturing and logistics processes
  - Processes can be systematically designed, evaluated and improved
- Enabler of continously improving building
  - Reuse of processes and designs gives pay-back on investments in better design and processes
- Demand driven design and sales

Localize manufacturing?

- Reduction of scale benefits => more on site or close-to-site manufacturing
- Potential benefits
  - Opportunity to simplify construction project?
  - Less need to plan ahead?
  - Possibility to postpone detailed design to construction process?