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Vision of a viable global ecosystem around predictive maintenance and additive manufacturing

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This presentation

Introduction: Additive manufacturing & Predictive maintenance

Relationship between maintenance and manufacturing

From single designs to collections to platforms – strategic angle

Trusted networks and importance of "cryptography"

Some conclusions

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Introduction - Additive manufacturing

- Additive manufacturing goes typically under the name 3D-printing, but what it encompasses are all the techniques that are **based on creating shapes by adding material and not removing material**
 - Typically this means that there is **lot less material wasted**, as only what is needed is added
- Additive manufacturing is one key component in what is referred to as **Manufacturing 4.0** – other key components include:
 - Interoperability of systems – automatic data interchange
 - Advanced **automation in manufacturing**
 - Advanced **manufacturing robotics**
- Additive manufacturing is based on the notion that a **”3D printer can print anything it is given a recipe to print”**
The recipe is the digital blueprint of the printable object

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Introduction - Additive manufacturing

- Research is ongoing among other things in:
 - Advancement of printers (precision, methods, complexity)
 - Advancement of robotics and automation involved
 - Advances in materials research (including "smart" materials)
 - Printing of machines rather than only of single components
- Cost reduction and durability of printed goods
 - Method and "tool" –based issues
 - Materials based issues
 - Volume of printers increasing rapidly (very rapidly)
 - Standardization work not yet finished

Bottom line: **The abilities of additive manufacturing will go UP and the costs of additive manufacturing will go DOWN**

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Introduction - Predictive maintenance

- Predictive maintenance broadly is **the practice of scheduling and performing maintenance in a way that it precedes failures** and hence minimizes unexpected failures
- **Optimization** of the (predictive) maintenance schedule is often **a difficult problem** and is typically based on decisions about:
 - Selection of a maintenance policy
 - Acceptable failure levels
- The more complex the chosen maintenance policies are, the more difficult a problem their optimization is
 - Questions like "What else do we do, while the "hood is open"" make things more complicated
 - After each non-scheduled maintenance instance the whole system can **be re-optimized**
 - The system can be **"learning"** – if the parameters change (e.g. become more precise), based on data (experience)
- **So far, the typical target of optimization is a single system**, but this is not where it is going to end
 - Providers of maintenance services are interested in **multiple system optimization** AND will want **to tie the multiple-system optimization to their workforce scheduling**



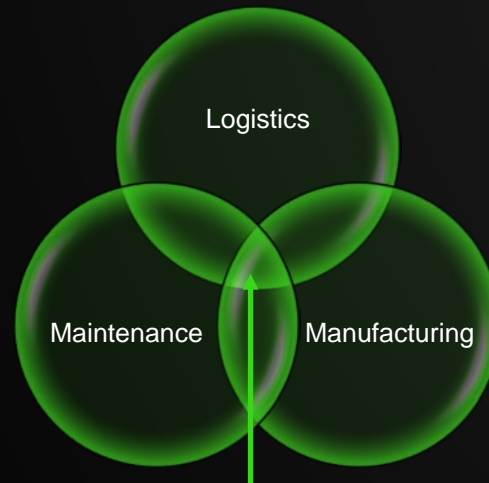
Introduction - Predictive maintenance

- The **goals** of predictive maintenance include:
 - To minimize the cost of operating the system (typically) by
 - Minimizing downtime
 - Maximizing component lifetimes
 - Minimizing maintenance cost
- **Benefits** of predictive maintenance, **apart from cost reductions** include
 - Ability to optimize maintenance resources better
 - Ability to minimize inventories of spare parts
 - Ability to make tougher production-related promises to clients = to sell more
- **Benefits accrue to both**, the **owner of the system and to the provider of the maintenance** service (can be the same)
- Ability to do maintenance better is a **source of lasting competitive advantage**

Relationship between maintenance and manufacturing (one way of putting it)



Clients of manufacturing businesses are a clients of maintenance businesses



Manufacturing businesses are a clients of maintenance businesses

Maintenance business

- Buys spare parts
- Installs spare parts
- Stores spare parts
- Sells spare parts

Manufacturing business

- Designs spare parts
- Makes spare parts
- Packs spare parts
- Stores spare parts
- Sells spare parts

Spare parts

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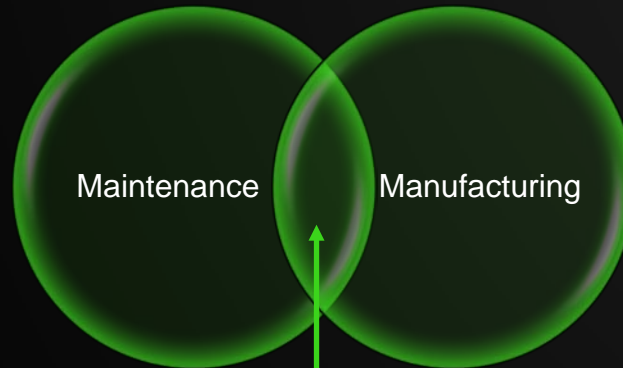
Logistics business

- Ships spare parts
- Stores spare parts

Relationship between maintenance and additive manufacturing



Clients of manufacturing businesses are a clients of maintenance businesses



Manufacturing businesses are a clients of maintenance businesses

Maintenance business

- Buys spare parts
- **Prints spare parts**
- Installs spare parts
- Stores **LESS** parts
- Sells spare parts

Manufacturing business

- **Designs spare parts**
- Makes **LESS** spare parts
- Stores **LESS** spare parts
- Packs **LESS** spare parts
- Sells spare parts

Trusted additive mfg. network

- **Prints spare parts**

"on location"

Logistics business

- Ships **LESS** spare parts
- Stores **LESS** spare parts

IMPORTANCE SMALLER

Relationship between maintenance and additive manufacturing



Clients of manufacturing businesses are a clients of maintenance businesses

As 3D printers start printing needed parts "on location" they no longer need to be shipped. First the "urgent" parts will be printed (printing is expensive at first), then more and more parts.

Manufacturing businesses are a clients of maintenance businesses

Maintenance business

- Buys spare parts
- **Prints spare parts**
- Installs spare parts
- Stores **LESS** parts
- Sells spare parts

Trusted additive mfg. network

- **Prints spare parts**
"on location"

Spare parts

Manufacturing business

- **Designs spare parts**
- Makes **LESS** spare parts
- Stores **LESS** spare parts
- Packs **LESS** spare parts
- Sells spare parts

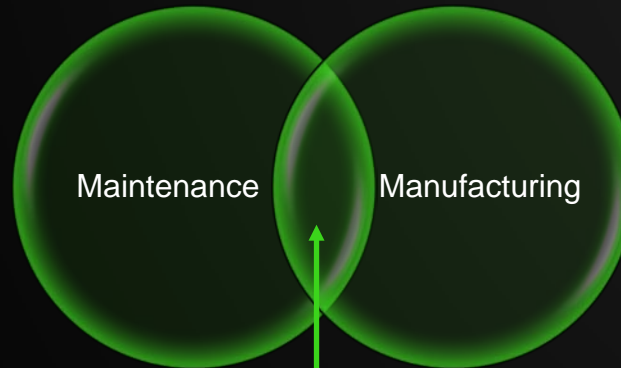
Logistics business

- Ships **LESS** spare parts
 - Stores **LESS** spare parts
- IMPORTANCE SMALLER**

Relationship between predictive maintenance and additive manufacturing



Clients of manufacturing businesses are a clients of maintenance businesses



Manufacturing businesses are a clients of maintenance businesses

Maintenance business

- Buys spare parts
- **Prints more spare parts**
- Installs spare parts
- **Stores parts?**
- Sells spare parts

Spare parts

Manufacturing business

- **Designs spare parts**
- Makes **MUCH LESS** spare parts
- Stores **MUCH LESS** spare parts
- Packs **MUCH LESS** spare parts
- Sells spare parts

Trusted additive mfg. network

- **Prints more spare parts "on location"**

Logistics business

- Ships **MUCH LESS** spare parts
- Stores **MUCH LESS** spare parts
- IMPORTANCE MUCH SMALLER**

Relationship between predictive maintenance and additive manufacturing



Clients of manufacturing businesses are a clients of maintenance businesses

Predictive maintenance will be able to "sniff" a fault and the needed parts "enough ahead" to have the needed parts ordered in time, on demand. The ordering of printing and installation can be fully automated.

Manufacturing businesses are a clients of maintenance businesses

Maintenance business

- Buys spare parts
- **Prints more spare parts**
- Installs spare parts
- **Stores parts?**
- Sells spare parts

Spare parts

Manufacturing business

- **Designs spare parts**
- Makes **MUCH LESS** spare parts
- Stores **MUCH LESS** spare parts
- Packs **MUCH LESS** spare parts
- Sells spare parts

Trusted additive mfg. network

- Prints more spare parts "on location"

Logistics business

- Ships **MUCH LESS** spare parts
 - Stores **MUCH LESS** spare parts
- IMPORTANCE MUCH SMALLER**

Relationship between predictive maintenance and additive manufacturing



- In the future, one can expect that manufacturing of spare parts will increasingly go towards additive manufacturing
 - This means that logistics will no longer be very important
- Maintenance (changing parts and performing other actions) will increasingly be automated and done by robots
 - Predictive systems will be able to "order" automatically new parts, which will start printing autonomously
 - Packing and delivery by robots autonomously
 - Maintenance and changing parts autonomously, by robots
- All this means that large maintained facilities will most likely have an integrated parts manufacturing "unit"

Additive manufacturing design stores



- Imagine what an "appstore" for additive manufacturing designs would look like!
 - Would such a store include designs from many producers (designers) of spare parts, or would each producer have a separate store?
- It is clear that if there is a universal store, then the "owner" of the store is able to assert certain "control" over the business and extract a fee for all transactions made
 - Would it be allowed that someone somewhere would print "licensed" components and store them for immediate use?
 - Would such a store be accessed automatically by additive manufacturing infrastructure (printers), or would they operate via a human?
- Pricing issues?

Trusted networks and importance of cryptography



- When the digital "recipes" used in additive manufacturing are used as a commodity **copyright issues become very important**
 - As the key asset becomes digital, protection of the digital asset becomes key in the ability to make money
 - Piratism is a "big problem" potentially – in reality there is a lock-in to the manufacturer by certification / guarantee systems
- Cryptographic solutions for additive manufacturing problems must be found, tested, and validated
 - **Standardization of cryptography** methods used and coordination with "printer" manufacturers
 - Bringing cryptography skills to the manufacturing and design scene
- **Trust** becomes very important in the digital manufacturing world
 - This will have an impact on who the players are that can / will dominate = only trusted partners will be able to "print" critical parts?

Industry Future / Consolidation – scenarios?



- Will logistics companies start running the additive manufacturing business, as their high revenue shipping business of "urgent delivery" spare parts disappears? and slowly the majority of the spare parts delivery business in general.
- Will maintenance companies adopt the additive manufacturing business of spare parts?
- Will there be a network of smaller companies specializing in additive manufacturing of different types (for example around different materials / technologies)?
- Will large manufacturing companies want to maintain a network of additive manufacturing sites "on location", or will they operate a "trusted network" of additive manufacturing service providers that will "print on demand"?
- What is the role of OEM manufacturers after this change? Will they also start selling their designs or will the OEM manufacturers adopt the additive manufacturing business?



Takeway message

Additive manufacturing is also a **logistics revolution**

Predictive maintenance and additive manufacturing form together a **basis for a further extensions** to the **service-based business models** in maintenance

Commoditizing additive manufacturing designs is a future **platform economy**

A clear agenda for **relevant research around predictive maintenance bundled with additive manufacturing** can be formulated

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