AM for defence – Increasing resilience in the supply chain

Rapid.Tech 3D, 2024 – Erfurt

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15 May 2024

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Contents

An international RTO Based in Denmark

Key figures

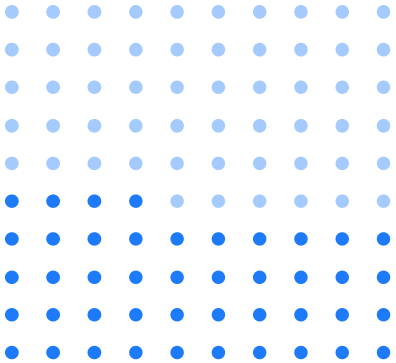
2022

1,063 million

Turnover in DKK

950

Employees



Share of turnover abroad

Almost half of FORCE Technology's turnover comes from international customers through exports or foreign activities.

7,000+

Customers

Key figures

Research and development

250+

Unique facilities

5,000+

Participants courses and events

150+

Collaboration projects

35+

New R&D projects

50+

Disciplines

Motivation

Supply chain issues?

Lead-time?

Price?

Environmental footprint?

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What constitutes ”Supply Chain resilience”?

ChatGPT

”Supply chain resilience refers to the ability of a supply chain to withstand and recover from disruptions while maintaining its functionality and efficiency. Several key components contribute to supply chain resilience:”

1. **Redundancy**: Having backup plans and **alternative suppliers** in place ensures that the supply chain can continue operating even if one supplier or component is disrupted.

2. **Flexibility**: A flexible supply chain can quickly adapt to changes in demand, supply, or disruptions by reallocating resources, adjusting production schedules, or **finding alternative routes for transportation**.

3. **Agility**: An agile supply chain can **quickly adjust to** changes in **market conditions, customer preferences**, or **disruptions**. […]

Motivation

AM enables alternative supply chains

- Alternative supplier: Produce your own (spare)parts
- Materials savings
- Processing time reductions of upto 95 %
- Refurbishing made possible
- Re-manufacturing enabled

… all of the above adds resilience to the supply chain

And in addition:

- Cost reductions upto 90 %
- Freedom of design

Challenge:
F-35 component

Baseline

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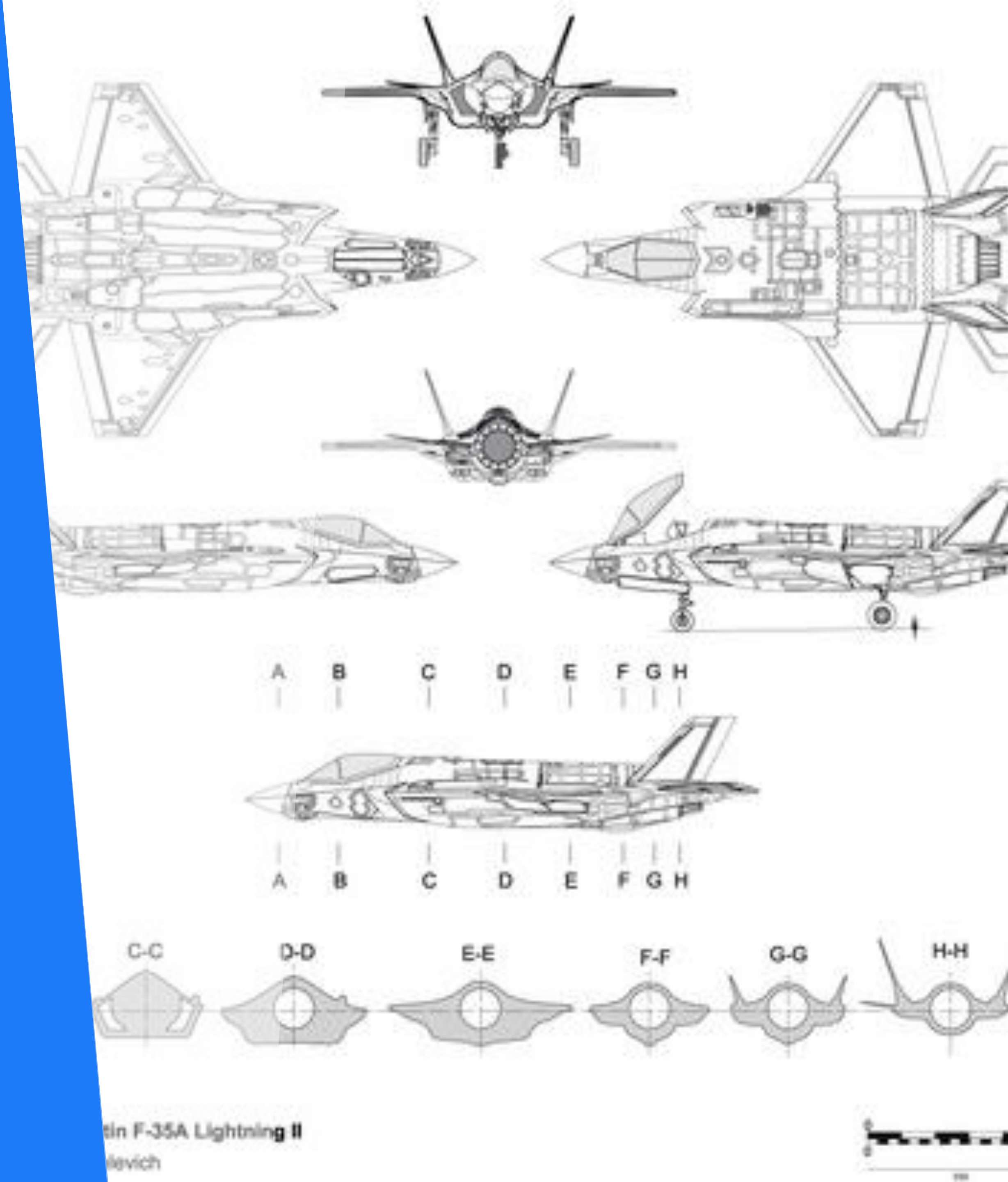
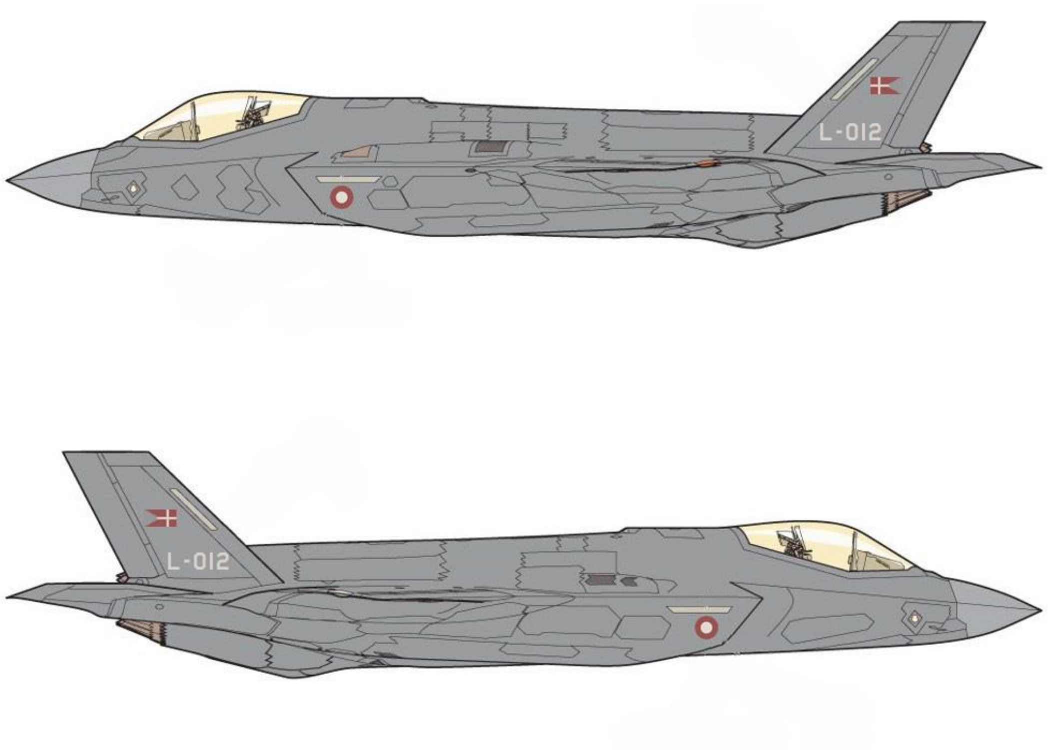
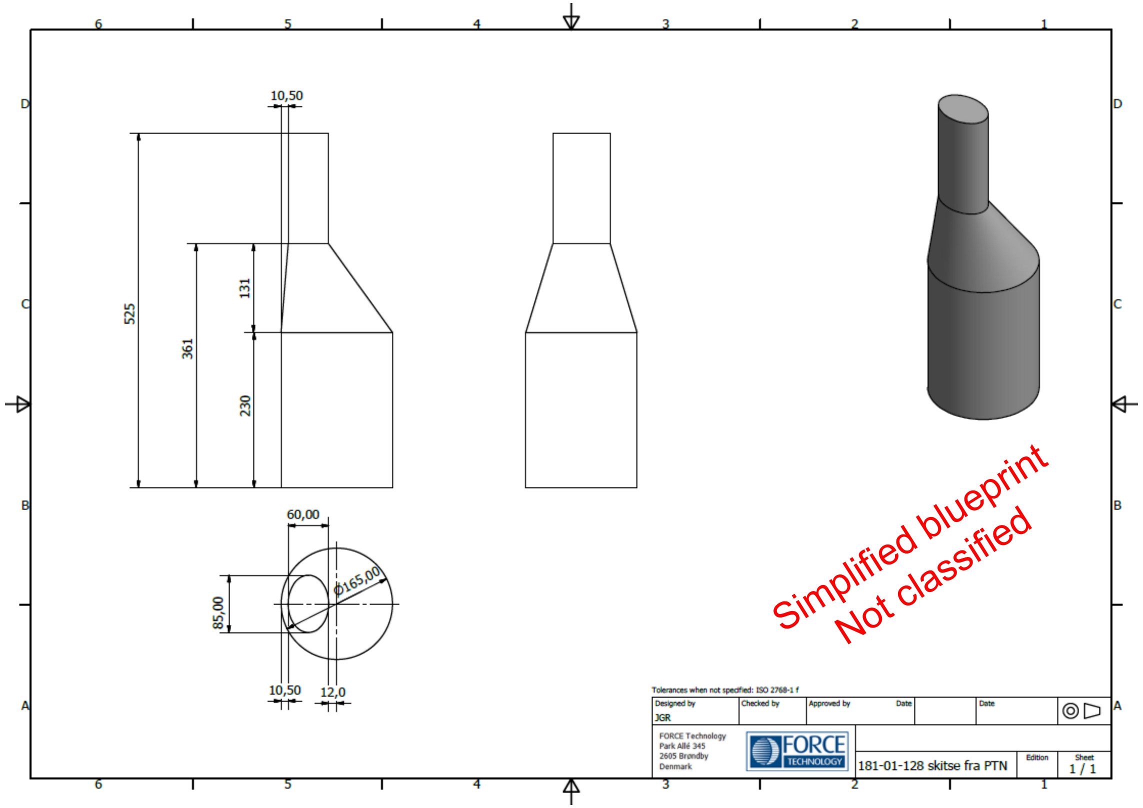


Example: Large-scale 3D printing for F-35

”A component” for the F-35 Joint Strike Fighter

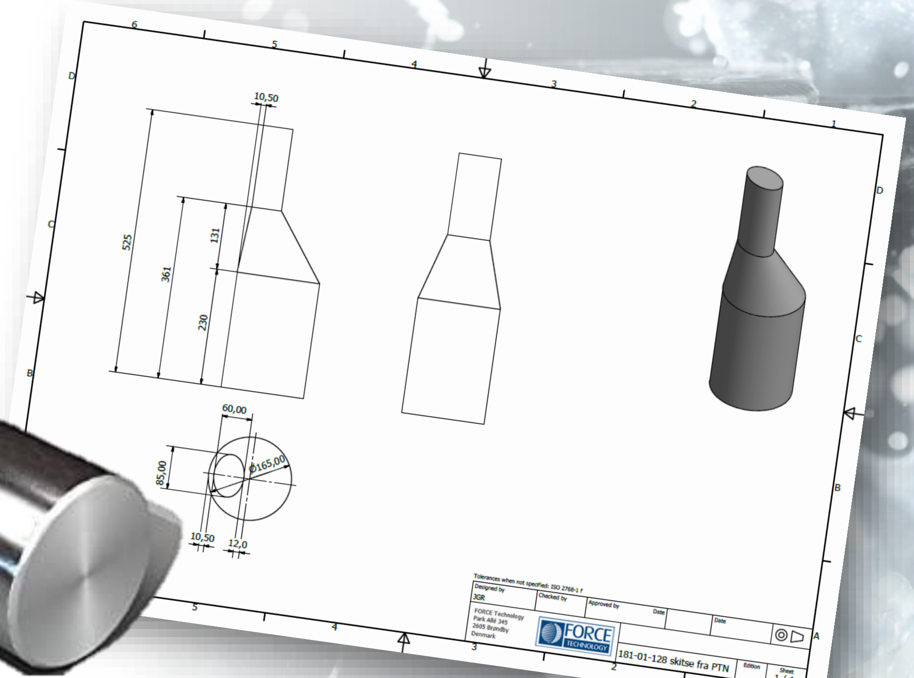




Present day state-of-the-art

CNC machining – Baseline

- Alloy: 15-5 PH (Approx. 2x the price of AISI 316L)
- **219 kg** rod base
- App. **120 hrs** milling time



Technique

The ‘How’

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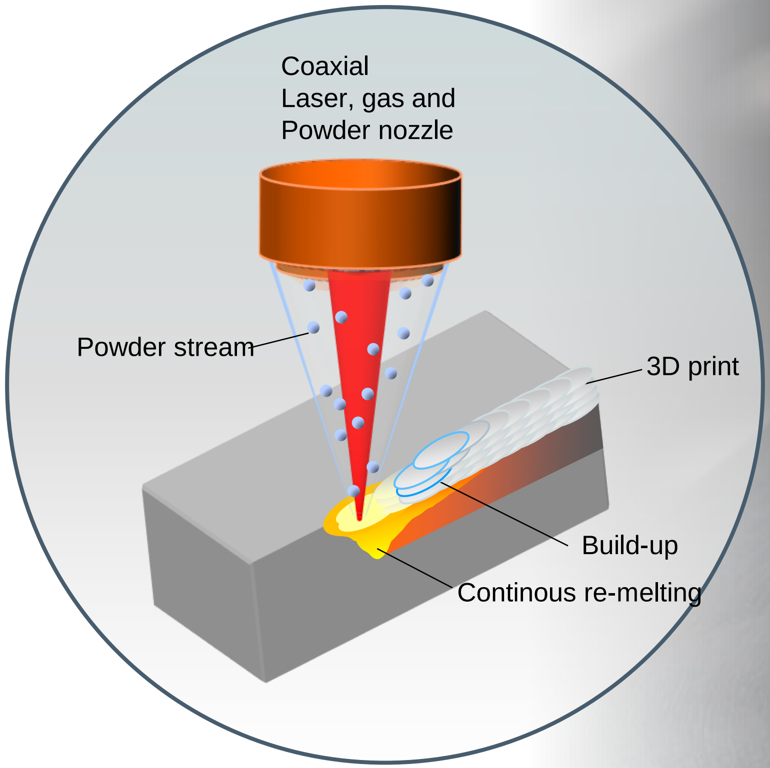
Next generation large-scale 3D printer

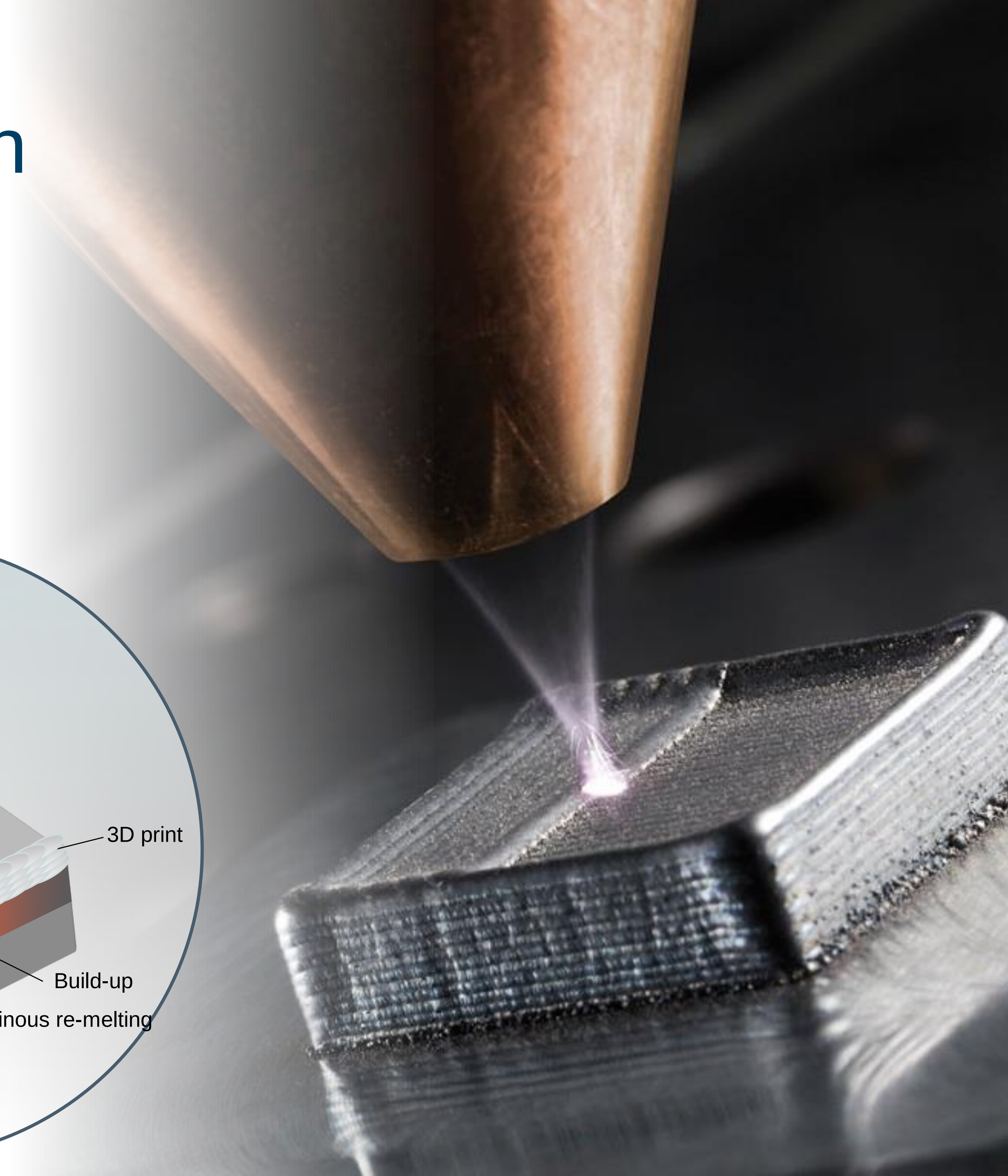
Directed Energy Deposition

DED – Technology keywords

- Direct (blown) powder
- Laser energy source
- Shielding gas inherent
- Industrial robot control

- Large-scale
- High-deposition rates





Free-form 3D printing

High-temp super-alloy for aerospace

Run time: 1:27 mins

Machined
219 kg
120 hrs

3D printed
9 kg
4.5 hrs

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3D printed components – Are they any good?

Mechanical test results

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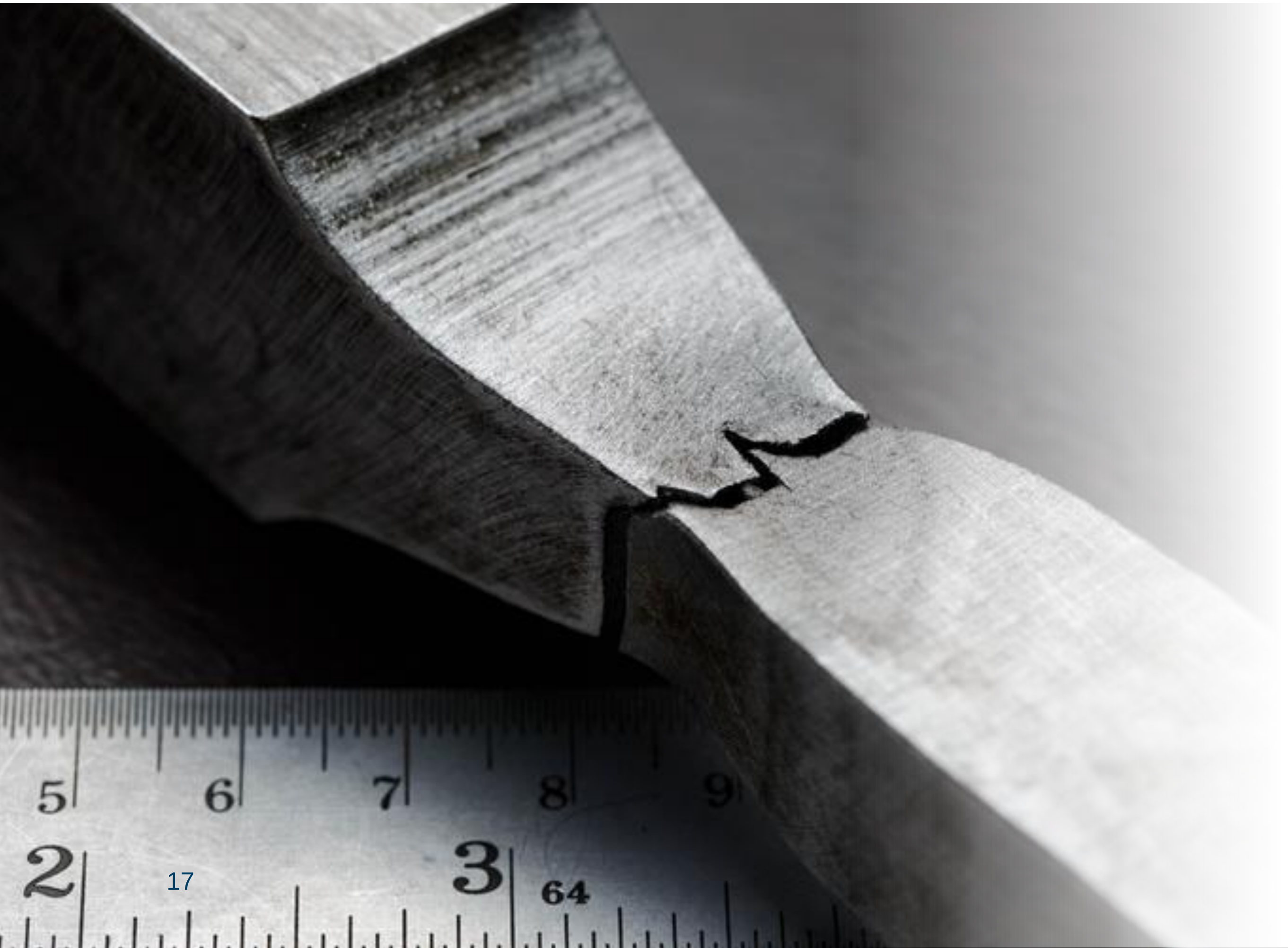
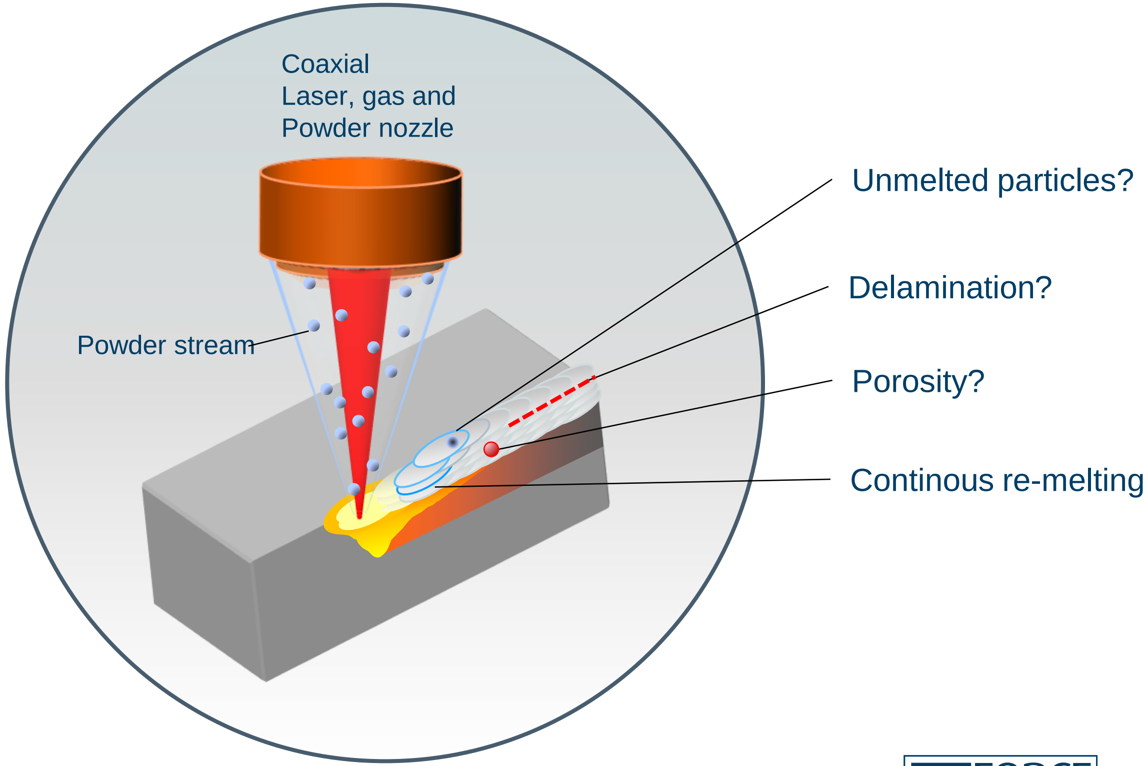
What may happen during 3D printing?

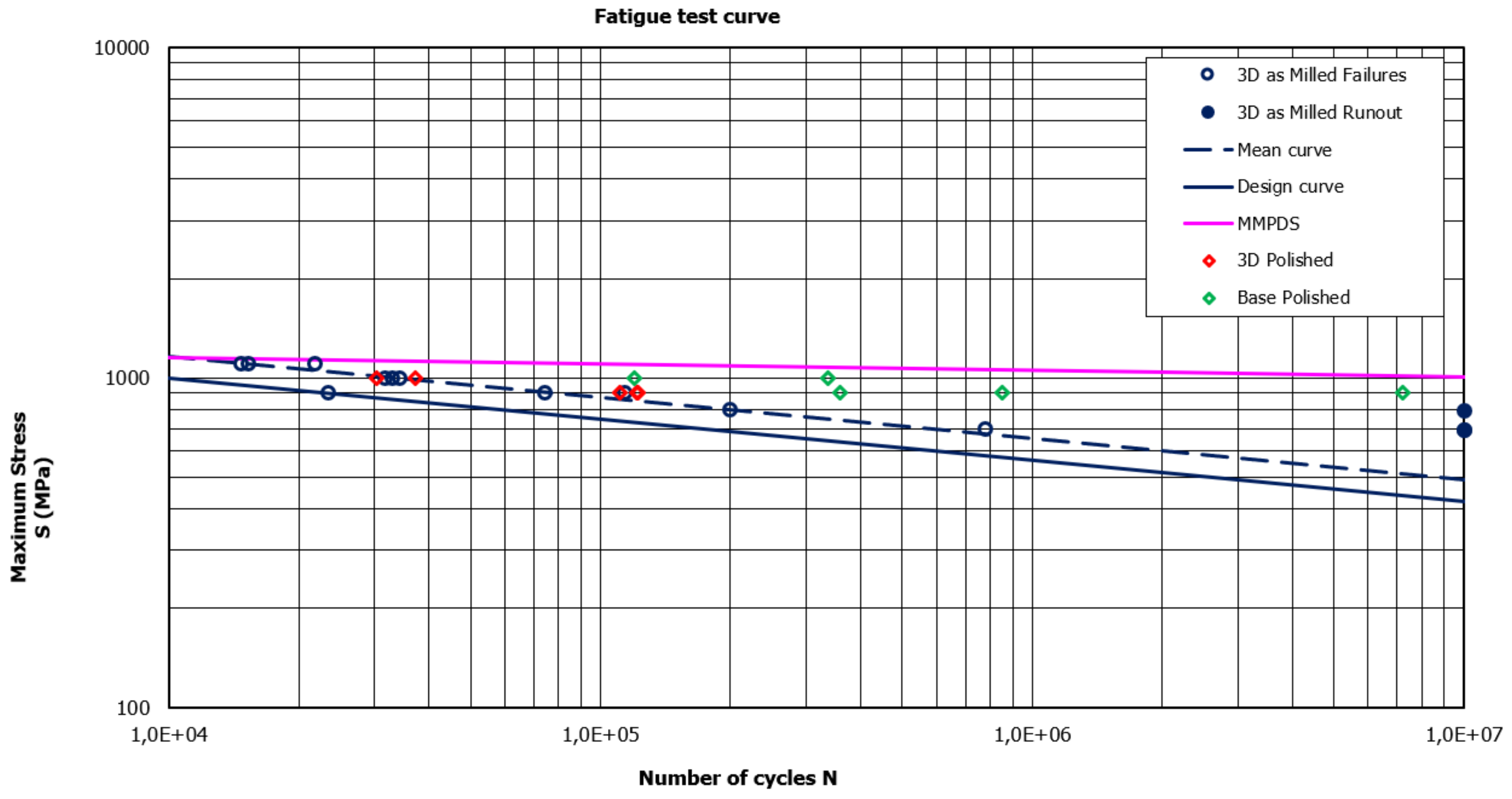
Potential failure mechanisms





Fatigue life

Polished vs. milled samples – All comply with the Design Curve



Powder particle impact on print quality

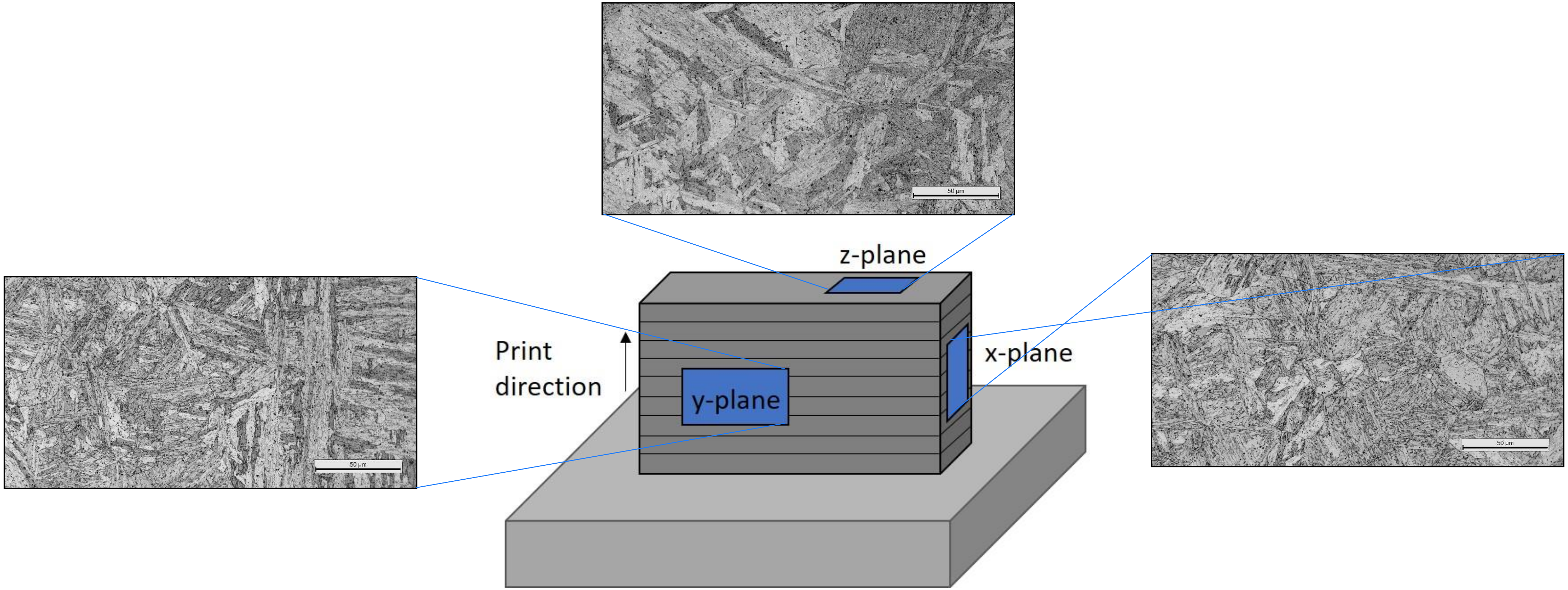
Minor impact on DE and build rate

Some impact on spatter and seam width

PSD [µm]	Spatter	Seam width [mm]	Build rate [mm]	Deposition Efficiency (DE)
53 < ø < 90	Yes	4.0	1.0 28.7 g/min	77%
22 < ø < 53	No	4.5	1.0 30.4 g/min	85%
15 < ø < 45	No	4.8	1.0 30.9 g/min	86%

Structural dependance on print direction

… it does not matter much



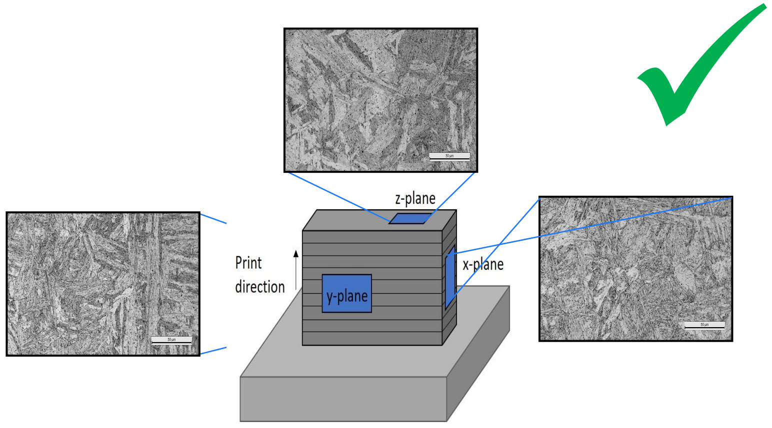
Service conditions test at elevated temperature

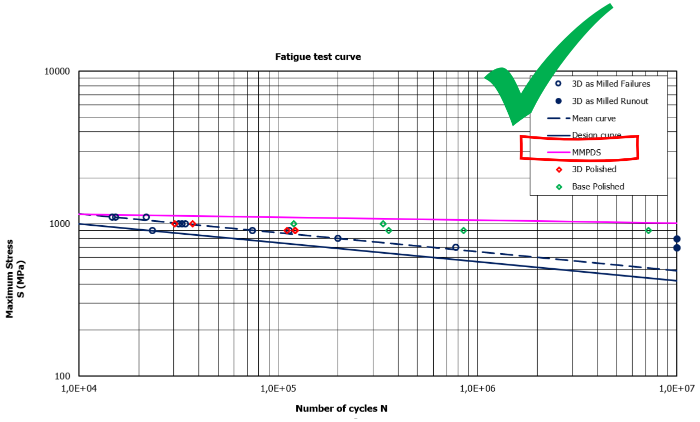
Hot tensile test at 600 deg C

Temp.	Test vs. Spec.	Tensile [MPa]	Yield [MPa]	Elongation [%]
20°C	Obtained	**1133**	**1077**	**14.8**
	MMDPS	1067	1000	12.0
600°C	Obtained	**534**	**485**	**10.3**
	MMDPS	?	?	?
Reduction (20-600°):		53 %	55 %	30 %

Litterature study indicates:
A drop of 40-60 % is to be expected

3D printed parts – Mechanical properties: Results





Tensile and yield strength

- Passed ✓
- Regardless of particle size

i.e.: 3D-printed samples are ”As strong” as reference

Homogenity

- Passed ✓
- No influence of print direction

i.e.: 3D-printed parts are *”As homogenous” as reference*

Fatigue test

- Passed ✓
- No (metal) fatigue observed

i.e.: 3D-printed parts are *”As durable” as reference*

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Economical benefits – Does 3D printing pay off?

Calculated examples

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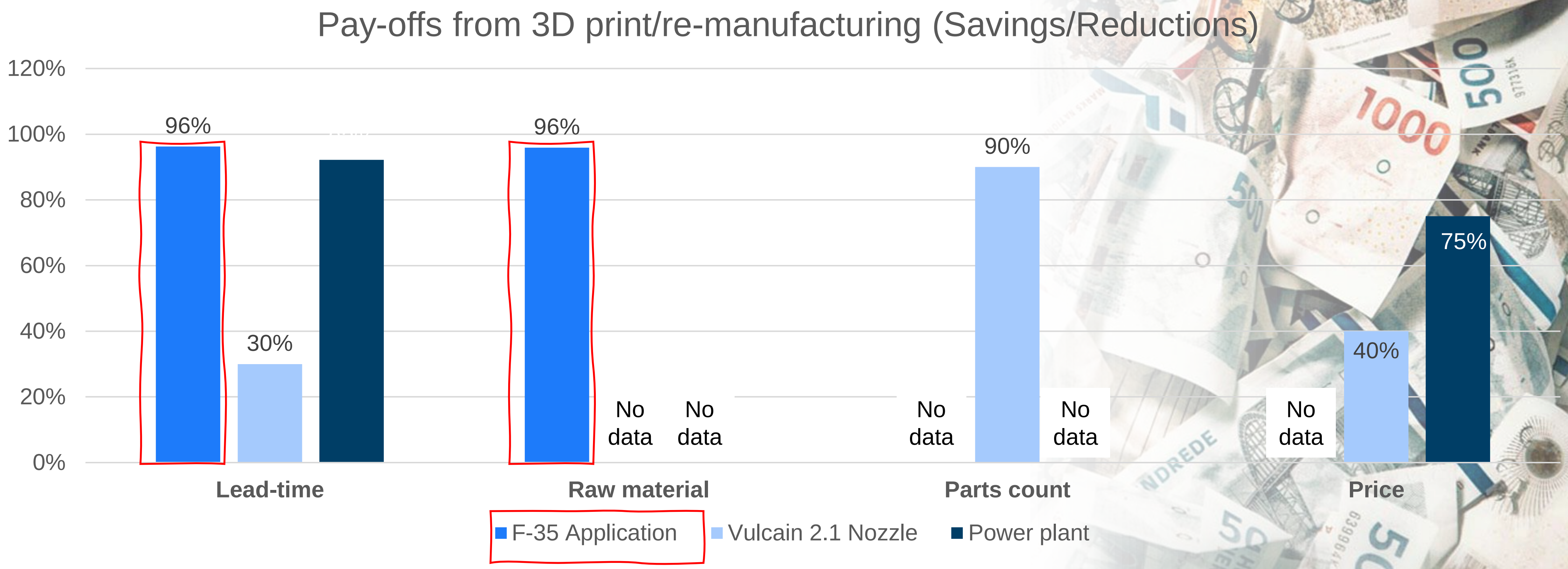
Does Large-Scale 3D print pay off?

Actual examples (FORCE Technology)



Carbon footprint – A calculated comparison

F-35 part:
CNC-machined vs. 3D printed

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Carbon footprint – A calculated comparison

F-35 part: CNC machined vs. 3D printed

Assumptions:

- 1.85 kg of CO2 emission per 1 kg steel manufactured [1)]
- 0.135 kg of CO2 emission per 1 kWh consumed [2)]

96 % saved on processing time

95 % saved on Carbon emission

96 % saved on Raw materials

93 % saved on electricity

AM processing saves:

- 115 hours of processing time
- 150 kWh of electrical energy
- 538 kg of CO_2 emission

	CNC		3D Print		Savings
	Units	CO_2 [kg]	Units	CO_2 [kg]	
Processing time [hrs]	120		4,5		**115,5** hrs
Raw materials [kg]	219	405,2	9	16,7	**210** kgs
Machining [kW/hr]	10	162,0	20	12,2	**1110** kWh
Carbon emmission		567,2		28,8	**538,4** kg CO_2

Data sources:

[1)] McKinsey: https://www.mckinsey.com/industries/metals-and-mining/our-insights/decarbonization-challenge-for-steel

[2)] Klima, Energi og Forsyningsministeriet: https://www.ft.dk/samling/20191/almdel/kef/spm/380/svar/1674514/2215558/index.htm

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AM and 3D printing can **assist** the green transition

The technology cannot stand alone, but may considerably assist via e.g.:

- Reduced materials consumption
- Reduced carbon foot-print
- Smarter products
- Increased product lifetime
- Re-use and recycle
- The technology is already in widespread use…

Summary

The potential of large-scale metal 3D print and AM

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Summary – And the way ahead…

- **REDUNDANCY**:
  AM is an enabler to circumvent traditional supply chains – ”Build your own”
- **FLEXIBILITY:**
  Think outside of the box – or inside a much bigger box…
- **AGILITY:**
  Saves time and materials (upto 95 %)
- Save on cost (upto 90 %)
- Quality requirements are achieveable

Keep in touch

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