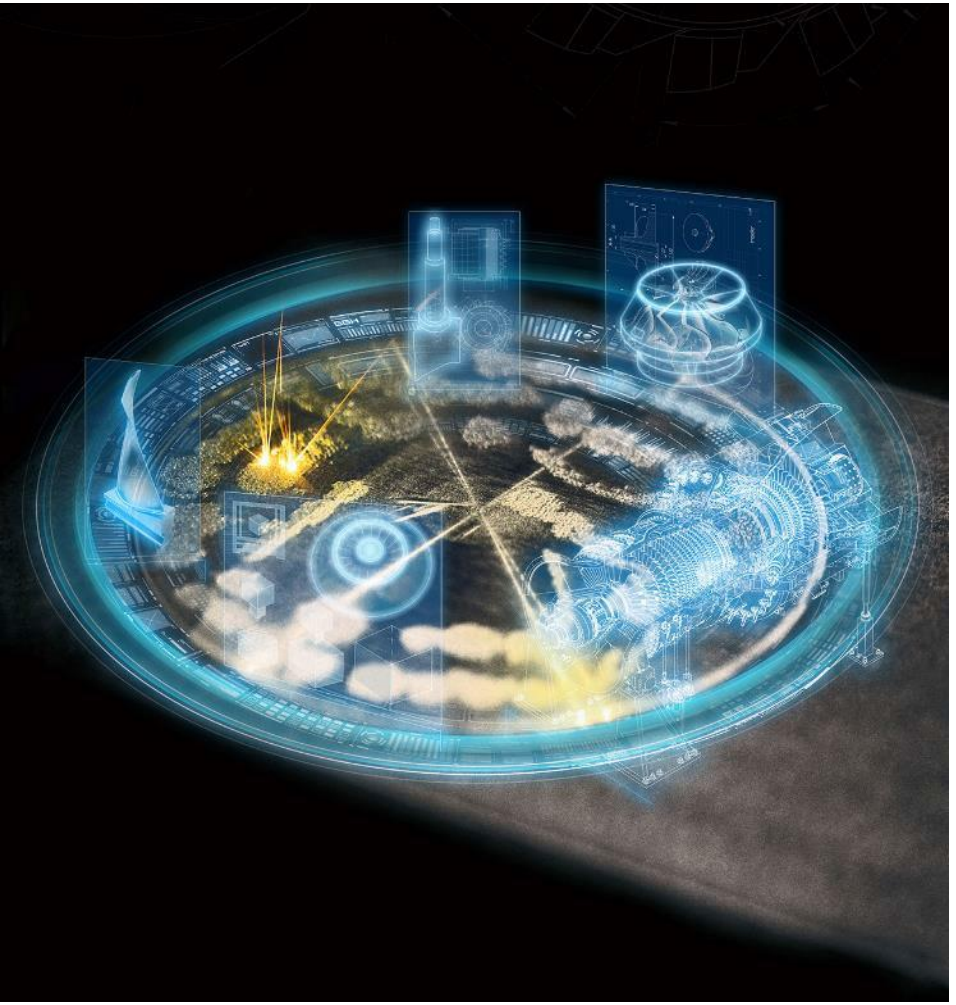
Industrialization of AM components

José M. Macho, 4 Dic. 2019

Table of content



Our Company –
Company structure since April 1st, 2019

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Operating Companies

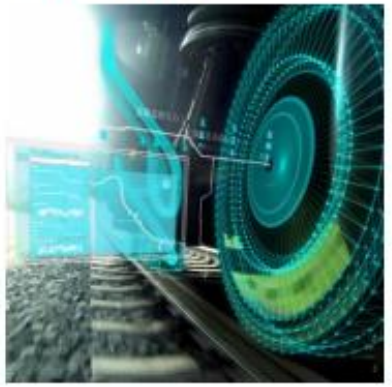
Gas and Power*

Smart Infrastructure

Digital Industries

Strategic Companies

Siemens Mobility



SIEMENS Gamesa* RENEWABLE ENERGY

SIEMENS Healthineers

Service Companies (Financial Services, Global Business Services, Real Estate Services)

Corporate Development (e.g., IoT Services, CT, Next47, Portfolio Companies)

Governance units

*Partial spinoff of Gas and Power planned; transfer of majority stake in SGRE (59%) to new company planned

Siemens key figures in Fiscal 2018

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Key figures

(Continuing operations; in € million except where otherwise stated)	Fiscal 2018[1]	Fiscal 2017	Change in %
Volume			
Orders	91,296	85,784	8%[2]
Revenue	83,044	82,863	2%[2]
Profitability and capital efficiency			
Net income[3]	6,120	6,094	0%
Return on capital employed (ROCE)[3]	12.7%	13.3%	
Liquidity			
Free cash flow[3]	5,824	4,769	

Employees (in thousands)	Sept. 30, 2018	Sept. 30, 2017
Total[4]	379	377
Germany	117	118
Outside Germany	262	259

Revenue by Industrial Business

Revenue by Region

1 Since the beginning of fiscal 2018, the accounting standard IFRS 15 (Revenue from Contracts with Customers) has been in effect at Siemens. Prior-year information is presented on a comparable basis 2 Excluding currency translation and portfolio effects 3 Continuing and discontinued operations 4 As of the beginning of fiscal 2018 part time employees are included to the full extent rather than proportionally. Prior-year information is presented on a comparable basis
5 Commonwealth of Independent States

Siemens Additive Manufacturing setup

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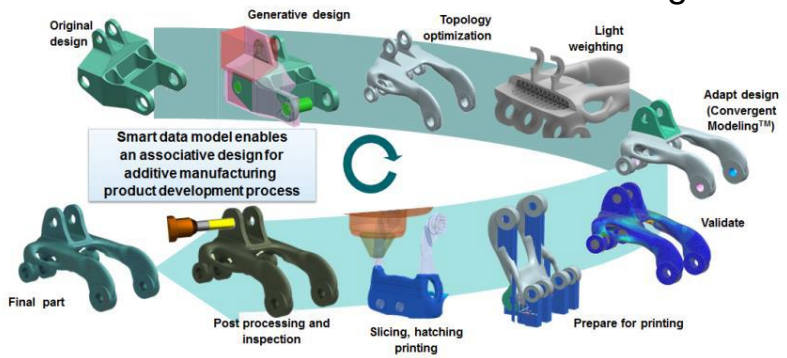
1 Product design | 2 Production planning | 3 Production engineering | 1 Machine concept | 2 Machine engineering | 3 Machine commissioning | 4 Production execution | 5 Service

PLM Software

Digital Factory



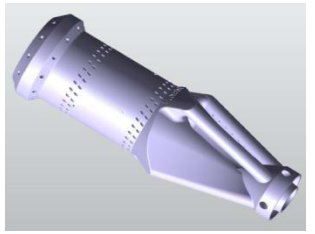
Digital end2end Chain with NX12 for AM

Automation

New generation AM machines will be equipped with automation systems from Siemens

Engineering & Manufacturing Services

Power Generation / Service



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Materials Solutions
A Siemens Business

AM serial components designed for AM, printed and successfully tested

AM end user

Cross-division development of AM technologies

End-to-End digital AM chain

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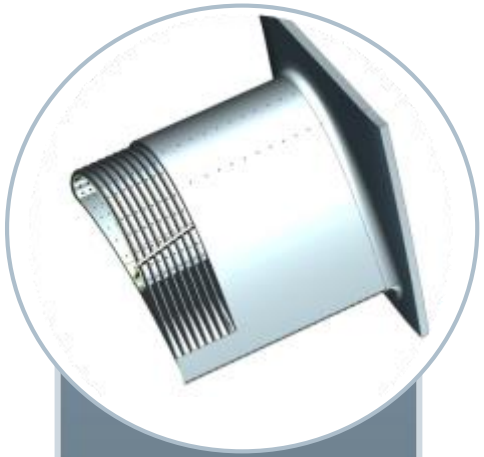
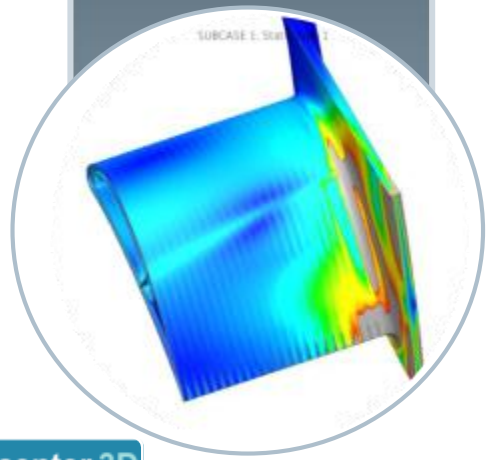
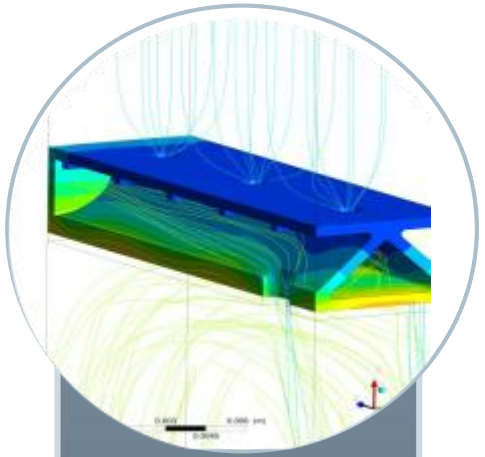
SIEMENS AM
Material Database



Design for AM / Reverse engineering in NX

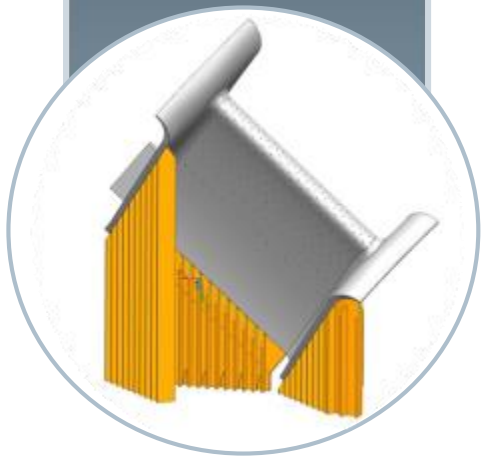
Structural FE Analysis in Simcenter 3D

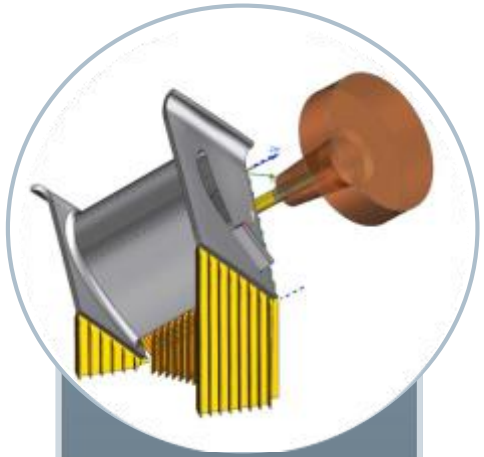




CFD / Heat Transfer Analysis in Simcenter 3D

AM build preparation & support structure optimization in NX AM





Integrated post-processing & quality analysis in NX CAM

Simcenter 3D

NX

TEAMCENTER

Siemens Power and Gas
Rising challenges within Power Generation businesses

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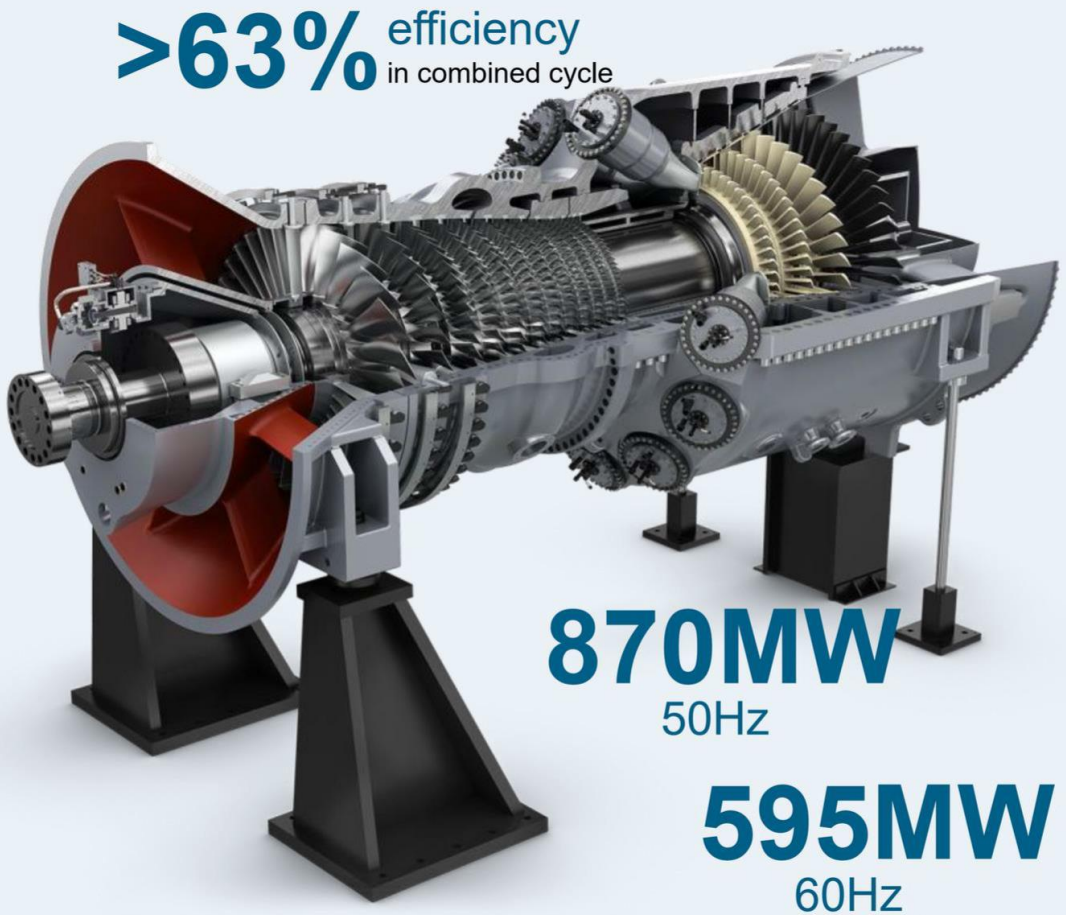
Product

Decreased LCOE

Improved efficiency & flexibility

Enhanced power density

Less emissions



Supply Chain

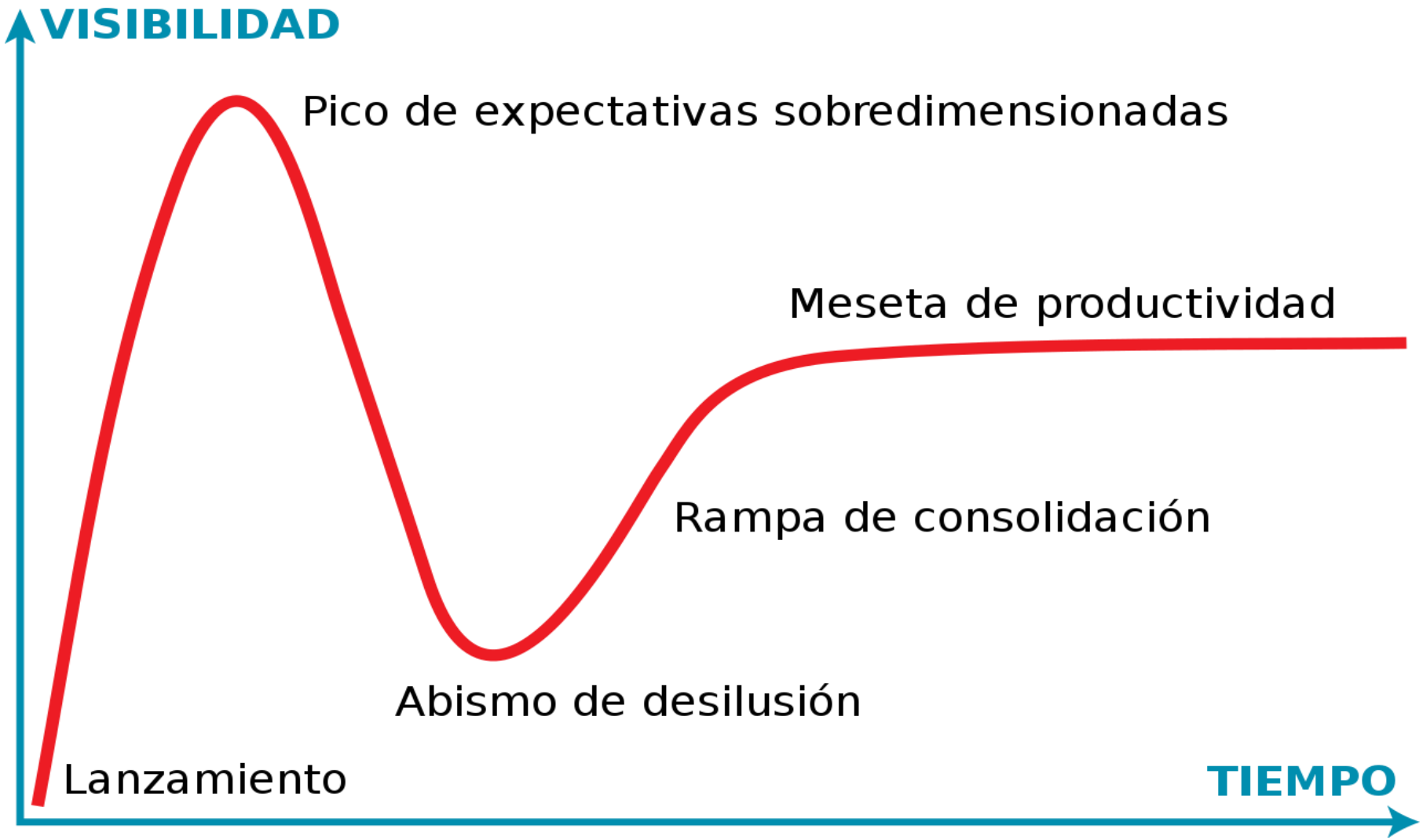
Faster repairs

Spare part availability

Risk reduction

Faster time to market

The Gartner Hype Cycle



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¿En qué parte de la curva de Gartner se encuentra actualmente la tecnología de fabricación aditiva <u>industrial metálica</u>?

1.- Lanzamiento

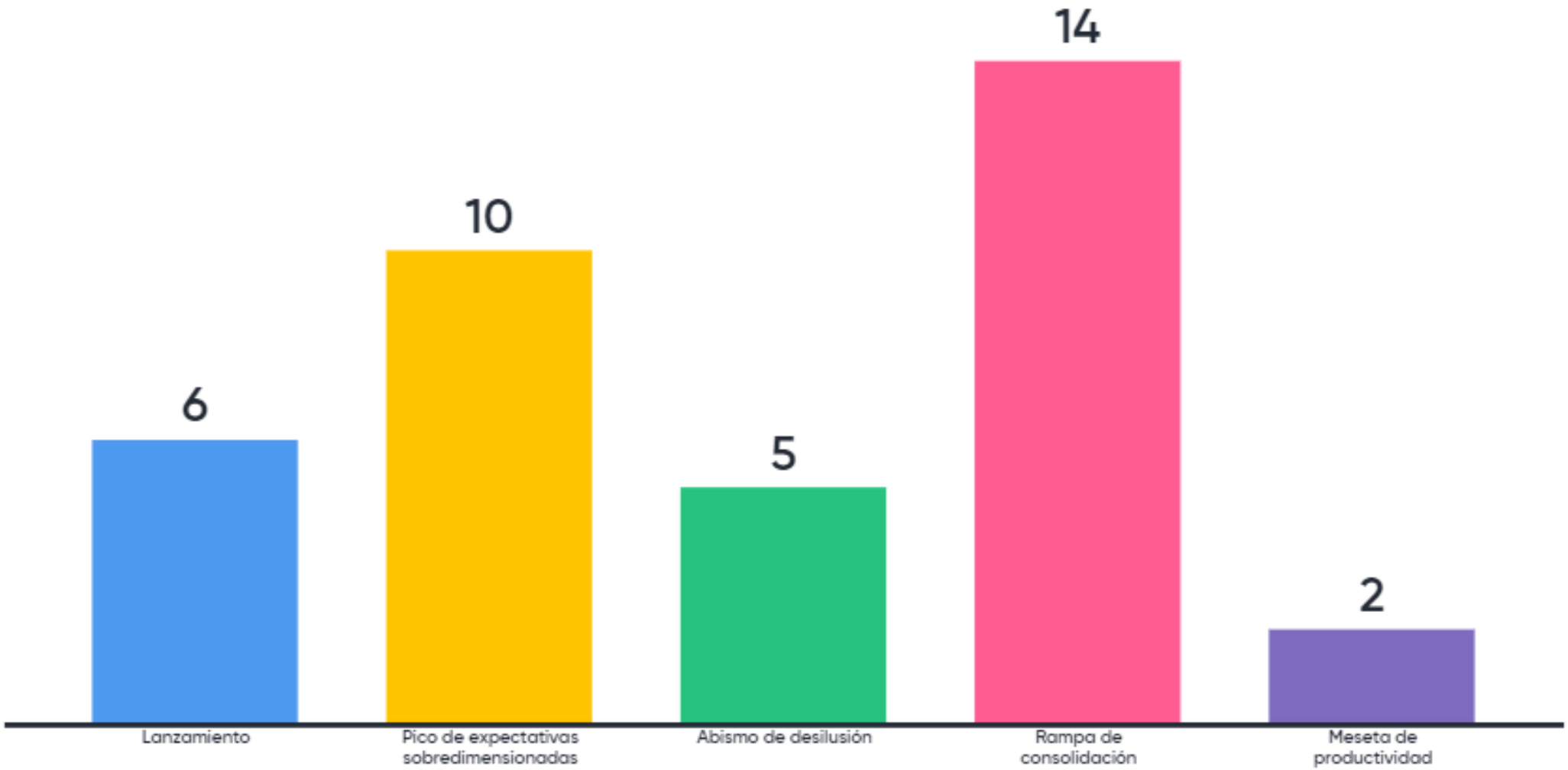
2.- Pico de expectativas sobredimensionadas

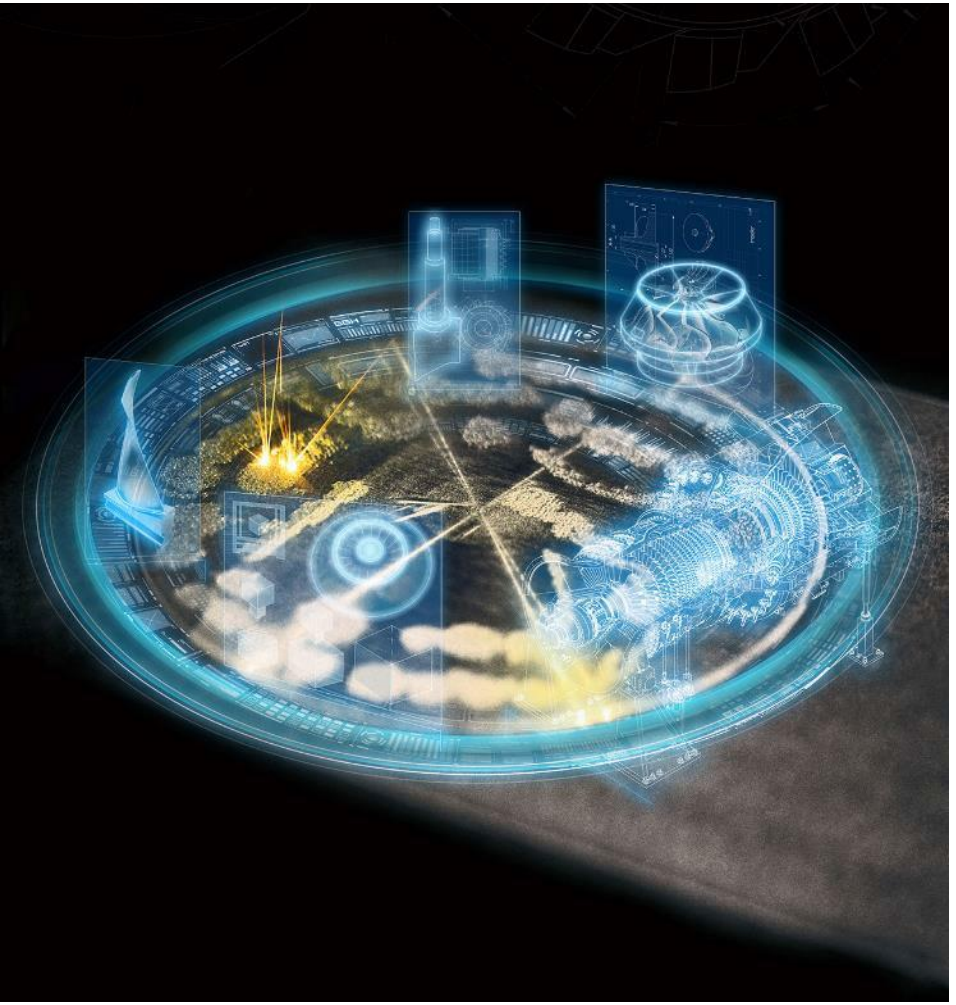
3.- Abismo de desilusión

4.- Rampa de consolidación

5.- Meseta de productividad

Answers





- **Siemens in Additive Manufacturing**
- **Case Study: PCS Swirler**
- **What´s next ?**

AM serial parts production

PCS Main Swirler

Why go for AM?

- Introduce **high-tech component**
- **Demonstrate** performance and **capability of AM**
- **Expand** Siemens **AM serial component** footprint
- Gain further **experience with serial production**

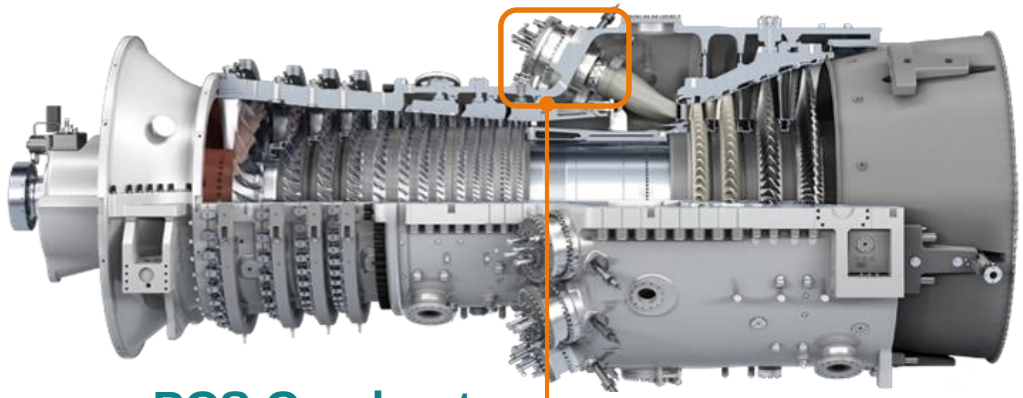
Our starting point

- **AM PCS main swirlers in operation** at Bugok / Dangjin
- **6,000 EOH successful operation**
- **No issues** found at **regular inspection**

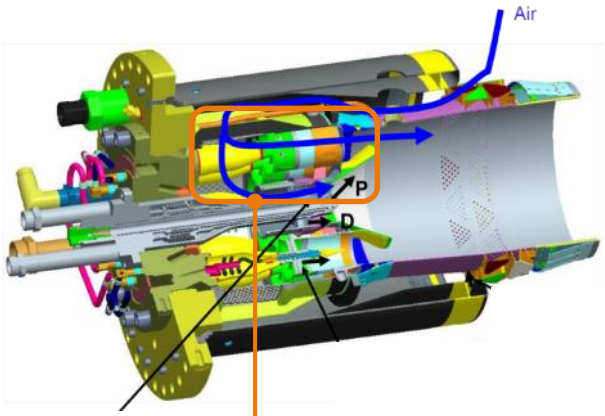
The opportunity

- **Substitution** of conventional **casting part** by L-PBF
- Prove **positive business case** for the component
- Enable **faster design iterations** for future development

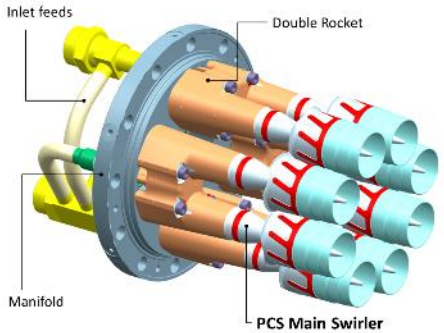
SGT5/6-8000H



PCS Combustor



PCS Main Swirler



Printed Test Swirlers (Bugok)

AM serial parts production

PCS Main Swirler

The Project

- **Full redesign** of the part for AM
- Develop & certify **processes for serial production**
- **Qualify part** for commercial operation

The Challenge

- Lengthy conventional **processing** (cast / machine / weld)
- Cost-**efficiently build-up** of such a large part.
- **Repeatability and Quality:**

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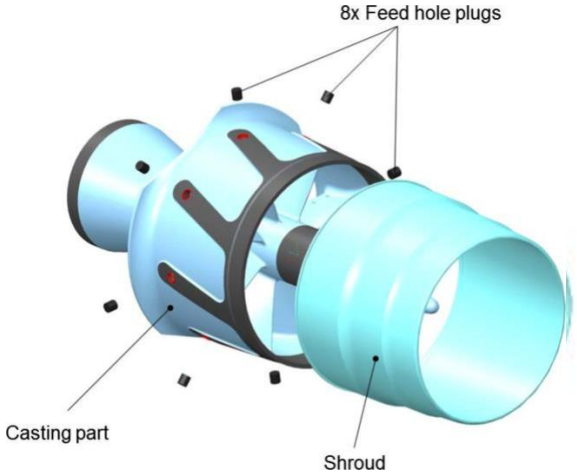
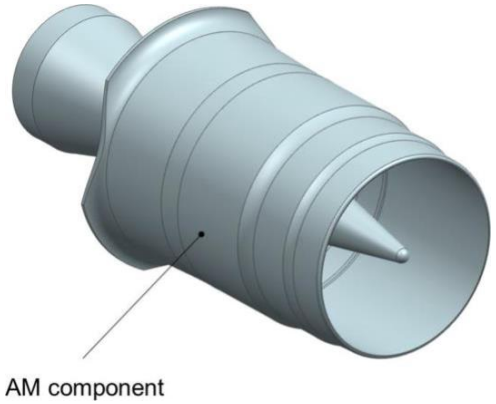
From conventional component pieces…



… to fully integrated AM part



AM parts qualification

PCS Main Swirler

Overview

Results

- ✓ **Post processing time per part reduced by 80% (from 6hrs to 1hr):**
  - Near net shape design by functional integration and part reduction from 10 to 1
- ✓ **Bild time per part reduced by 33%:**
  - Innovative parameter adaptions for individual part regions.
  - Nesting: 16 parts per build plate
- ✓ **20% lead time reduction**
- ✓ **Positive business case achieved**

Next steps

- First high volume additive serial production for LGT begins with ~1000 parts p.a.

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Serial production

Materials Solutions –
A Siemens Business

Final build plate of 16 parts including full quality documentation

Siemens PG/PS global AM footprint

Growing manufacturing, engineering and Sales network

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Worcester (UK)
21+ various printers

Finspång (SWE)
19+ various printers

Charlotte (US)
1x printer

Orlando (US)
3x various printers

Berlin (GER)
2x printers

More than
25’ EUR
R&D p.a.

more than
150 people
dedicated to AM

more than
40 printers
with factory space
for up to 100 printers

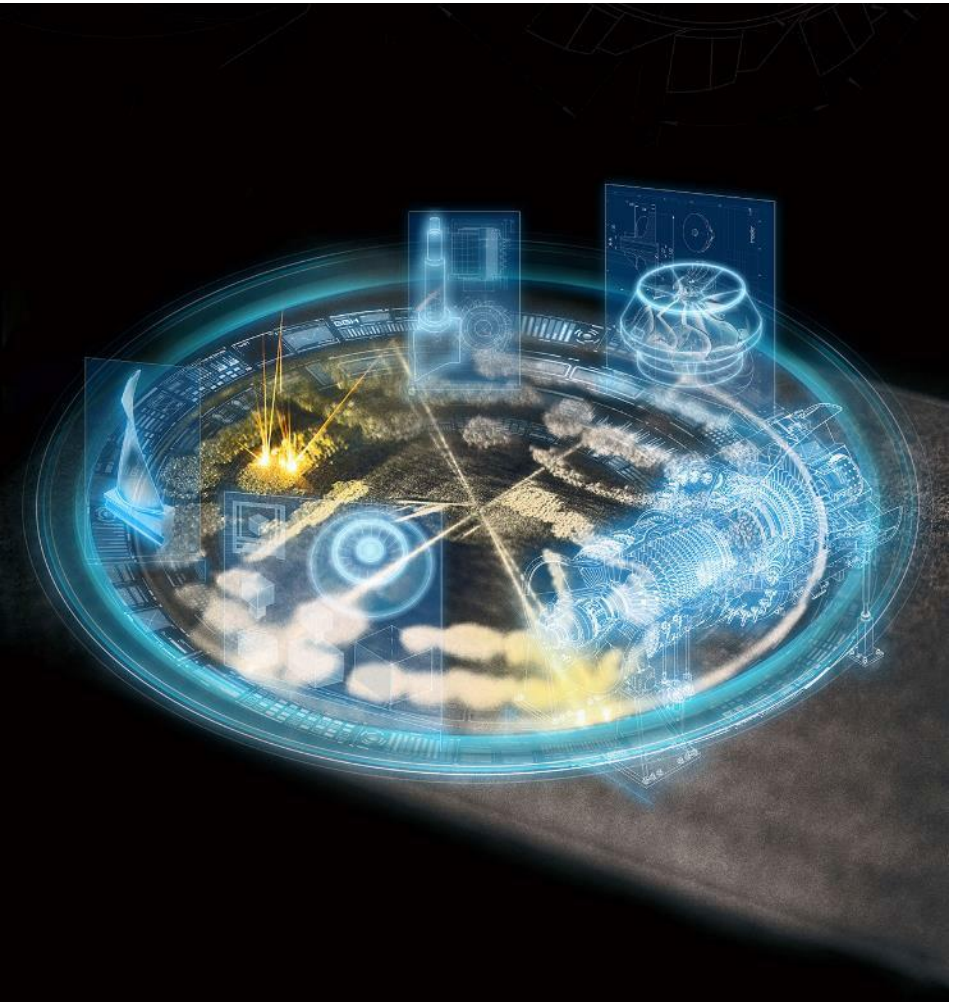
Capabilities

- Production and Development
- Prototype and Development
- Sales and Business Development

Finspång

José M. Macho

Worcester

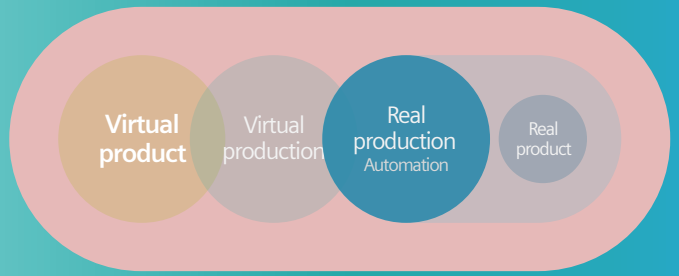


- **Siemens in Additive Manufacturing**
- **Case Study: PCS Swirler**
- **What´s next ?**

Integrated software and automation solutions, including post-processing

Mandatory for industrializing Additive Manufacturing

Automated post printing processes for powder removal and support removal



Automated powder removal

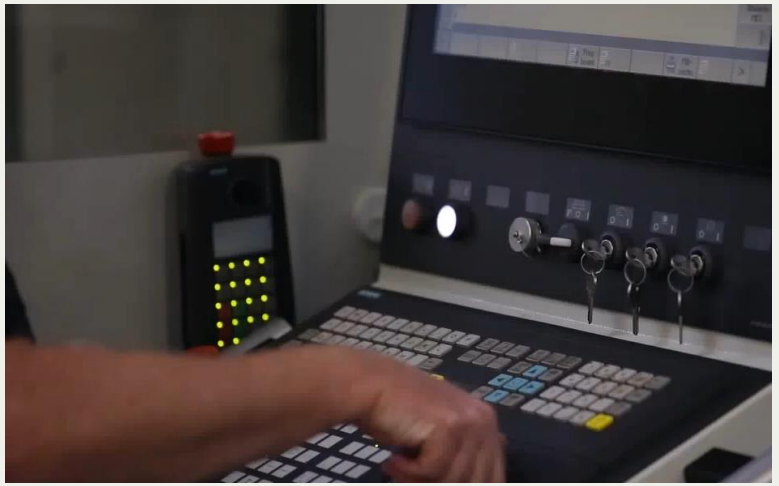
Controller
SIMATIC ET200SP Open Controller
combining standard and failsafe functionality

Drive Systems
SINAMICS S110

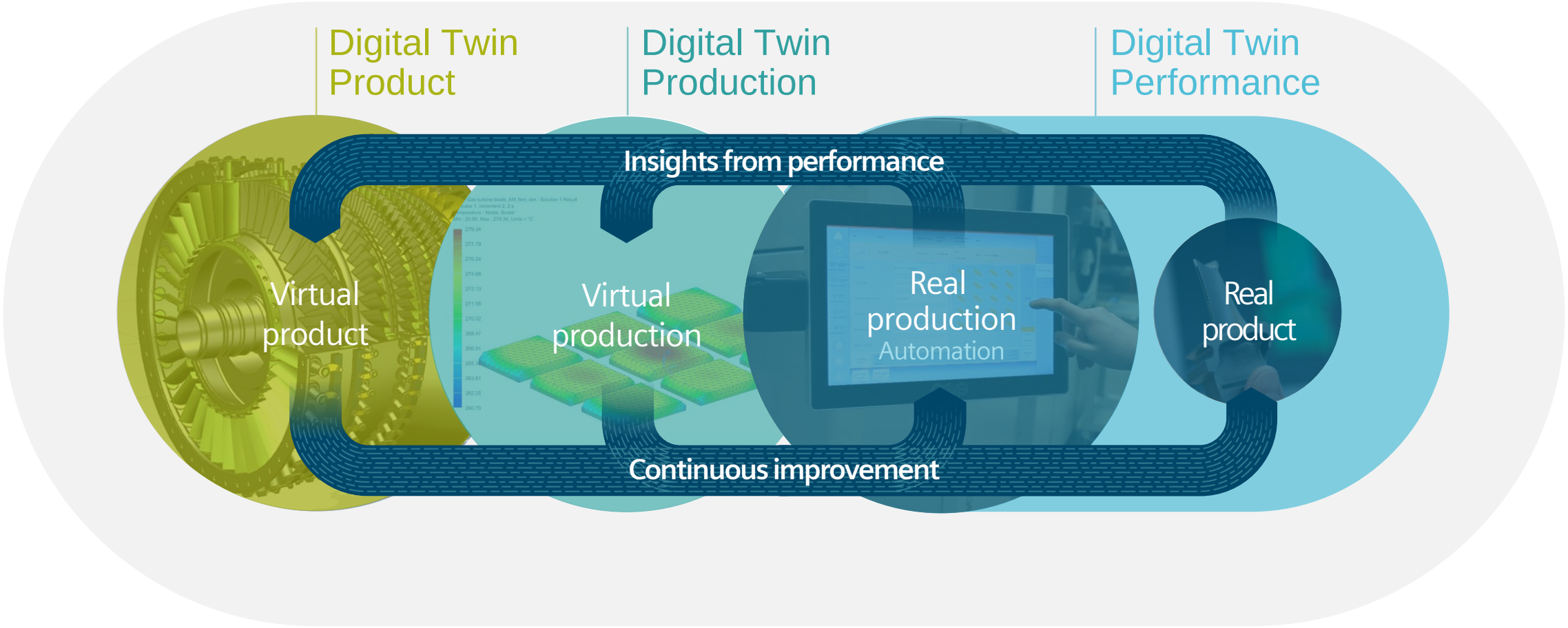
Geared Motors
SIMOTICS S-1FG1

Additive Manufacturing and CNC integrated software

CNC controlled removal of support structures

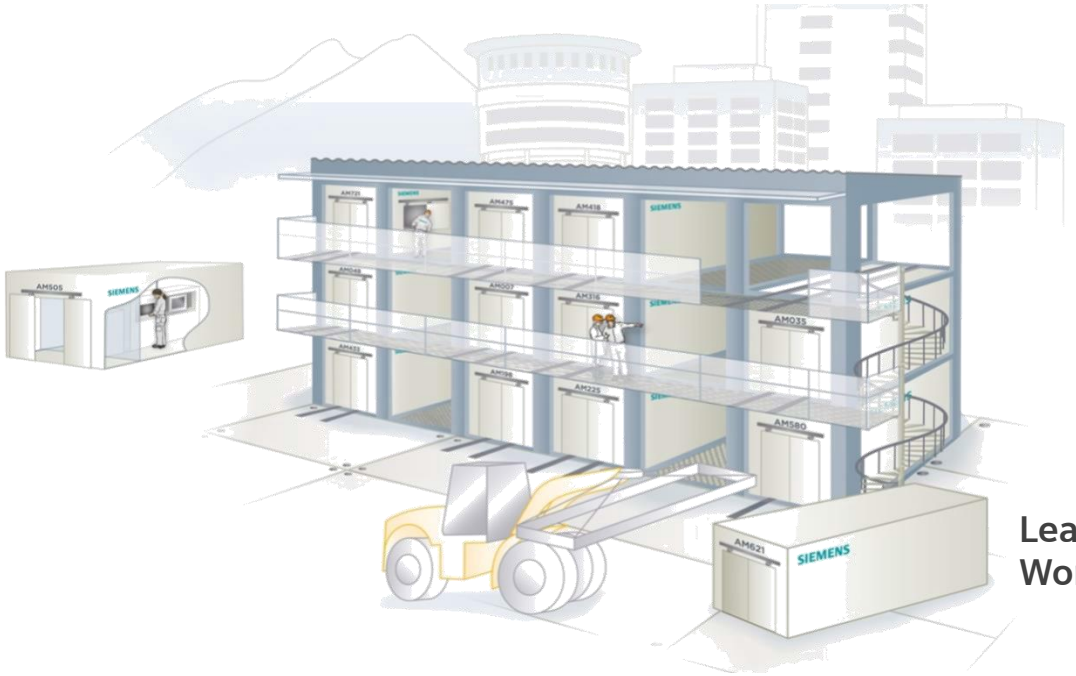


Digital Twins are enabling industrial additive manufacturing



Vision: Full digitalization / automation of Additive Manufacturing

Decentralized, autonomous facilities



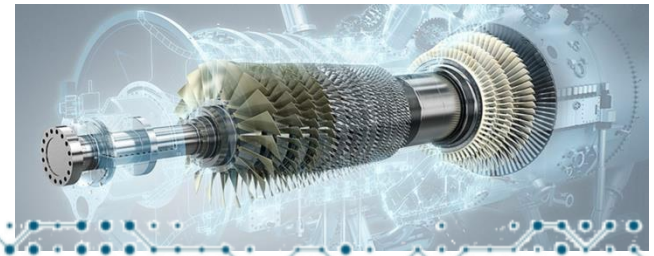
Traditional Workshop

Connected Workshop
- MES / SCADA
- Machines connected

Learning Workshop
- Big Data
- Machine learning

Intelligent Workshop
- Robotics
- AI

Autonomous Workshop
- Self healing processes
- Automatic order execution



MindSphere

2020+

Additive Manufacturing changes everything

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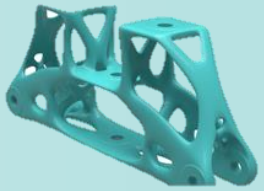
Reimagine products

- Reduce weight, material
- Scan-to-product
- Expand performance
- Accelerate innovation cycles



Rethink business

- Individualization, personalization
- Zero inventory – on demand printing
- Design anywhere. Print anywhere.
- Accelerate innovation

Reinvent manufacturing

- Eliminate molding/castings/tooling
- Eliminate/simplify assembly process
- Reduce supply chains
- Affordable low volume production

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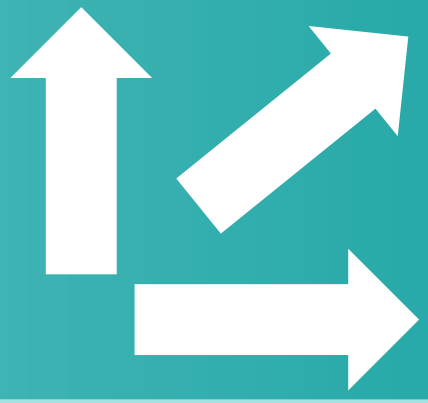

Product transformation
Shift from conventional design to innovative DFAM

Manufacturing transformation
Shift from prototyping / experimentation to mainstream industrial production

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En mi entorno, ¿cuál es la dificultad principal que ralentiza la introducción de fabricación aditiva?

1.- Ignorancia / No hay tiempo o interés en estudiarlo

2.- Desconfianza en la tecnología

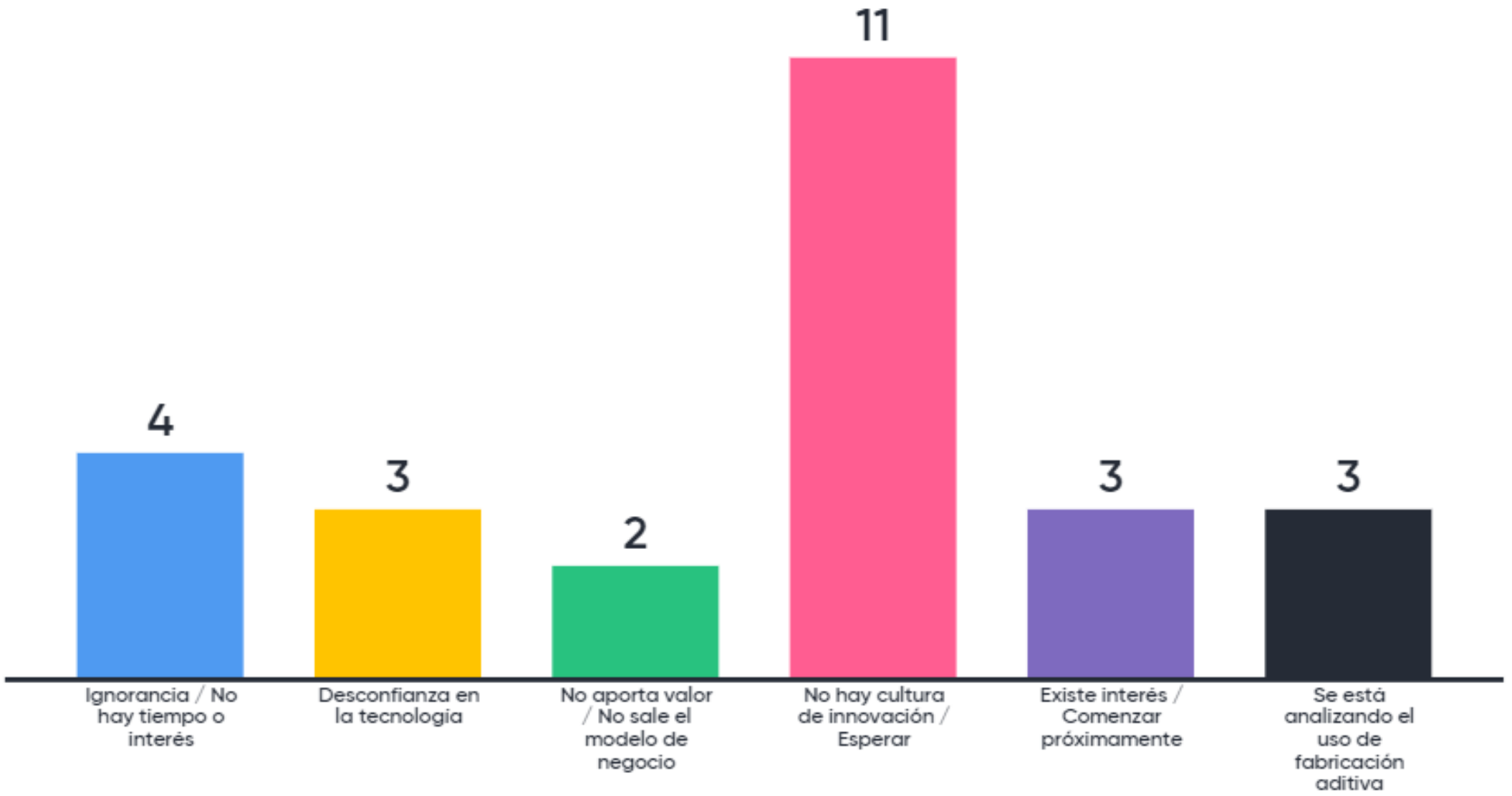
3.- No aporta valor / No sale el modelo de negocio

4.- No hay cultura de innovación / Esperar a que esté más extendida.

5.- Existe interés / Comenzar a estudiarlo próximamente

6.- En la actualidad se está analizando el uso de fabricación aditiva

Answers



Aditiva4.0

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The best way to predict the future is to invent it.

Alan Kay (1971)

Thank you

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