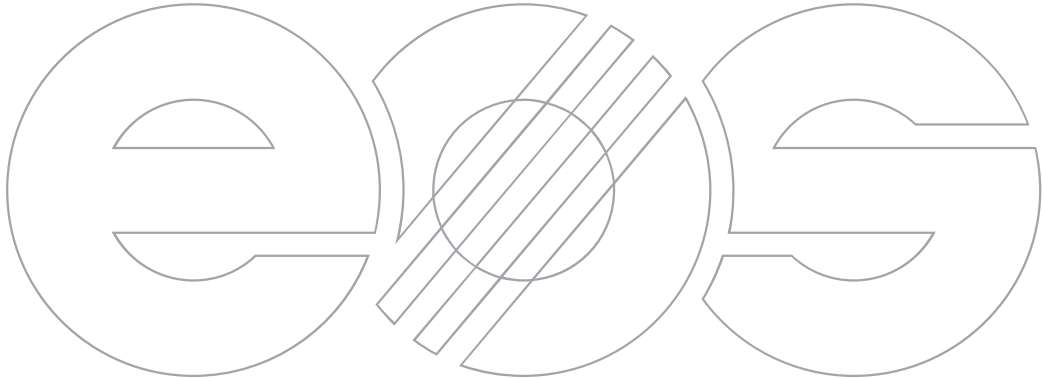
Additive manufacturing advantages

M Production ramp-up with in-process monitoring

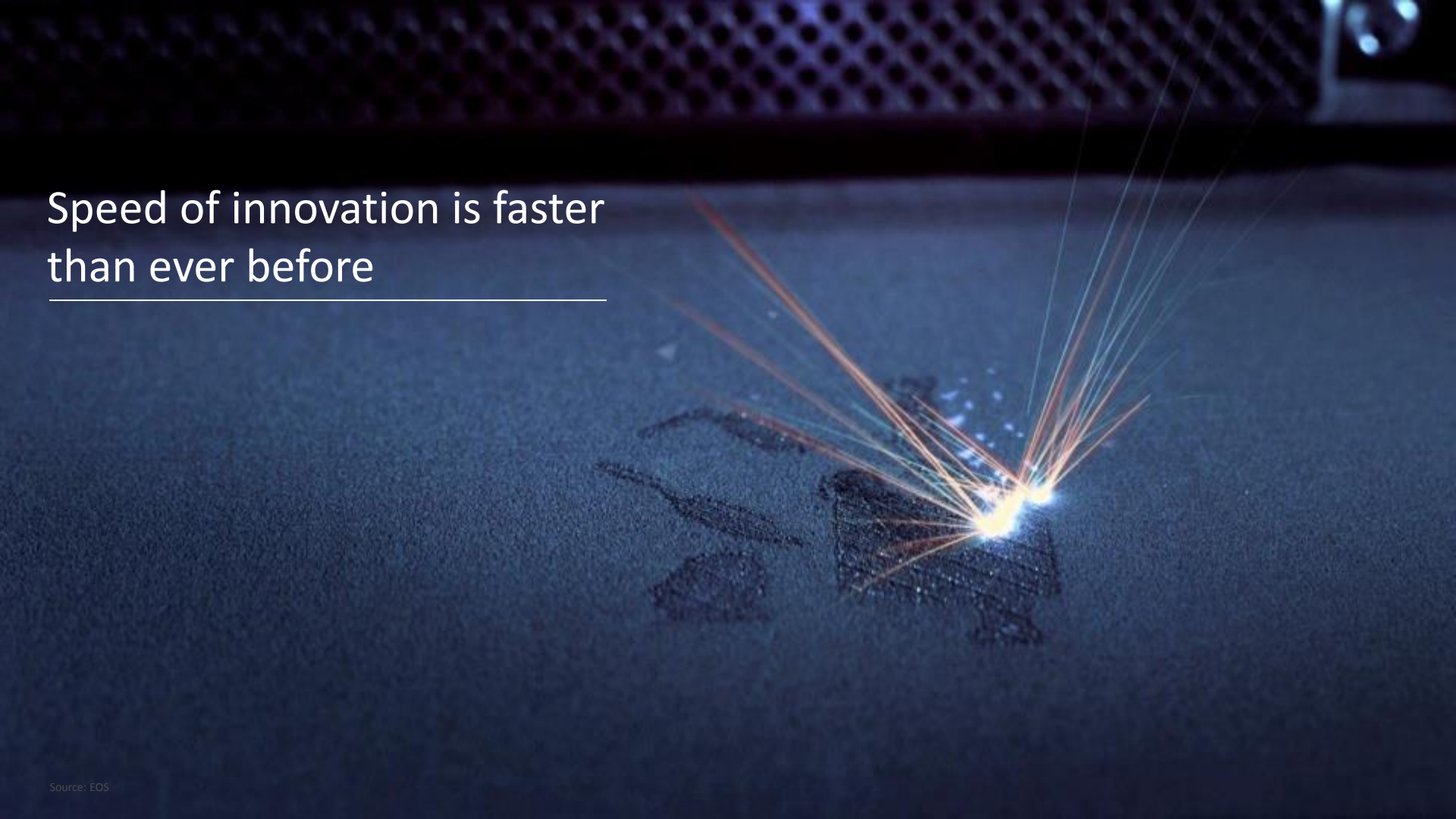
Padova, 20 Settembre 2019

Ing. Enrico Marchioni

Additive Manufacturing Workshop



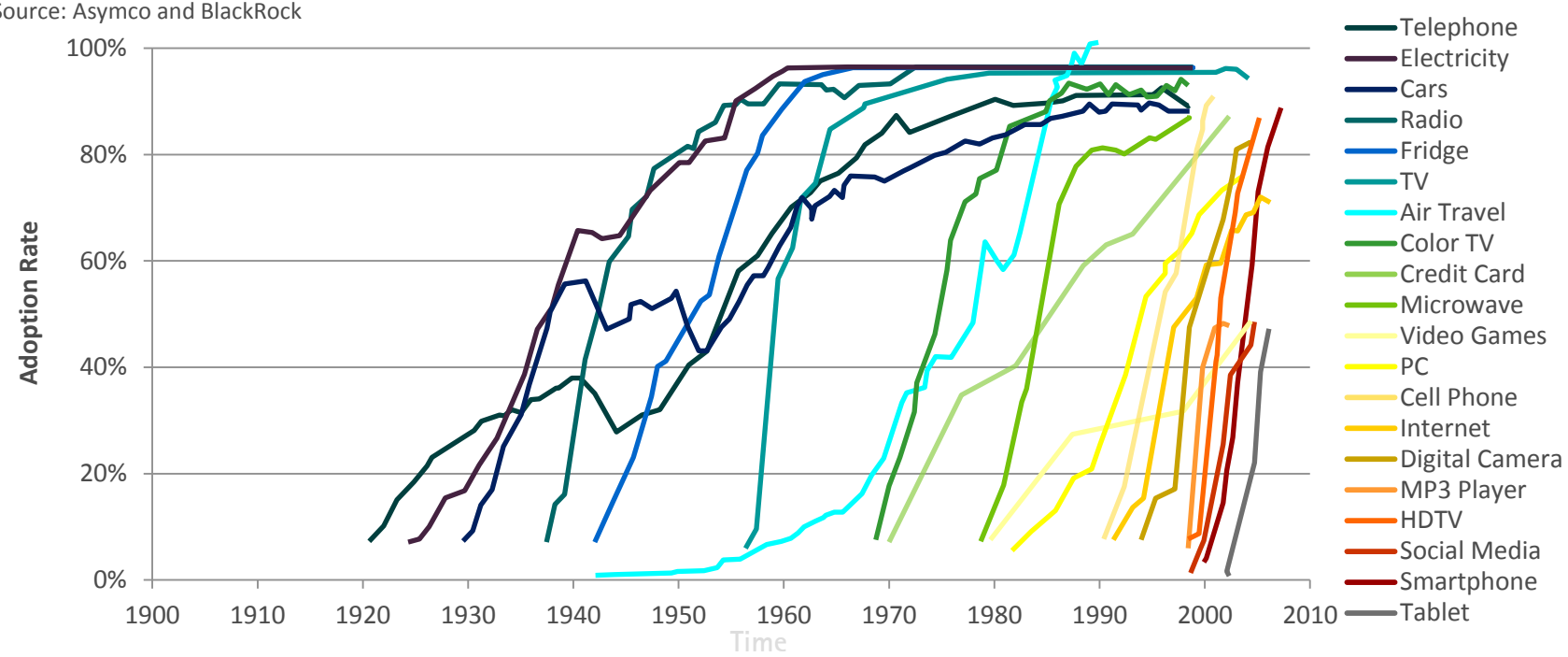
Speed of innovation is faster than ever before



Source: EOS

Speed of Innovation is faster than ever before: Companies are forced to innovate radically

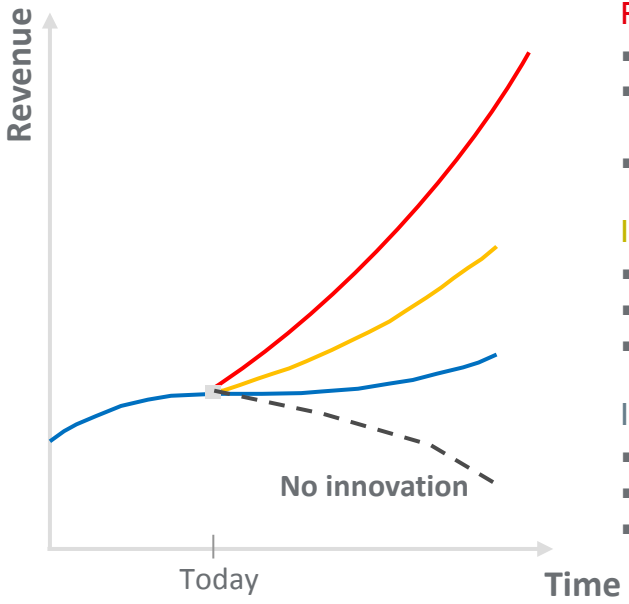
Source: Asymco and BlackRock



Digitalization and IoT will increase pressure for companies and force them to innovate

AM is an innovation driver which enables slight improvements up to radical innovation

3 types of innovation and their impact on revenue



Radical Innovation – Very strong growth

- Become clear market leader in your segment
- Outperform competitors by increased part performance and reduced total cost
- Maximize customer value through multiple benefits

Incremental Innovation – Strong growth

- Increase current market share
- Optimize part design and number of parts
- Increase part performance and customization

Improvements – Moderate growth

- Protect current business and grow slightly
- Optimize supply chain cost and complexity
- Reduce lead time

Gas Burner

Robotic gripper

Truck spare parts

EOS Vision

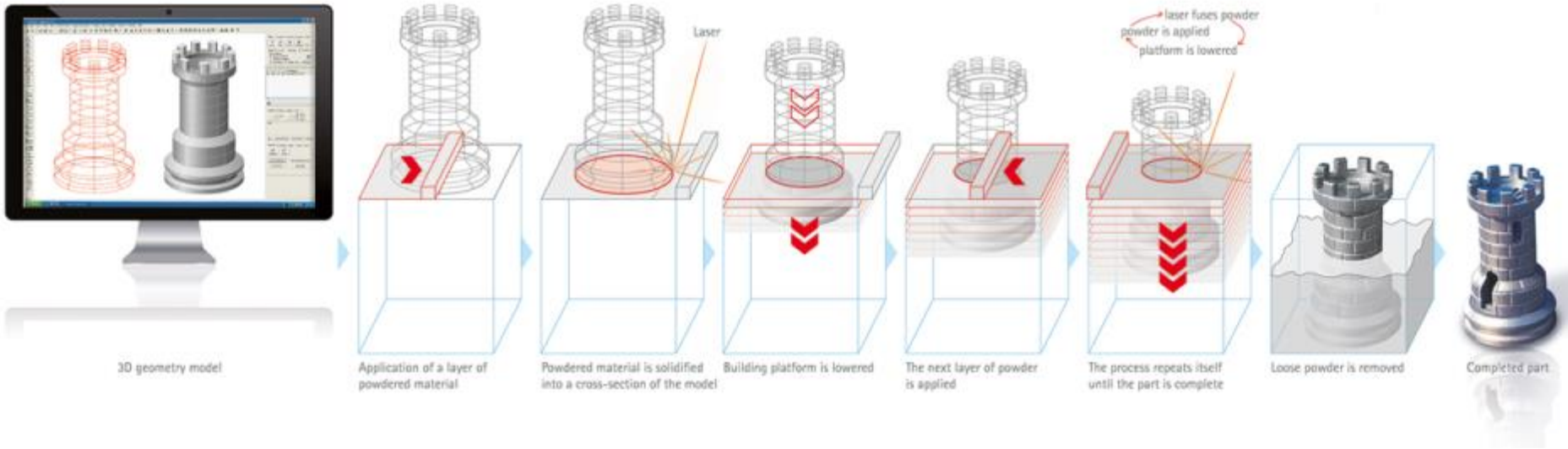
Additive Manufacturing is a key technology to disrupt industrial production.

EOS: technology and market leader for 3D printing solutions

- **EOS** is the **world's leading technology** supplier in the field of **industrial 3D printing** of metals and polymers
- **Family-owned**, founded in **1989**
- Headquartered in Krailling near **Munich,** Germany
- **Solution portfolio:** Additive Manufacturing (AM) systems, materials (plastics and metals), software, services and consulting
- Complete **end-to-end solutions:** from part design and data generation to part building and post-processing
- **EOS helps companies leverage competitive advantages in a variety of industries**, such as medical, aerospace, tooling, industry, lifestyle products and automotive
- Revenue FY 16/17: 346 Mio €

EOS Technology - powder bed fusion

General functional principle of laser-sintering



We are experts
in plastic and metal AM PBF technology …

EOS Polymer Portfolio

Factory Line

EOS P 500

FORMIGA P 110 Velocis

EOS P 396

EOS P 770

EOS P 800

EOS P 810

EOS Metal portfolio

Factory Line

EOS M 300
+ EOS Shared Modules

EOS M 400
+ EOS Shared Modules

EOS M 100

EOS M 290

EOS M 400

Source: EOS

The technology is evolving …

Yesterday:
Prototyping

Technological capabilities

Today:
Pre-production

- Part quality
- Process robustness
- Cost per part

By 2020:
Production ramp-up

- Quality control
- Differentiation
- Total cost (TCO)
- Automation
- Technology integration

Advantages of Additive Manufacturing

Laser sintering offers various advantages over traditional manufacturing processes

Freedom of design

Lightweight

- Static: weight of parts
- Dynamic: moving, accelerated parts

Complex components

- E.g. alternative structures of heat exchangers

Functional integration

Total cost optimization

- Embedded functionality without assembly
- Material efficiency
- No tooling costs

Customization

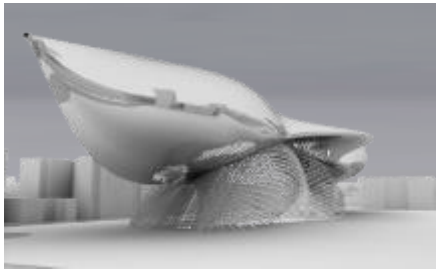
Individualized parts

- Customer-specific adaptations
- Cost-efficient small series up to 'lot size one'

Time to market

Rapid prototyping

- Fast feasibility feedback of virtual models
- Haptic feedback



Freedom of design:
High efficiency 3D surface outperform benchmarks

Example AM design freedom

Conflux Core™ heat exchanger

Challenge

- Production of a compact, low weight, heat exchanger with higher heat rejection an low pressure drop in multi-fluids domain

Solution

- Additive manufacturing with EOS M 290

Advantages

- Improvement in pressure drop and heat rejection
- Weight and overall dimension improvement
- Internal 3D surface optimization
- Pre-validated design with CFD simulation of the characteristics of the actual component

Functional integration
One component instead of 248

Example complex component

Baseplate of an injector head

Challenges

- Production of an injector head for rocket engines with as few components as possible and lower unit costs

Solution

- Additive manufacturing with EOS M 400-4 and functional integration

Advantages

- Simplified: One component instead of 248
- Cost-efficient: 50% lower costs
- Fast: Significant reduction in production time

Customization
surgical tools for high precision

Example customization

MINI – Sides Scuttles and Trims

Situation:

- MINI with strong customer brand and pioneer in innovative production processes

Challenge:

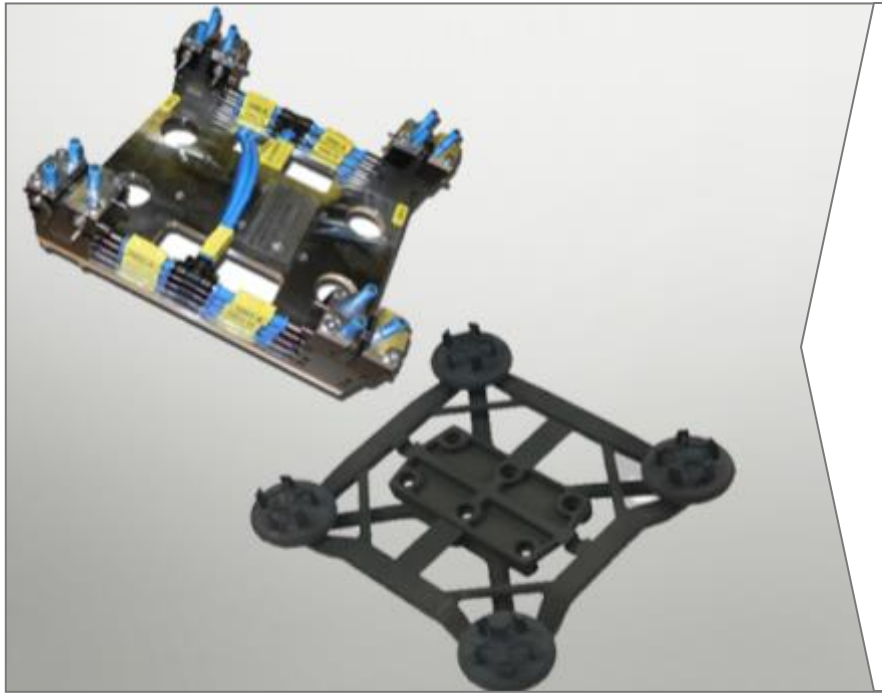
- Remain market leader and drive digital services

Solution:

- 100% customer intimacy: Customers can select, design and order the parts at the new Online Shop
- New supply-chain concept: Production on-demand, direct customer delivery, less than 1 week

Time to market:
shorter lead time for validation and manufacturing

Example time to market



Lightweight gripper

Advantages

- Base plate generates lightweight stiffness and allows integrated air channels
- Three components vs. 21, leading to less list positions and logistics effort
- LS gripper produced “overnight” – reduction of manufact. time by 17 days
- Cost reduction of -50%
- -86% less weight leading to smaller robot size
- OPEX reduction – Lightweight and smaller build height resulting in shorter cycle times of injection molding machine

EOS solutions enable the production ramp-up

Maturity Level

Novice to AM	Application optimization	Production
Understand AM possibilities	Optimize application for serial production	Ensure continuous quality and document part quality
Speed up learning curve through process insights	**Shorten development time** and avoid trial and error	**Gain insights early** in the production process

EOS solutions enable the production ramp-up

Maturity Level

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Metal additive manufacturing
EOS Process Monitoring Suite: EOSTATE

Reduce quality cost & system downtime & allow learning about the process with EOSTATE

EOSTATE Exposure OT

- Possibility to:
  - Deepen laser sinter process understanding
  - Detect defects in parts
  - Analyze homogeneity and temporal behavior of melt pool

EOSTATE System

- Monitoring of process influencing conditions, e.g.
  - Axis and hardware
  - Atmosphere and temperatures
  - Laser power
  - Online Laser Power Control (OLPC)

EOSTATE MeltPool

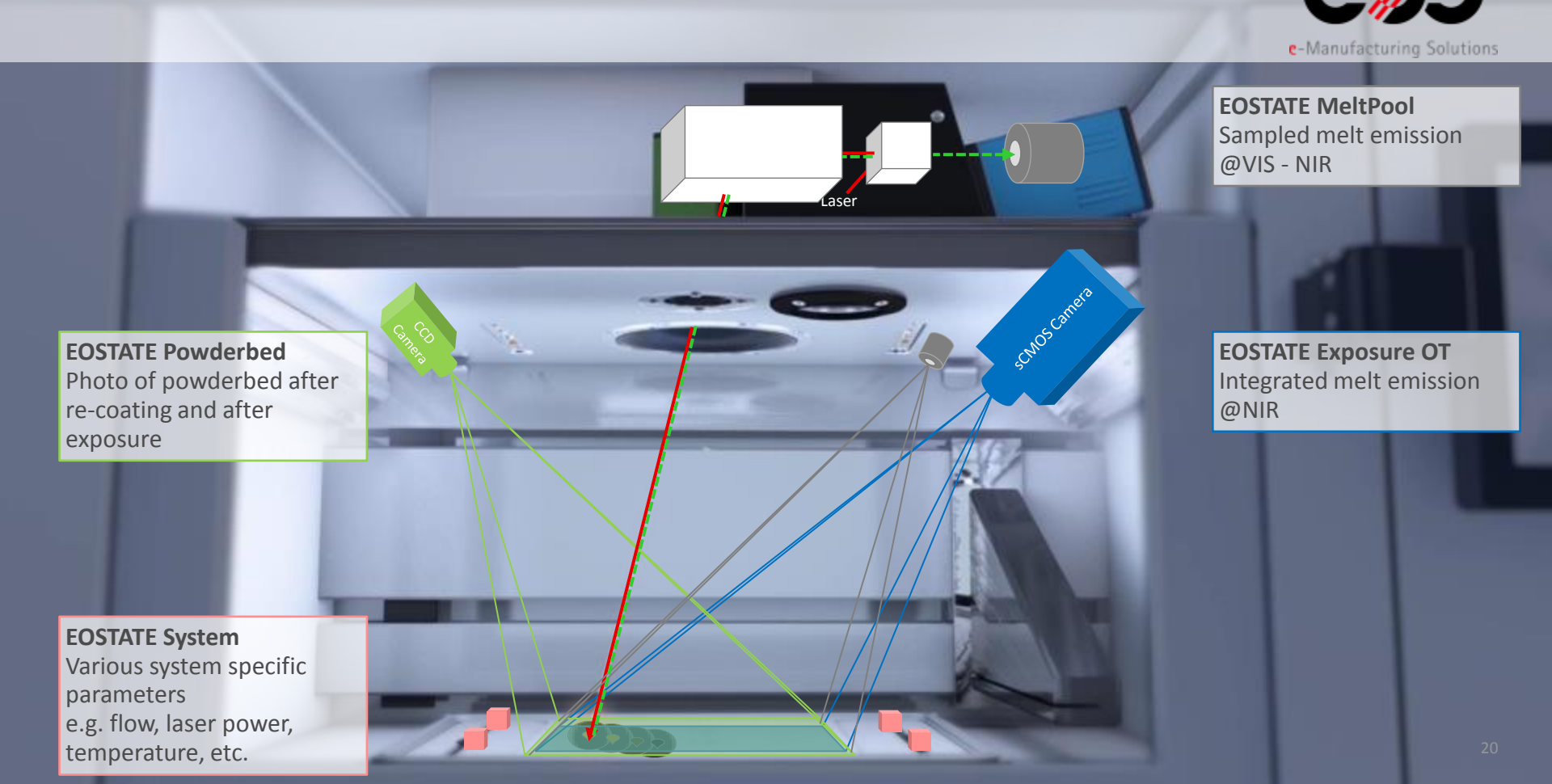
- Possibility to:
  - Deepen laser sinter process understanding
  - Detect defects in parts
  - Analyze homogeneity and temporal behavior of melt pool

EOSTATE PowderBed monitoring

- Possibility to:
  - Analyze reasons for job crashes
  - Manual detection of
    - Recoating failures
    - Particles or grooves in powder bed

In-process monitoring for QA and Process development

e-Manufacturing Solutions



EOSTATE MeltPool
Sampled melt emission @VIS - NIR

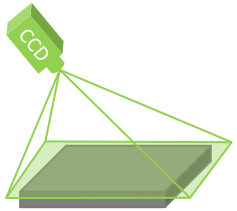
EOSTATE Powderbed
Photo of powderbed after re-coating and after exposure

EOSTATE Exposure OT
Integrated melt emission @NIR

EOSTATE System
Various system specific parameters
e.g. flow, laser power, temperature, etc.

EOSTATE Powder bed
After exposure and after recoating imaging

- In-process global recoating quality bed monitoring
- Powder recoating data for whole job
- Fast recognition of recoating problems
- Optimized recoating strategy



Post process QA

Follow up on job crashes

Closed-loop recoating monitoring

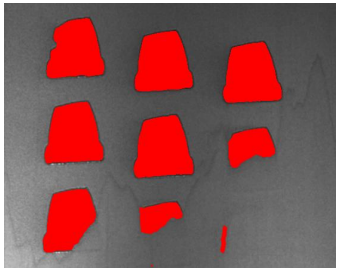
PowderBed Imaging

After exposure

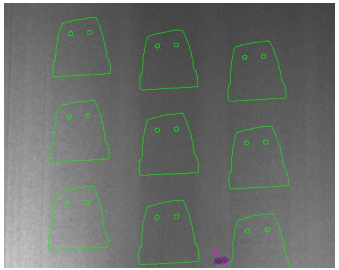
After recoating

PowderBed Supervision

1st recoating



2nd recoating



System data base

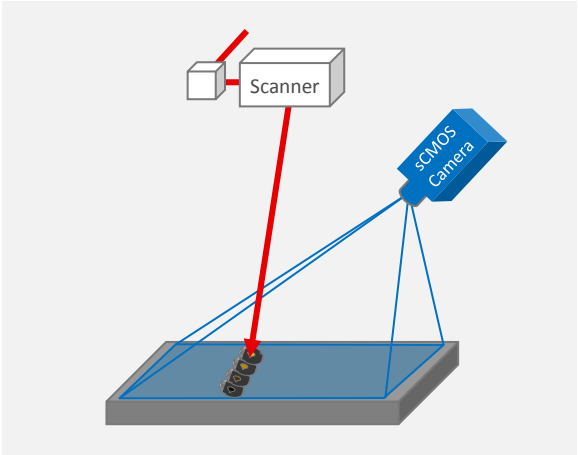
LogDB

End-User PC

EOSTATE Exposure OT
long time exposure of the meltpool

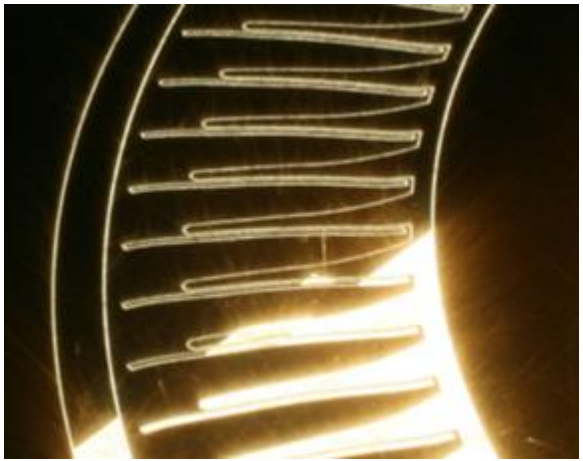
- Long time exposure of urban traffic

Traffic volume



- Brightness in the picture equals (radiance x time)
- Measurement for energy input / distance energy

Independent of beam path



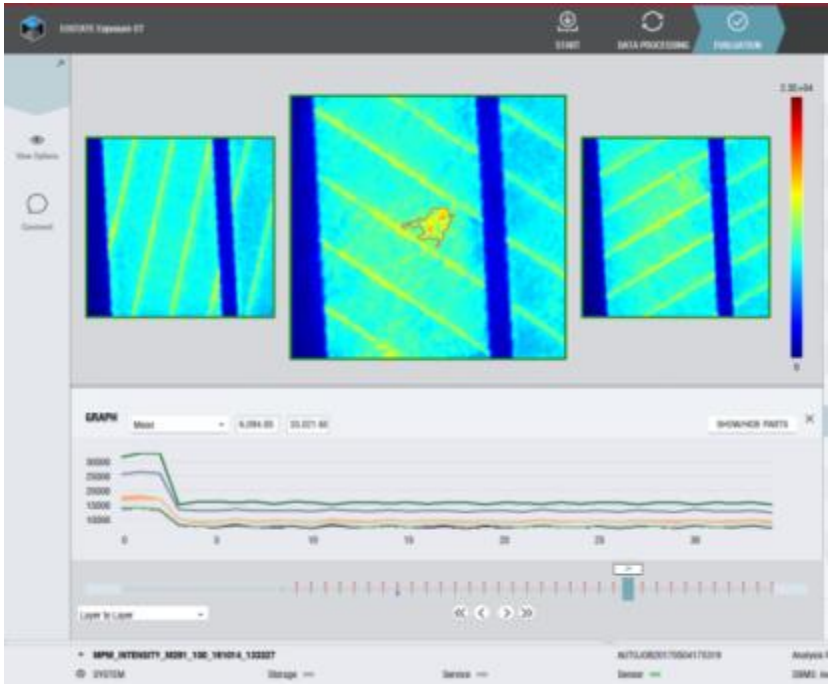
- Long time exposure in
- additive manufacturing

Amount of heat

EOSTATE Exposure OT Software

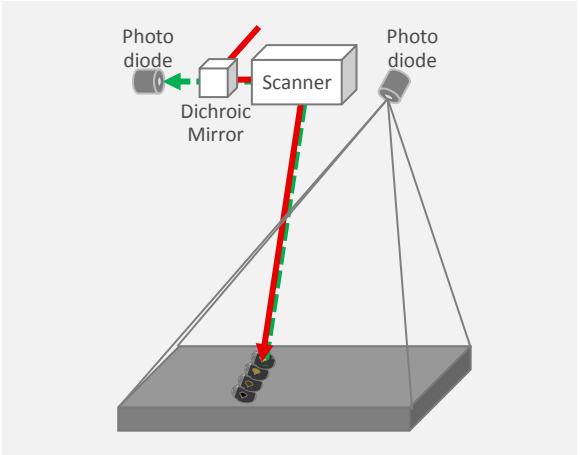
Advantages of EOSTATE Exposure OT software

- Full documentation of the job
- Automatic analysis of each layer
- Reduced risk
- Save time in post build quality assurance
- Saving costs in post build quality assurance
- Intuitive software interface
- Quick feedback of process changes effects
- Lower effort to gain information and insights
- Quicker learning curve in deepening process understanding

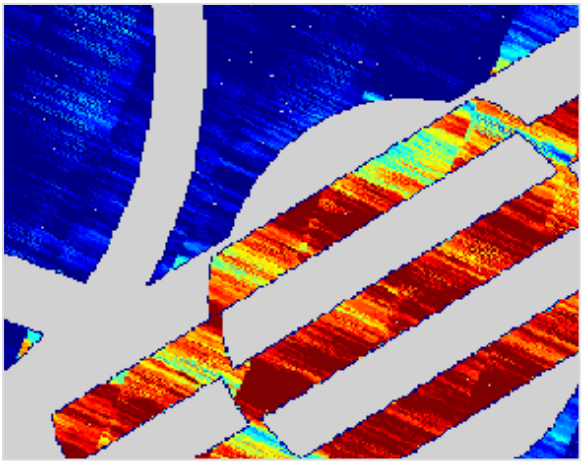


EOSTATE MeltPool Monitoring collects signals from the melt pool with a high frequency and hence high resolution

- Short time measurement of emissions



- While the on-axis photodiode delivers the main signal, delivers additional information from a different perspective



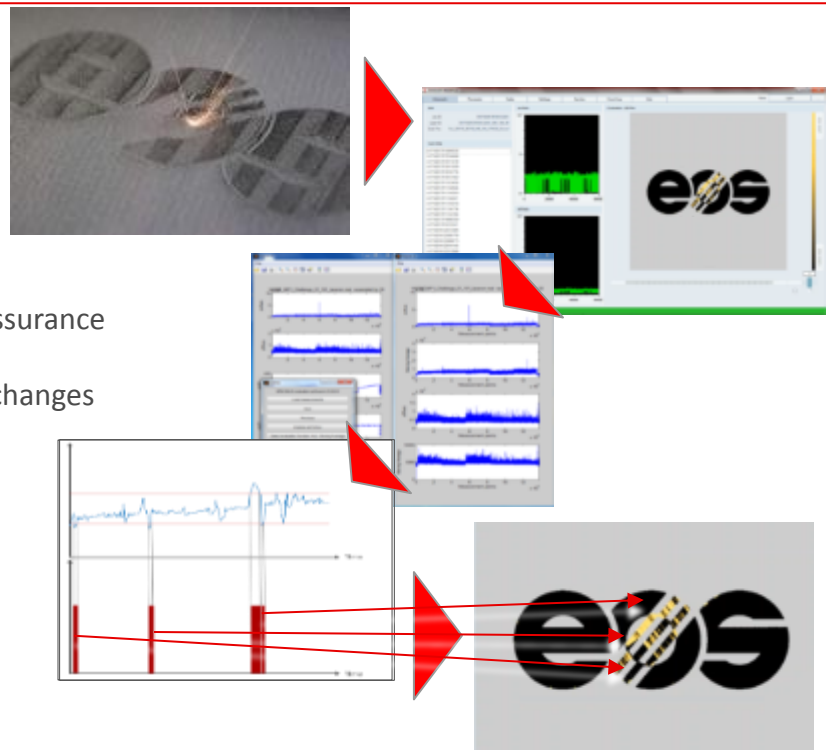
- Each Pixel is the emission intensity of a very small area

Blink of an eye

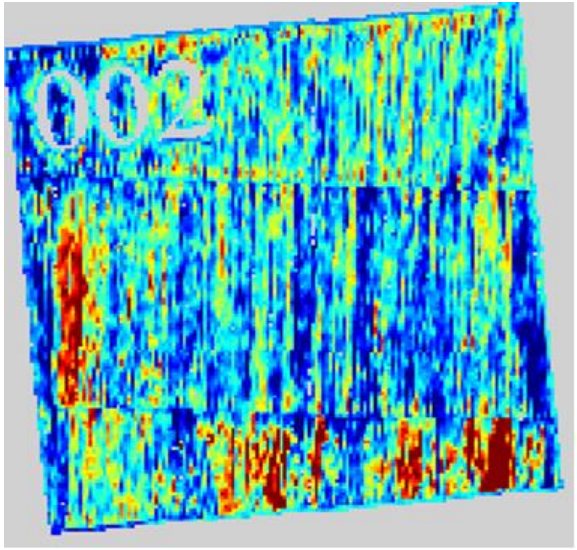
EOSTATE Meltpool monitoring

Advantages of EOSTATE MeltPool monitoring

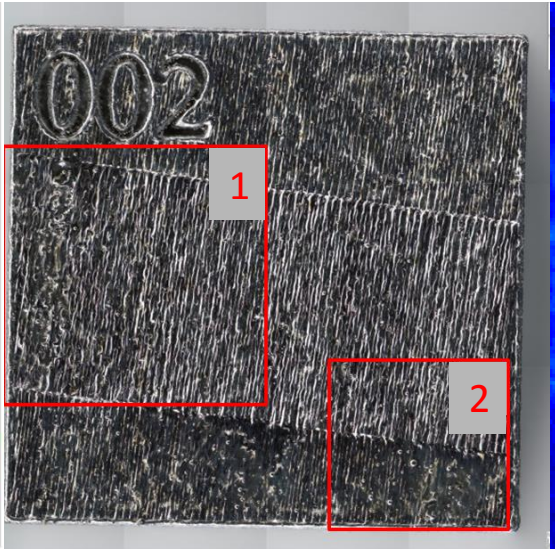
- Automatic analysis signals
- Reduced risk
- Save time in post build quality assurance
- Saving operating costs in post build quality assurance
- Quick feedback regarding effects of process changes
- Lower effort to gain information and insights
- Quicker learning curve in deepening process understanding
- High detail resolution



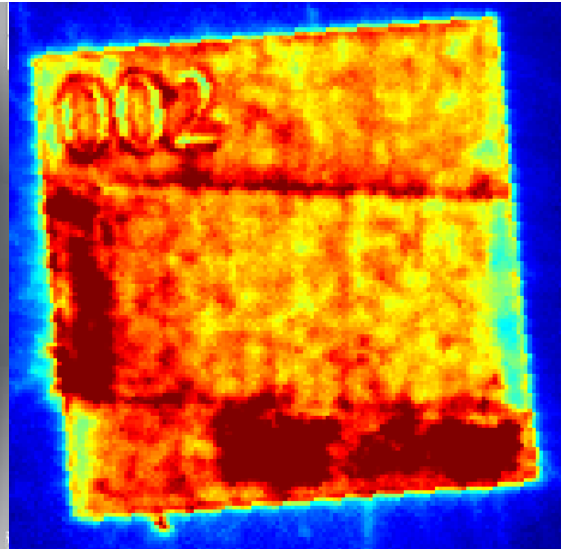
EOSTATE OT & MPM: Bright spots ifluence on the surface



EOSTATE MeltPool
Resolution 100µm/pixel



Microscopy record of surface

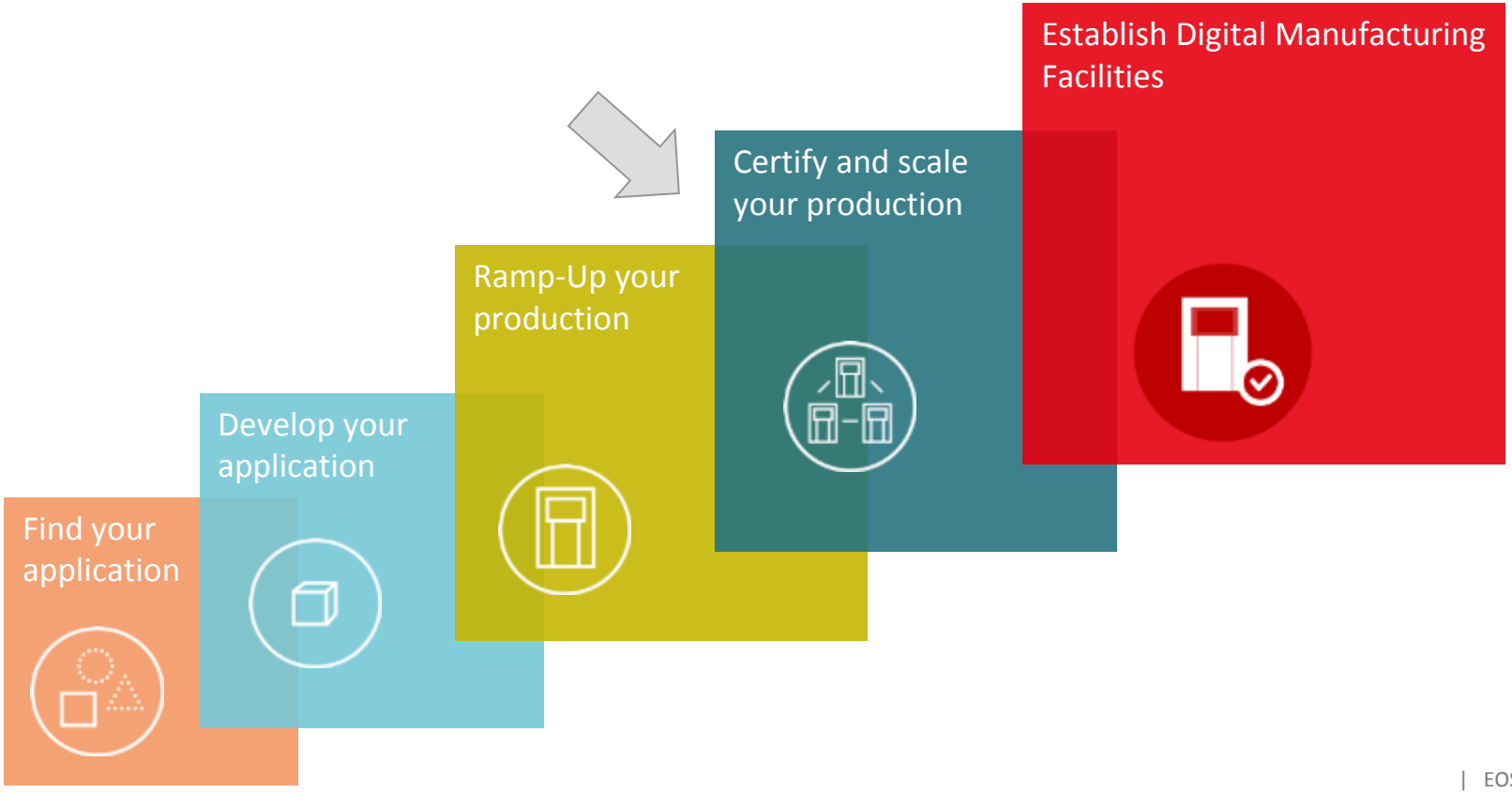


EOSTATE Exposure OT
Resolution 130µm/pixel

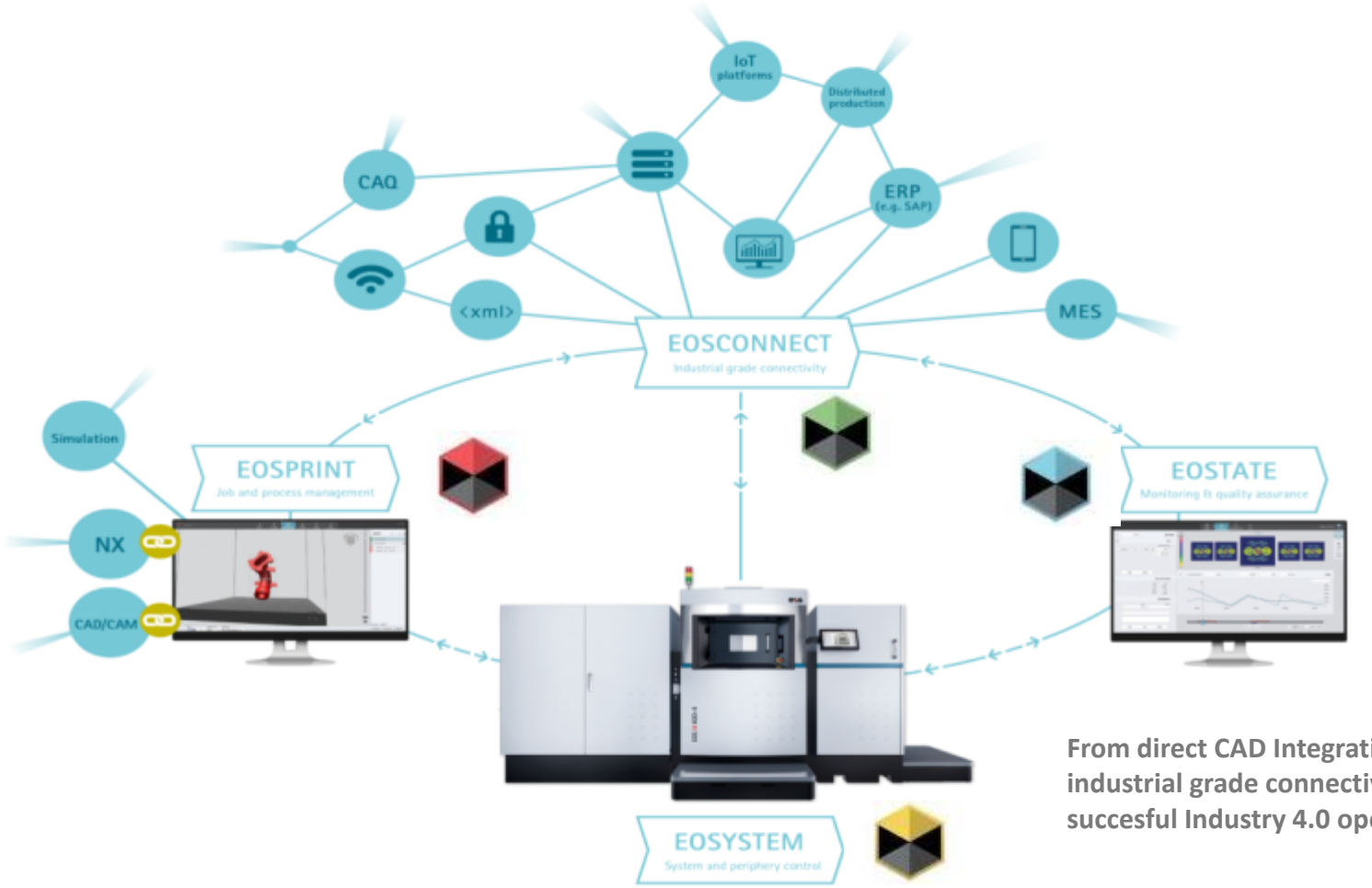
EOSTATE Process Monitoring Suite – benefits

- Shortening the QA loop
- Reduction of cost per part
- Process optimization
- Process documentation/optimization
- Base for process qualification and comparability
- Insight into building process
- Customizable analysis
- Reproducibility

EOS support your AM transformation



The Digital Industrial AM Suite of EOS.



From direct CAD Integration up to industrial grade connectivity to enable succesful Industry 4.0 operations.

The future of manufacturing: digital factory

Source: EOS

Thank you!

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