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# Industrialization and Current Field Experience of Additively Manufactured Gas Turbine components

Dr. Vladimir Navrotsky CTO, Senior Principle Key Expert, Siemens, October 11, 2018

# What is additive manufacturing and how is it different from conventional production ?

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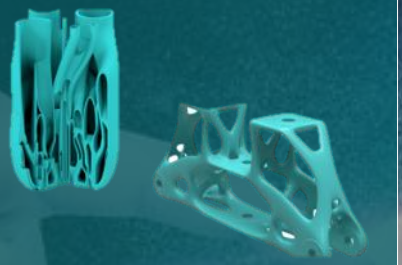
**Product transformation**
Shift from conventional design to innovative DFAM

## Reimagine products



- Reduce weight, material
- Scan-to-product
- Expand performance
- Accelerate innovation cycles
- Freedom of design is no longer restricted by design rules of conventional manufacturing

## Rethink business

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

## Conventional production

- Multiple components/part
- Long lead times for design & prototyping
- Design limited by mftg process, e.g. casting

## Reinvent manufacturing

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

**Manufacturing transformation**
Shift from prototyping / experimentation to mainstream industrial production

# Siemens was an early adopter of SLM AM technology and have successfully scaled its production

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## Outcomes


First SLM demonstrators

Firs SGT-800 BuTiR

SGT-750 combustion swirlers in commercial operation

Prototyping of qualification parts for LGT, IGT, AGT, IST

SGT-1000F Burner head in commercial operation

Turbine blade printed & tested in engine (SGT-400)

SGT-700 Burners Commercial operation

**2006** | **2009** | **2012** | **2013** | **2014** | **2015** | **2016** | **2017**

## Key enablers

Material Solutions founded in the UK

Installation of the 1st EOS M270 SLM machine in FSP

Installation of 1st EOS M280 SLM machine in FSP, specifically adapted for Burner repair

Dedicated Additive COCs established in PG and PS

Development and qualification of Processes and Materials

Material Solutions acquisition

Materials Solutions
A Siemens Business

Finspong Industrial workshop inaugurated

Joint PS and PG Additive team formed

**From R&D to serial parts production with SLM technology in 8 years**

# Siemens is pursuing 2 major business objectives with driving AM into our core products and building an external service business

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## Gas / Power Generation Service

### 1 Leading User of AM Technology to strengthen competitiveness

### 2 Leading AM Service Provider to leverage internal capabilities


**Aero Engines** | **Aviation / Space** | **Automotive / Motorsports**

## Digital Factory

### Only Supplier of seamlessly integrated AM solution

- Early Adoption NX / MES
- Pilot User PMP
- Joint Services & Marketing

- Software
- Control & Automation
- Part Manufacturing Platform (PMP)

# Manufacturing Footprint expansion signed for FSP and MSL
# Global footprint growth into North America

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Finspong

Worcester

Finspång –
various EOS units

Worchester –
various EOS units

Berlin – 1 x M290, 1 x Trumpf

Montreal – 1 x M290

Charlotte – 1 x M400

Production and development

Prototype and development

Planned prototype

# Three main pillars when applying AM

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## Rapid Prototyping

**Significant reduction of time to market**

## Rapid Manufacturing / Spare Parts on Demand

**Completely new design only possible via SLM**

## Rapid Repair

**10 times faster and easy upgrades**

# WE achieved a major BREAKTHROUGH …
# … first turbine blade is printed an tested in the engine

## Approach

- Use SLM for rapid prototyping of blades
- Rainbow test in gas turbine for selection of best design
- Calibration of calculation tools and design methods
- Full scale engine test performed


## Benefits

- Excellent tool for optimization of blade cooling designs
- Substantial lead time reduction for engine upgrades - 1st blade manufactured already 2 weeks after receipt of 3D model
- Minimized risk by verification of blade temperature prior to casting

# Burner manufacturing by means of SLM for flexibility, shorter lead time and improved life time

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## Approach

- Manufacturing of SGT-700/SGT-800 burners by means of SLM
- Redesign of existing burners for SGT700/800 to utilize the design freedom offered by SLM
- Full scale engine test performed
- Commercial operation in 2018

## Benefits

- Reduced lead time by 23 w
- Enabling customization for fuel flexibility
- Removal of TBC

## Conventional

- **13 parts / 18 welds**
- **TBC on front**
- **26w lead time**

## SLM burner

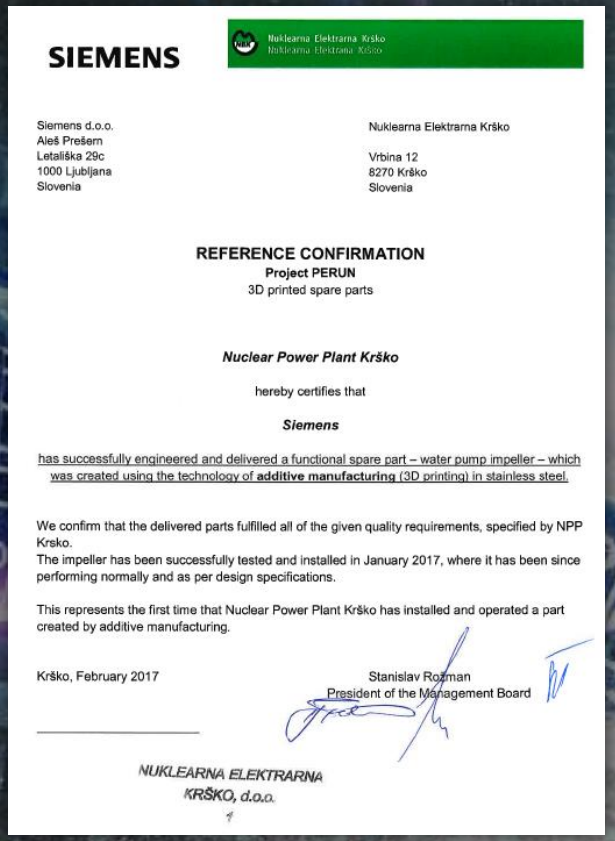
- **1 integrated part**
- **No TBC due**
- **3w lead time**

# 3D printing parts are already in use at Nuclear Power Plant Krško, Slovenia

## First 3D printed water pump impeller is on successful commercial operation at nuclear power plant

**Customers benefits:**

- Obsolete parts can be re-produced
- Significant lead time reduction
- Parts on demand



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**REFERENCE CONFIRMATION**
**Project PERUN**
3D printed spare parts

***Nuclear Power Plant Krško***

hereby certifies that

***Siemens***

has successfully engineered and delivered a functional spare part – water pump impeller – which was created using the technology of **additive manufacturing** (3D printing) in stainless steel.

We confirm that the delivered parts fulfilled all of the given quality requirements, specified by NPP Krsko.
The impeller has been successfully tested and installed in January 2017, where it has been since performing normally and as per design specifications.

This represents the first time that Nuclear Power Plant Krško has installed and operated a part created by additive manufacturing.

Krško, February 2017

Stanislav Rozman
President of the Management Board

NUKLEARNA ELEKTRARNA
KRŠKO, d.o.o.

# AM technologies overview
# Laser Cladding - Smart Repair

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## Rotor Repair

**Achievements & Capabilities**

- Fully operational since 2016
- > 40 rotor repairs successfully performed
- Covering extended range of rotors (steam turbines, compressors, generators) & filler materials
- Repair time reduced by approx. 50%

## Valve Repair

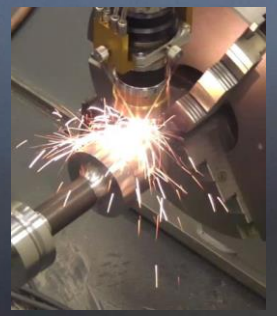
**Achievements & Capabilities**

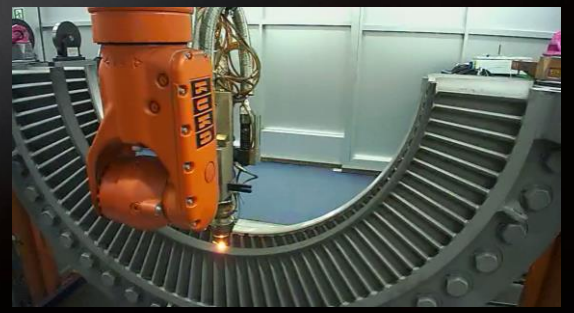
- Fast track repair for valve spindles & valve cages (lead time down to several days)
- Stellite & Hard surfacing of valve components (for new manufacturing)

## Stator Repair

**Achievements & Capabilities**

- Substitute repair method of sealing faces of guide blade carriers (earlier: weld in forged ring and final machining)
- For both cast iron & cast steel
- Repair time reduced by approx. 30%

# Current field experience of AM manufactured & repaired components > 100 000 hours

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## Successful in commercial operation

### Rapid Repair

- **Product**: SGT-700/800
- **Component**: Burner tip
- **Benefit**:
  - 90% lead time reduction
- **Status**: In commercial application since 2013
  **> 30 000 EOH**

### Rapid Manufacturing

- **Product:** SGT-700
- **Component:** Burner
- **Benefit:**
  - Longer life
  - Higher reliability
- **Status:** In commercial application since 2017
  **> 8 000 EOH**

### Rapid Manufacturing

- **Product:** SGT-750
- **Component:** swirler
- **Benefit:**
  - Swirler can only be made via SLM
- **Status:** In commercial application since 2013
  **> 30 000 EOH**

### Spare parts on demand

- **Product**: SGT-1000F
- **Component**: Burner head
- **Benefit**:
  - Reduced lead time by up to 6 months
- **Status**: In commercial application since 2016
  **> 10 000 EOH**

# AM Vision: ”Autonomous”, Closed Loop & Self Healing Processes, Gas Turbines Order Spare Parts by Themselves

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2025

Autonomous Workshop

IoT for AM

Intelligent Workshop

”Intelligent Workshop” Through Robots, VR/AR and AI

Learning Workshop

”Learning Workshop” Through Big Data Analytics and Machine Learning

Connected Workshop

”Connected” Through MES and Use Build Job Simulation

Traditional Workshop

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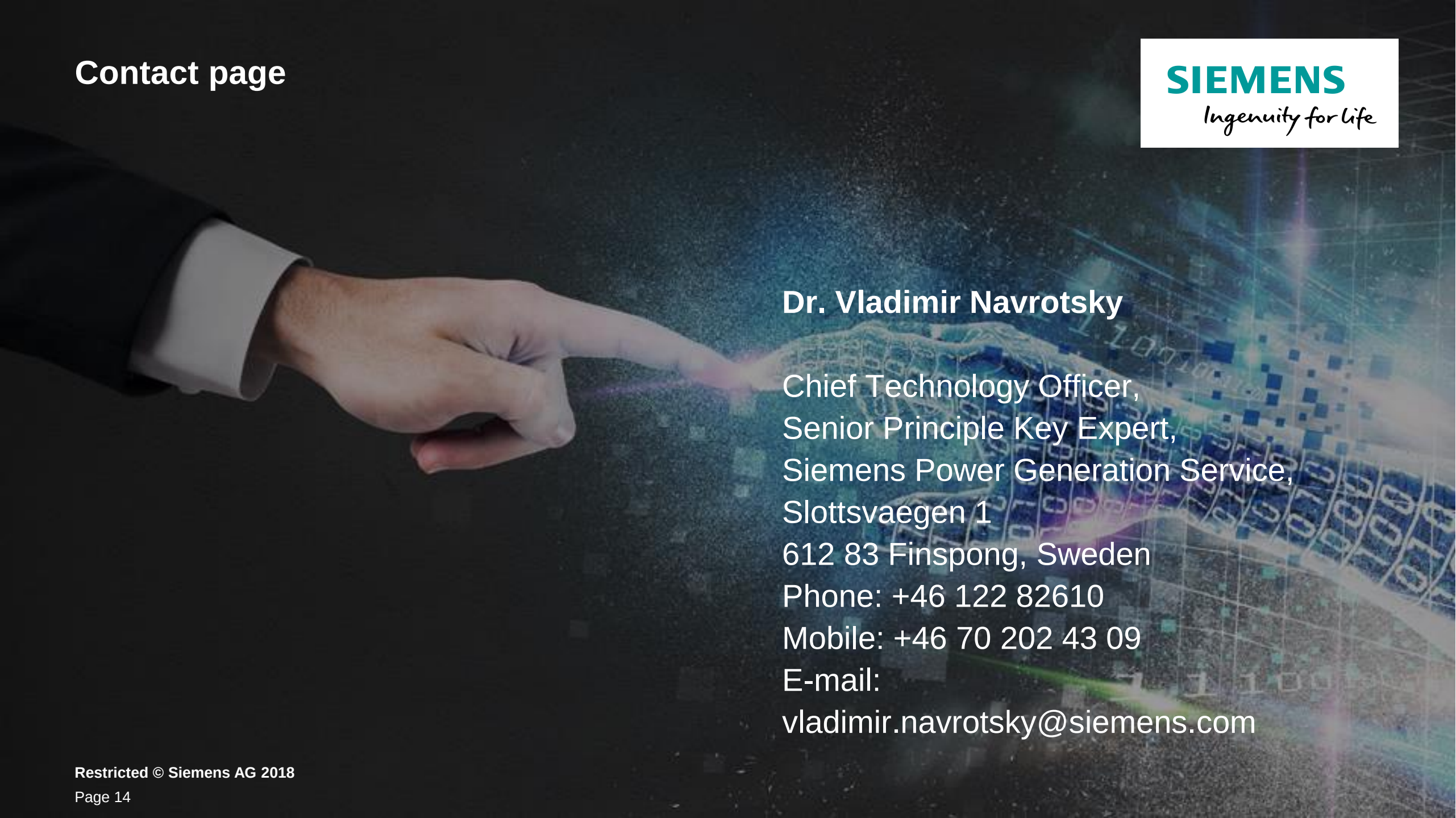


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