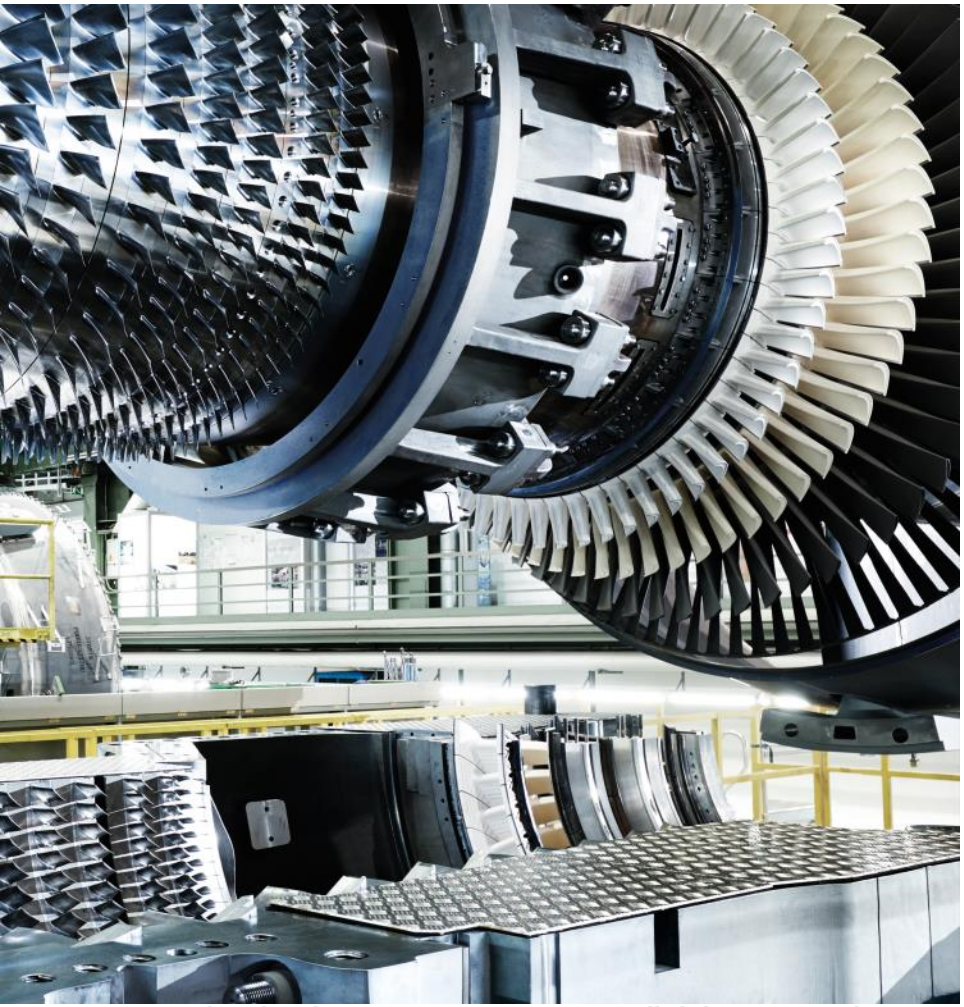
Allister James

UTSR Workshop – Atlanta, November 3, 2015

Advanced Manufacturing for Large Industrial Gas Turbines



- Drivers for LGT manufacturing innovation
- Key components for Advanced Manufacturing
- Testing, validation and implementation
- Challenges & requirements for implementation of SLM in turbine production
- Conclusions

Drivers for Large Gas Turbine Manufacturing Innovation

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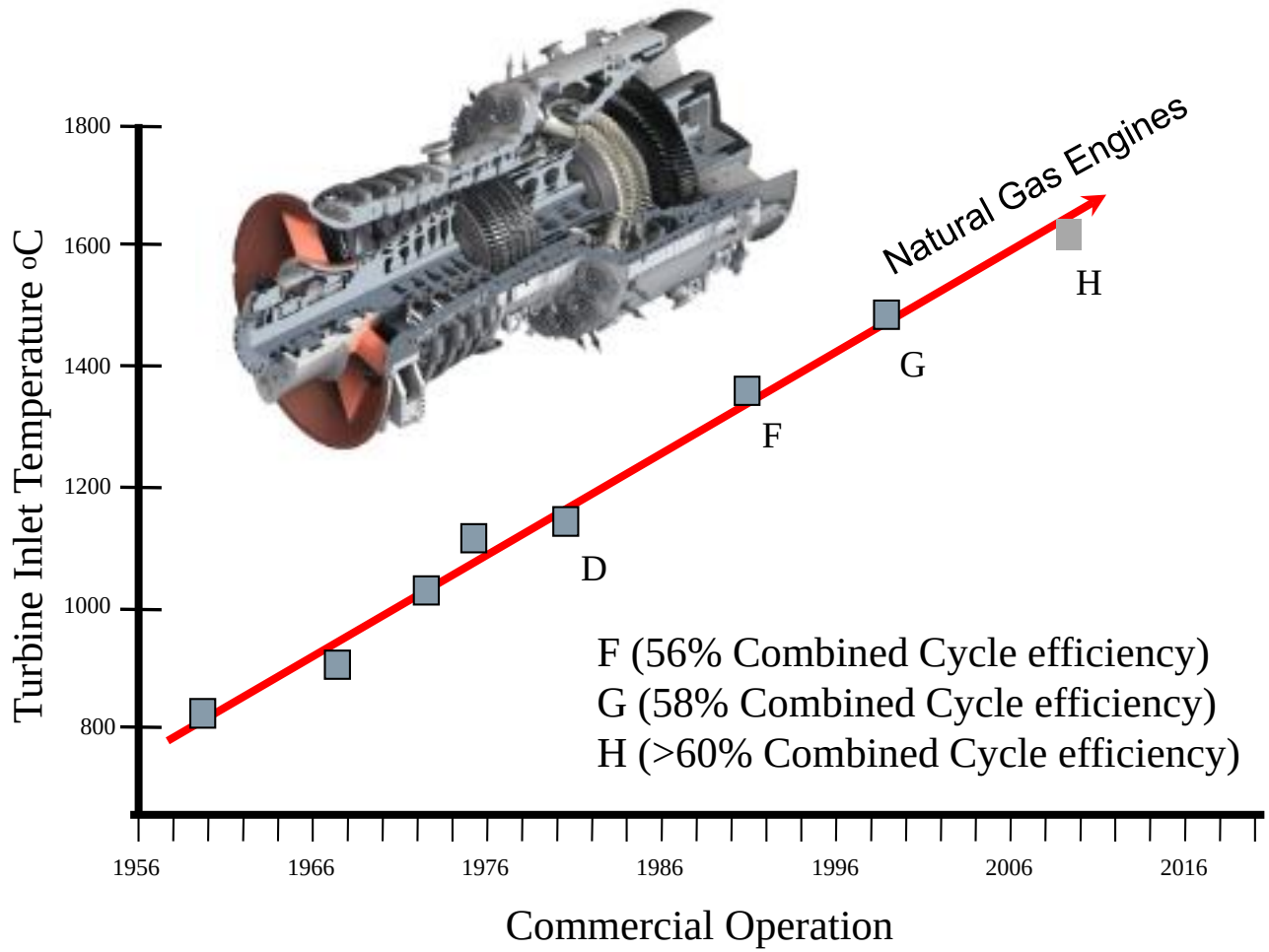
Business drivers/ Customer requirements

Cost
- First cost
- Life cycle cost
- Operation cost

Performance
- Plant power
- Plant efficiency

Capabilities
- Emissions
- Operational flexibility
- Regulatory compliance
- Upgradeability
- Reliability, availability
- Time-to-market



Key Components for the Development of Future Gas Turbines

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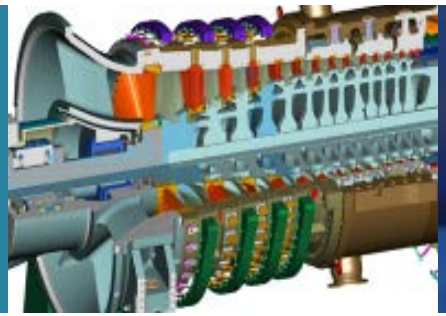
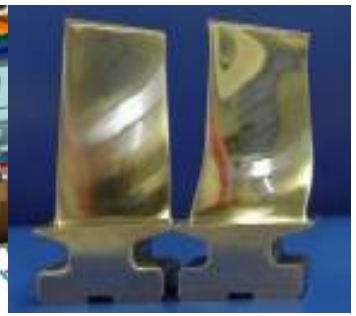
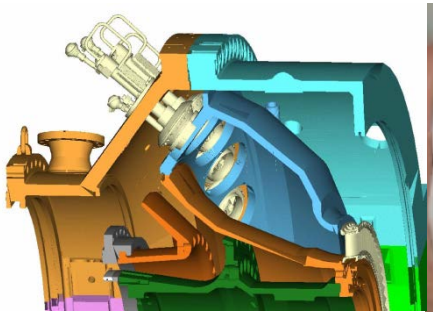
Compressor





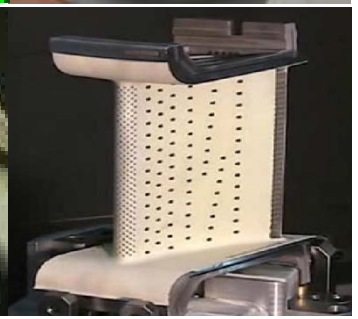
- Increase of mass flow
- Increase of pressure ratio
- 3D aerodynamics
- Reduction of aerodynamic losses

Combustion



- Higher combustion temperatures
- Optimized burner (fuel flexibility)
- Reduced emission
- Increased efficiency

Turbine



- Higher turbine inlet temperatures
- New materials and coatings
- Improved cooling and sealing
- 3D aerodynamics, loss reduction

These goals can not be reached with conventional development methods, conventional designs and conventional manufacturing technologies!

Use Cases for SLM as AM Technology

Lead time and performance gains are the major drivers

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	Technology Validation	Production		After Market
	Rapid Development	Rapid Tooling	Rapid Manufacturing	Rapid Repair / Spare Parts
Lead time & Availability				
Costs				
Performance & Innovation				
Combustion	• Injectors and nozzles • Mixer/Swirler • Heat shields • Instrumentation	• Bending tools for fuel pipelines • Customized tool holders	• Injection nozzles • Mixer/Swirler • **Burner heads**	• **Burner repair** • **Spare parts on demand** • Upgrades
Turbine	• **Mock-up parts for process development** • **Technology and product validation**	• Special tools • Seals for test rigs • Expandable parts for coating	• Blades/vanes with advanced cooling schemes • Heat exchangers • Seal plates	• Coupons for the repair of complex components • Refurbishment

SLM Rapid Manufacturing and Rapid Repair

Additive manufacturing has arrived in customer engines

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Rapid Manufacturing

Driver

- Long lead times
- Long time line for implementation of new designs

SLM-Swirler

Result

- Lead time reduction by six months
- short term implementation of re-designs

Rapid Repair

Driver

- Long repair times
- Costs for repair

SLM burner repair

Result

- Significant lead time reduction by 90 %
- Significant cost reduction (- 30 %)

Testing and Validation Chain

Change in R&D paradigms

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Integrated development: accelerated iteration cycles in few months

3D Design → **SLM processing** → **Post processing** → **Instrumentation** → **Testing**

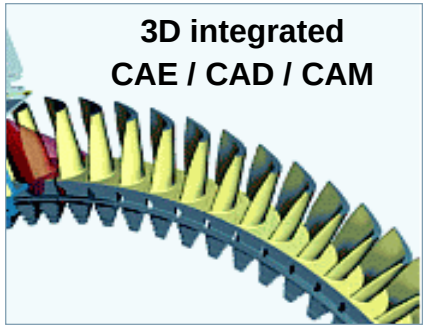

Figure: EOS GmbH

Conventional process

"Testing is final validation at the end of development process"

- Sequential development processes
- Conservative development approach
- Moderate development goals
- Long development cycles

Novel paradigm

"Testing is integrated part of development process"

- Parallel and integrated development processes
- Radical development approaches
- Ambitious development goals
- Accelerated development goals, short iteration cycles

SLM Rapid Prototyping of Turbine Blades for Rapid Development

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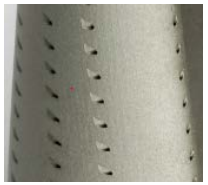
Conventional development cycle corresponds with standard manufacturing processes

Rapid Development

Coating

Drilling



Benefits:

- Reduced risk in critical path development steps
- Design optimization
- Reduced development time

SLM Process Chain for Production

Line integration is the prerequisite for industrialization

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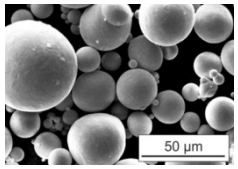
Challenges:

- Integration of horizontal AND vertical process chain
- Industrial machine standards
- Standardized processes, materials, and interfaces



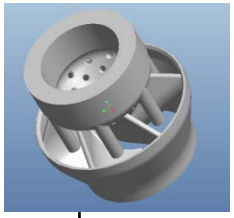
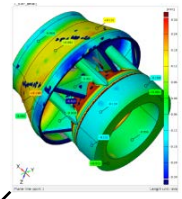
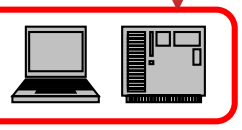


Figure: EOS GmbH

Figure: Schmetz GmbH

Figure: DMG Mori





Manufacturing Challenges & Considerations

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- **Costs:** *Implementation, validation and production*
- **Component size & complexity**
- **Location:** *Ability to source locally on globally basis; Export compliance*
- **Skill base:** *Qualified labor*
- **Incoming material:** *Quality control; storage; handling; mixing/blending*
- **Sourcing:** *Sole Source vs multi-source – stability, competition*
- **Inspection & Acceptance criteria:** *Destructive; NDE; sampling*
- **Vendor qualification and surveillance**
- **Compatibility/co-location with other manufacturing processes**
- **Re-work and non-conformance** – scrap rates
- **Residual powder / Revert**
- **Intellectual property:** *Component designs; process parameters*
- **…**

Conclusions

AM is not just a trend! It has already changed the way of producing and testing components.

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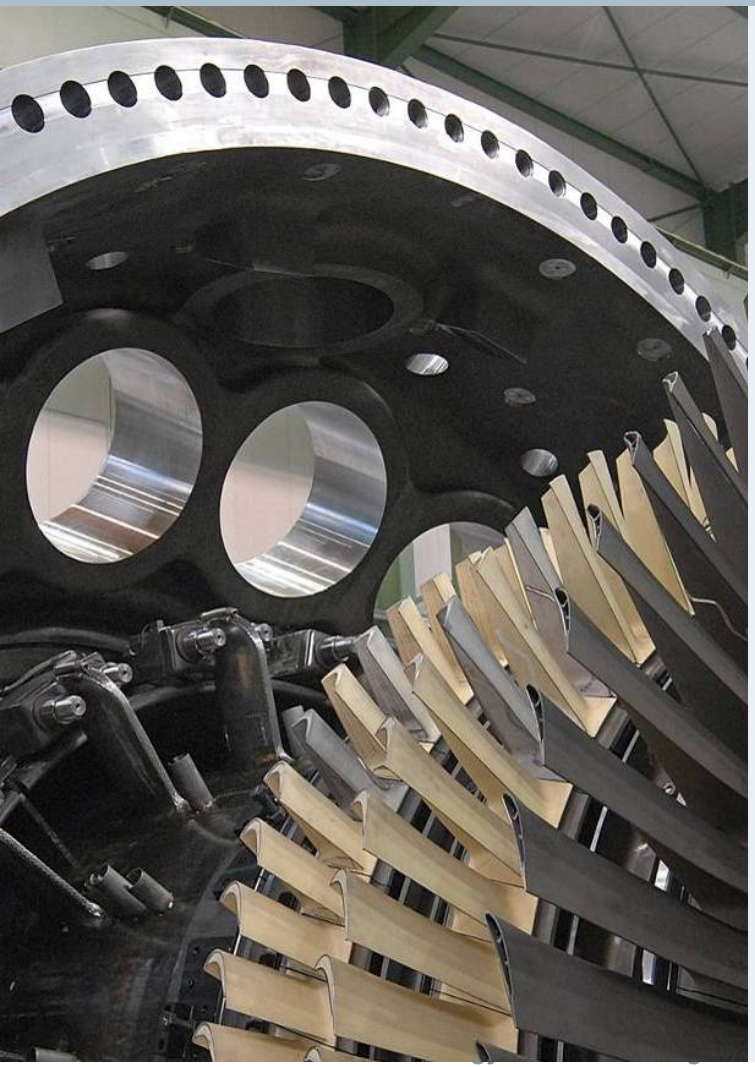

Opportunities

- SLM offers unique potential for the development of future gas turbines:
  - **Design innovations** → gain in performance
  - **Efficient repair** and refurbishment applications
  - **Paradigm change** in **development** and **validation**

Conclusions

AM is not just a trend! It has already changed the way of producing and testing components.

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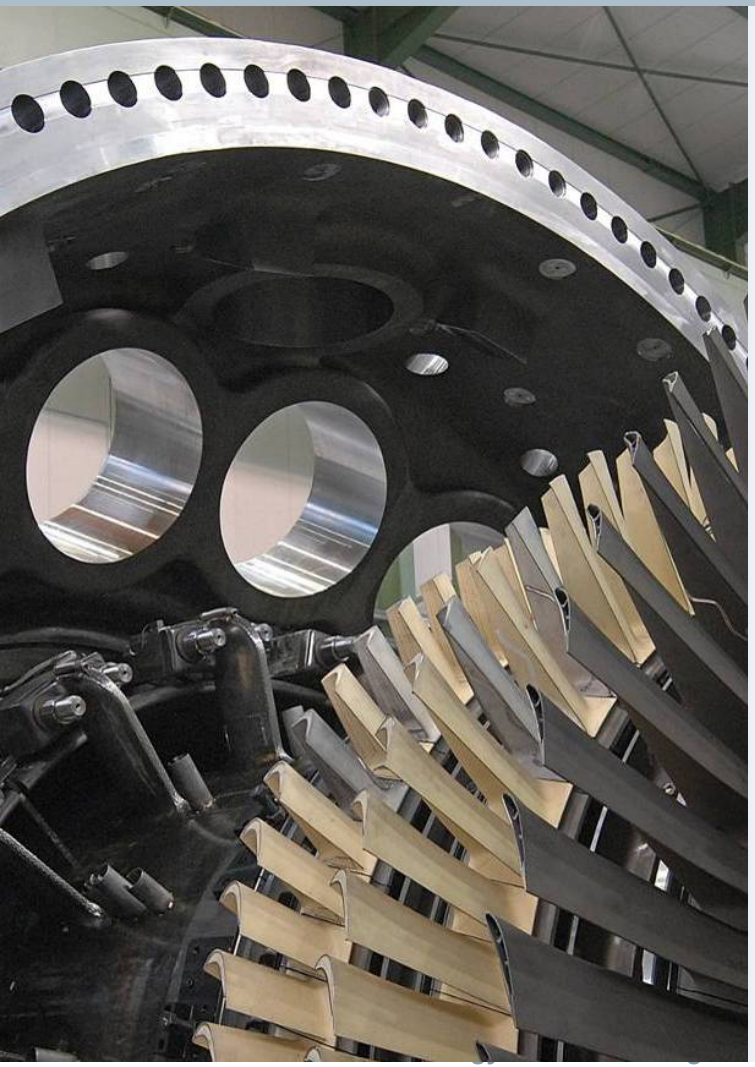

Challenges

- Industrial implementation of SLM has successfully started **BUT** additional development needs are substantial:
  - Capacities, build chamber sizes
  - **Costs**
  - Productivity → accelerated SLM processes (multiple lasers, laser arrays)
  - **Quality**
  - Robustness and repeatability → process control
  - Standardized processes, machines and materials
  - Industrial health and safety standards
  - **Line integration** → standardized interfaces are required
  - …

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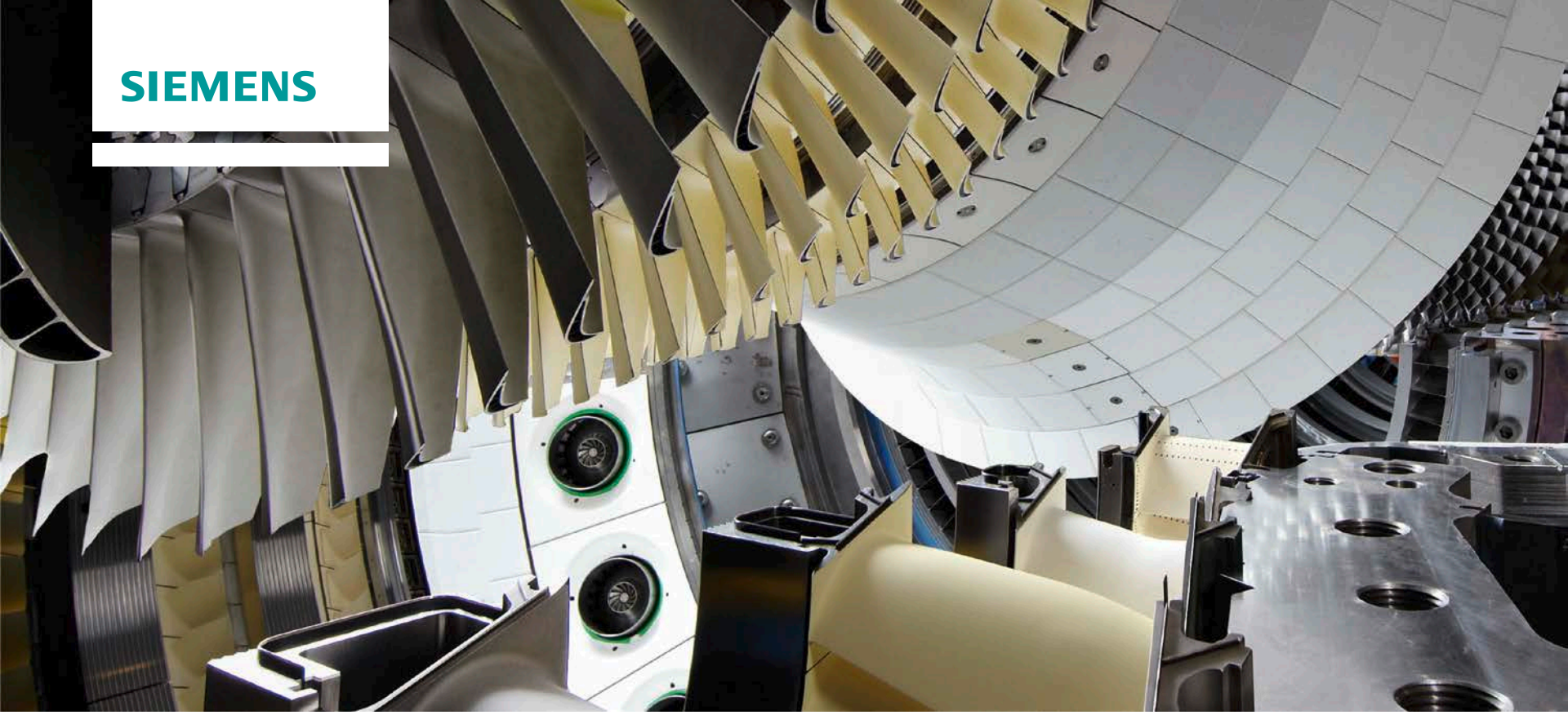

Thank you

Contact

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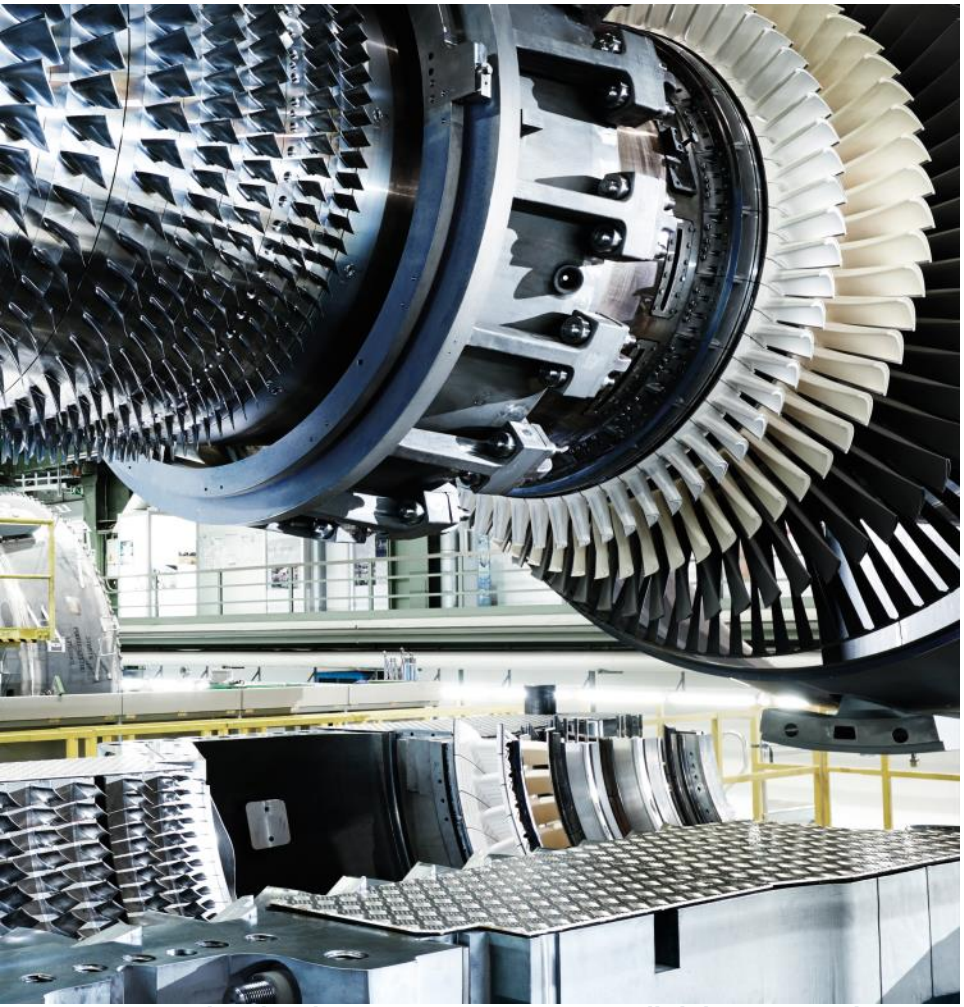

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