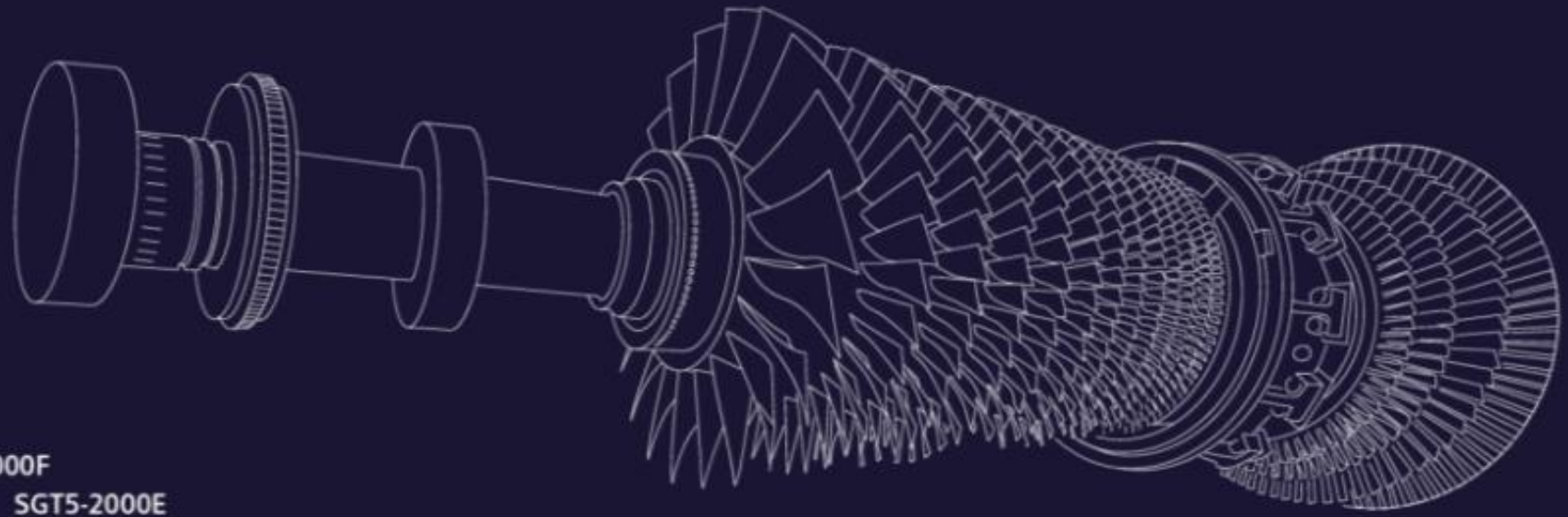
Siemens Energy
Additive Manufacturing Overview

Tad Steinberg



SGT5-9000HL
SGT5-8000H
SGT6-9000HL
SGT5-4000F
SGT6-8000H
SGT6-5000F
SGT5-2000E
SGT6-2000E
SGT-800
SGT-750
SGT-700
SGT-A35
SGT-600
SGT-400
SGT-300
SGT-100
SGT-A05
SGT-50

593 450 440 329-385 310 215-260 187 117 45-62 34-41 33-36 31-39 24-25 10-15 8-9 5-6 4-6 2 Megawatt

Every Siemens Energy Gas Turbine has AM designed hardware

Heavy-duty gas turbines
Aeroderivative gas turbines
Industrial gas turbines

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

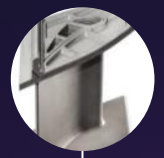
From R&D to serial parts production with SLM technology in 10 years

Outcomes

First Selective Laser Melting demonstrators

First SGT-700/800 rapid burner tip repair

SGT-750 combustion swirlers in commercial operation

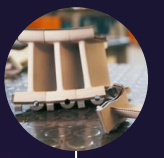


Prototyping of qualify-cation parts for LGT, IGT, AGT, IST

SGT-1000F burner head in commercial operation

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

- SGT-700 burners commercial operation
- SGT6-5000F vane inserts



- SGT-800 Heat shield field validation
- V64.3 row 1 vanes field validation

SGT5/6-8000H serial production DfAM parts

2006 2009 2012 2013 2014 2015 2016 2017 2018 2019 2020

Key enablers

Materials Solutions founded Worcester, UK

Installation of 1st EOS M270 SLM machine in Finspang

1st SLM Machine specifically adapted for burner repair in Finspang

Setup of Siemens Energy-wide AM Program and joint Team

Acquisition Materials Solutions

Materials Solutions
A Siemens Business

Finspang industrial workshop inaugurated

New Materials Solutions UK AM factory

Opening SE Additive Orlando, U.S.

Siemens Energy Global Production Overview

~175 LPBF components

Qualified for serial production

9 Materials Qualified

Qualified for serial production

51 LPBF Printers Globally

with factory space for up to 100 printers

~12,000 LPBF components produced in FY23

Delivered to SE production engines

+200 people

dedicated to AM (globally)

+2,000,000

Equivalent Operating Hours

Across new unit and repair services

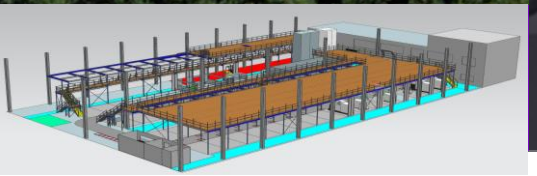
~2000 external production components delivered

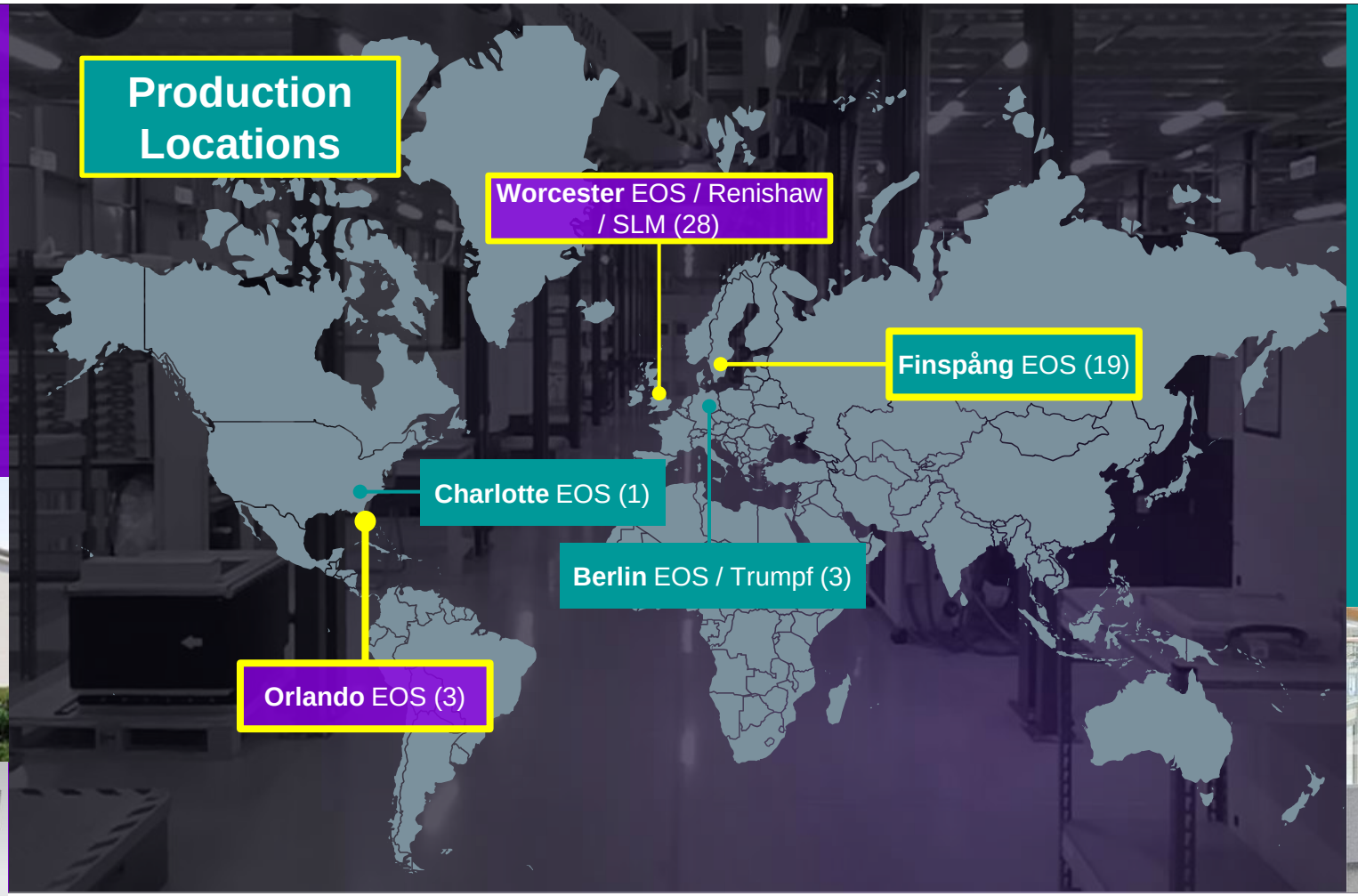
Delivered to external customers

LPBF Manufacturing Footprint

Worcester UK

+50,000 Sq.Feet





Finspång Sweden

+50,000 Sq.Feet

Siemens Energy Additive Manufacturing – Sectors Serviced

- Leading user of metal AM components for Siemens Energy power generation assets
- Reliable supply chain partner for prototype and serial production of metal AM components in adjacent industries
- Engineering and manufacturing AM services tailored to customer needs

Siemens Energy

Aero / Space

Autosport

DOD

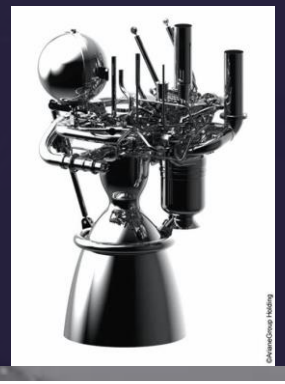
Aviation / Space

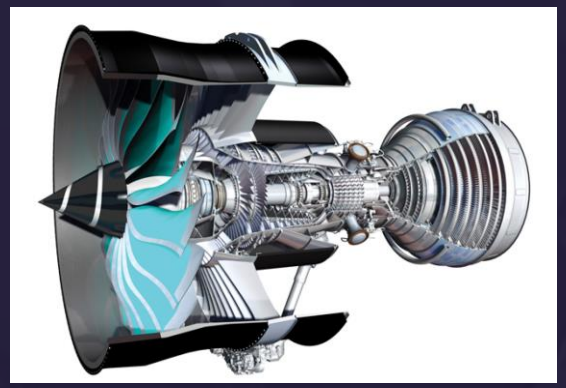
Service Provider:

- OEM’s
- Tier 1 Suppliers

R&D, Development & Production

- Airframe
  - Control systems
    - Example - Titanium high pressure hydraulic manifold
- Aerospace Propulsion
  - Combustion
  - Engine ancillaries
- Space
  - Propulsion





Siemens Energy Production Capability

LPBF Production Systems

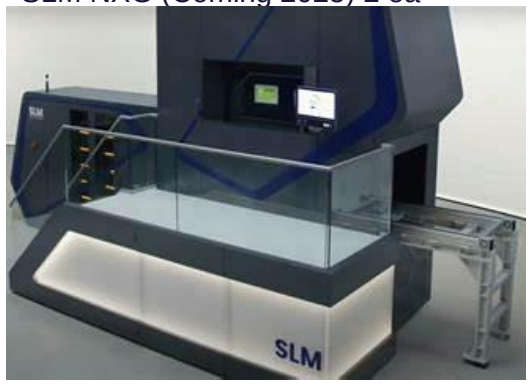
EOS M400-4: 13 ea

Multi-laser 400W systems; 12 Ni & 1 Ti

EOS M290: 7 ea

Single laser 400W system; 6 Ni, 1 Al

SLM NXG (Coming 2025) 2 ea



Multi-laser 1KW system Ni alloys

Renishaw 500Q: 2 ea

Multi-laser 500W system dedicated to Ni alloys

SLM500: 1 ea

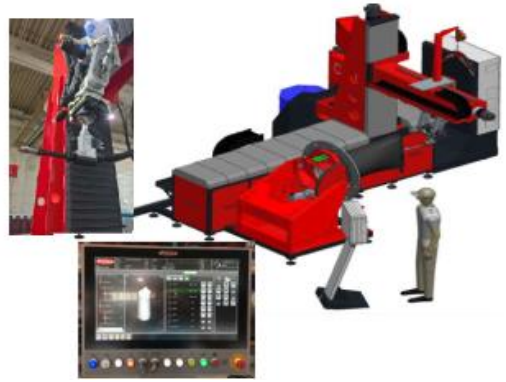
Multi-laser 700W system dedicated to Al alloys

EOS M270: 4 ea

Systems due to be retired in FY24

WAAM Production Systems

Fronius Overlay Welding (FOW) System 2 ea



8-Axis - TPS 5000-CMT system

Robotic WAAM - Fanuc ARC Mate 100iC/7L 3 ea

Servo positioner, 8-Axis unraveling degrees of freedom

Siemens Energy AM Production Capability

Post Processing Capability Examples

Powder conditioning

8x powder sieving, mixing & vacuum conveying

Depowdering

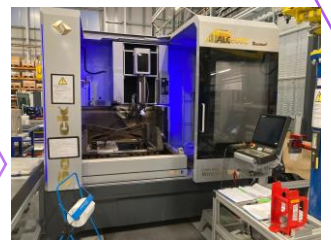
10+ dry depowdering units

Alloy family dedicated

Bandsaws

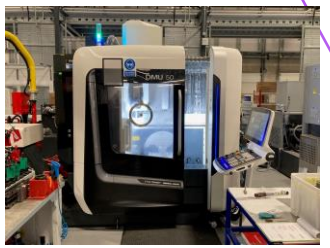
6+ Bandsaws

Wire EDM



Multiple EDM's

5 axis CNC



DMG, HAAS etc.

Abrasive blasting

Multiple blast cabinets

Laser part marking

laser part markers

Light Inspection

GOM / Creaform etc.

CMM Inspection

Various types / sizes

FPI testing

SE approved FPI

Airflow testing

Suction & pressure fed airflow rig

Laboratory testing

Microstructure, Oxygen & PSD analysis

Materials Processed

Qualified print process

Nickel Superalloys
- CM 247 LC
- In 738 LC
- C1023
- MAR M002
- Haynes 230

Aluminum
- A20X
- AlSi10Mg
- Scalmalloy

Titanium alloys
- Ti6Al4V

Ferrous alloys
- SS 17-4
- SS 15-5
- SS 304
- SS 316L
- Maraging Steel M300

Cobalt alloys
- CoCrMo
- MAR M509

Fully qualified with design data

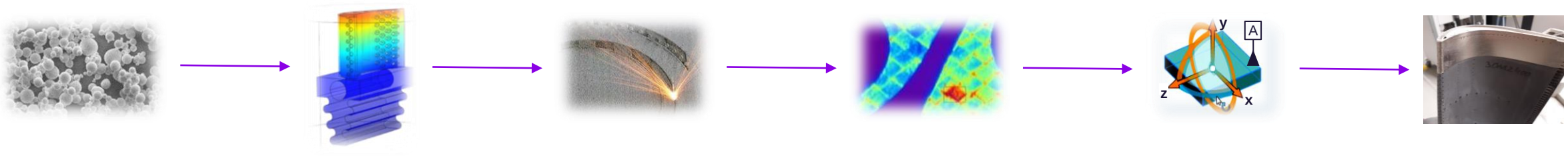
Nickel Superalloys
- Hastelloy X
- C 263
- In 625
- In 718
- In 939
- Haynes 282

Cobalt
- Merl 72

Machines at Siemens Energy are designated by alloy type, e.g. Nickel & steel, Titanium, Aluminum. From within the Siemens Energy AM network we currently have the following machines operational:
- 10+ EOS M400-4 designated to Nickel alloys
- 2+ A30EOS M400-1 designated to Nickel alloys
- 5+ EOS M290 designated to Nickel alloys & Steels
- 2 Renishaw 500Q designated to Inconel 625
- 7 EOS M270 designated to Nickel alloys & Steels
- 1 EOS M280 designated to Titanium
- 1 EOS M400-4 designated to Titanium
- 1 EOS M290 designated to Aluminium
- 1 SLM 500 designated to Aluminum
- 2 SLM NXG designated to Nickel Alloys (2025)

Siemens Energy Additive Manufacturing

Controlling the end-to-end AM Value Chain



1. Material & Process Development
2. Machine validation
3. Design for AM
4. Part Qualification
5. Powder Management
6. Build Prep & Simulation
7. Build & Monitoring
8. Post Process & Finishing
9. Quality Assurance
10. Repair

Lessons Learned

- Have the component design engineer sit next to AM Application engineer and let the magic happen
- Training for design engineering – get away from traditional manufacturing mindset – very difficult for seasoned Design Engineers
- Ensure to look at the system affected in its entirety “V Diagram” systems engineering
- Initial design considerations must include:
  - Build orientation, Datums, Post processing, Access, Depowdering, Surface finish, AM capabilities, etc. etc. etc. (AM Design Manual)
- Acceptance of metal AM can be a major barrier to those unfamiliar. Be ready to “Prove” or “Sell” the technology.
- Risk class / Use case / Business case analysis for components is key - Ensure AM is the right fit
- For existing / replacement parts, printing typically only gets you halfway there
- Don’t look at AM to be the only solution. AM may only be part of a solution, along with traditional manufacturing.

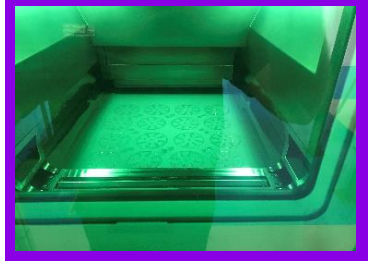
Experience in a Production Environment…

AM Serial Production requires full control of the entire Production Process Chain

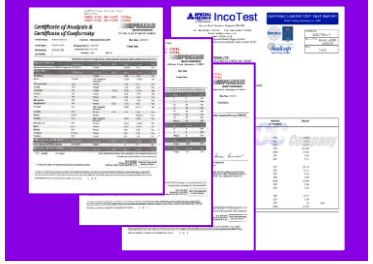
SIEMENS energy

Data Preparation

Printer Setup



L-PBF Process & Material

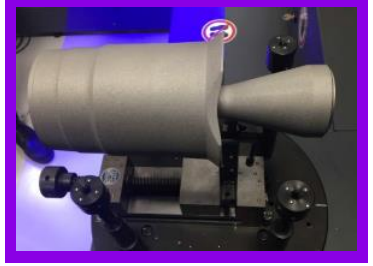


De-Powdering

Wire EDM

Heat Treatment

Final Inspection

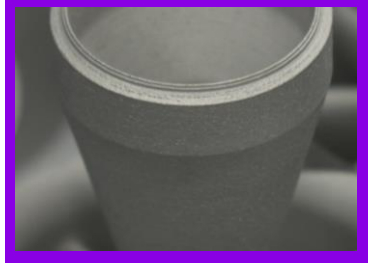


Ultrasonic Cleaning

FPI (dye penetrant)

Laser part marking

Grit Blasting



Support Removal

Every process step is optimized and released independently

Multiple Engines - AM Vane Performance to Date

Component	Material	TIT	EOH	Starts	Remarks
V64.3 TV1 Phase I	IN939	1390°C	27,000	72	Copy of conventional design, Dresden GT12, 8 rainbow parts, First Fire 07/2019
SGT-700B TV2	IN939	1190°C (at stage)	19,000	34	In-wall cooling design, E.ON Hattorf, set of 58 parts, First Fire 08/2020
V64.3 TV1 Phase II	IN939	1380°C	12,000	86	In-wall cooling design, Dresden GT11, set of 90 pcs., First Fire 08/2021
SGT-800B3 HS1	Alloy247	1260°C	10,600	29	In-wall cooling design, 15 rainbow parts, Thailand, First Fire 01/2019
SGT6-9000HL TV1	IN939	>1600°C	610	267	Endurance run 2022, 3 rainbow parts, serial production for HL2 on-going

Tad Steinberg

Additive Manufacturing

External Business Development

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Siemens Additive Link

Siemens AM: www.youtube.com/watch?v=8j86P2GKPvM