

Machine and Process Qualification from an Equipment Manufacturer's Perspective



A presentation by:

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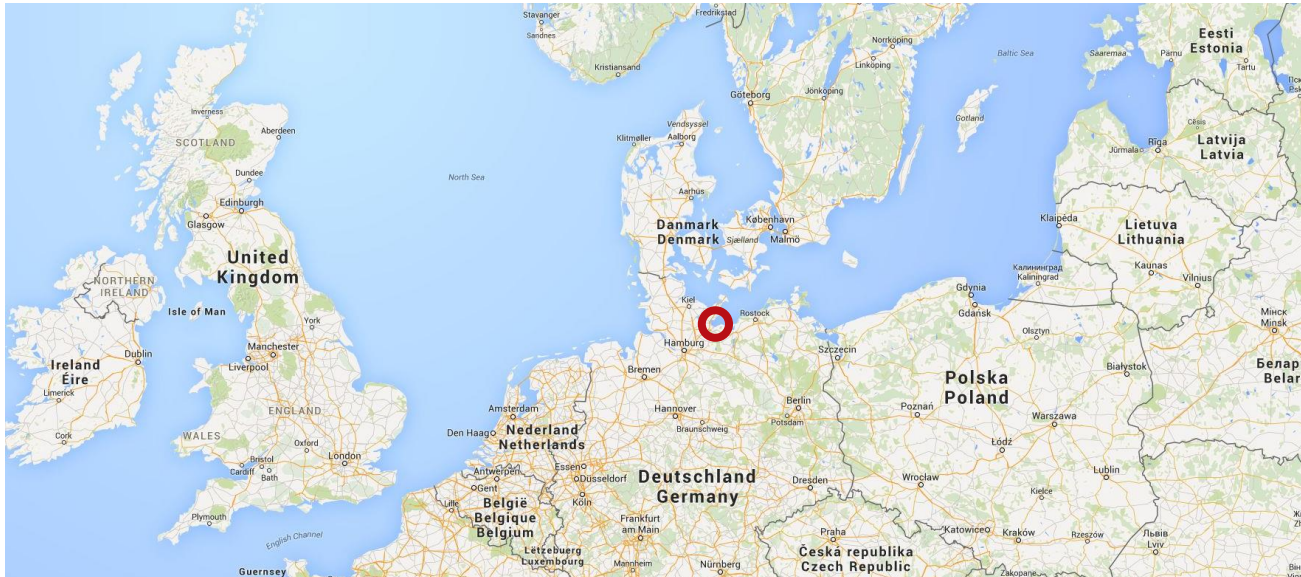
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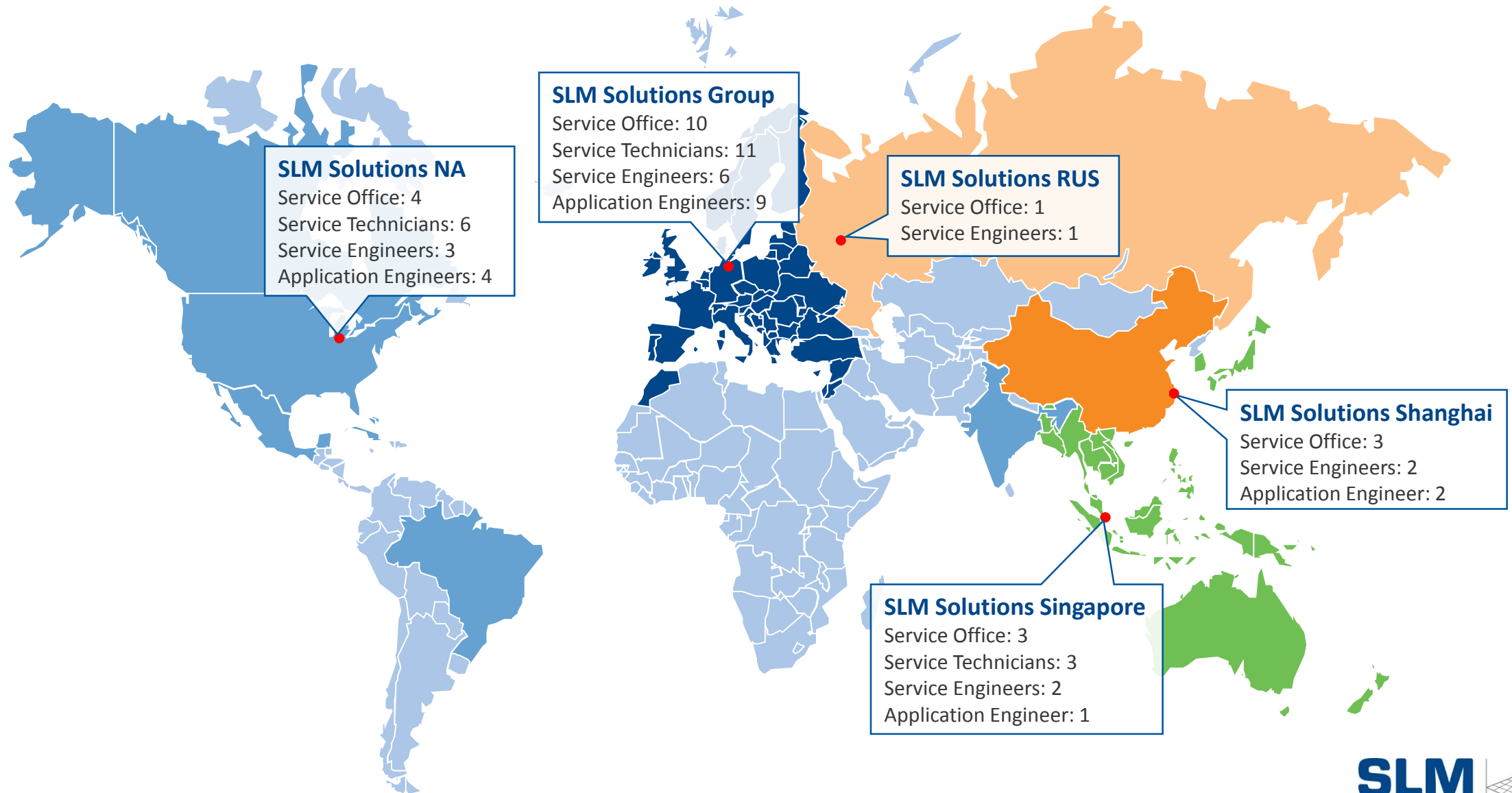
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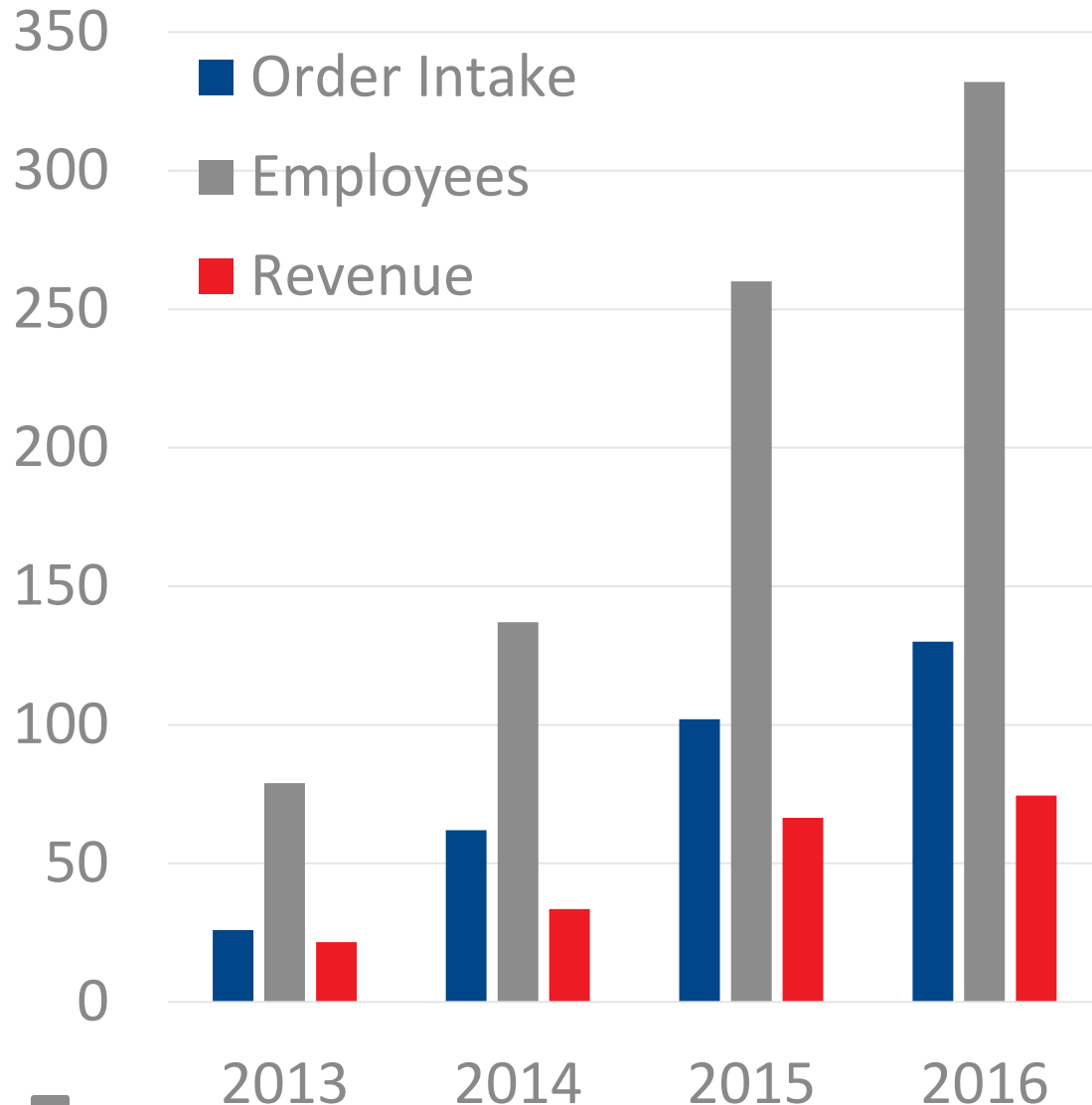
○ SLM Solutions – Headquarters in Lübeck, Germany



○ SLM Solutions – Global technical support



○ SLM Solutions – A strong growth story



- Public company listed in German TecDAX
- Strategic focus on Selective Laser Melting
- Proven multi-laser technology used in more than 60% of ordered systems
- Over 40% orders from existing customer base
- Global presence with subsidiaries in North America, China, Singapore, Russia

○ SLM Solutions – Products portfolio



SLM 125^{HL}

Build Chamber: 125 x 125 x 75mm

Laser – Single: 1 x 400W

Build Speed: up to 25 cm³/h



SLM 280^{HL}

Build Chamber: 280 x 280 x 365mm

Laser – Single: 1 x 400W or 700W

Laser – Twin: 2 x 400W or 700W

Build Speed: up to 55 cm³/h



SLM 500^{HL}

Build Chamber: 500 x 280 x 365mm

Laser – Twin: 2 x 400W or 700W

Laser – Quad: 4 x 400W or 700W

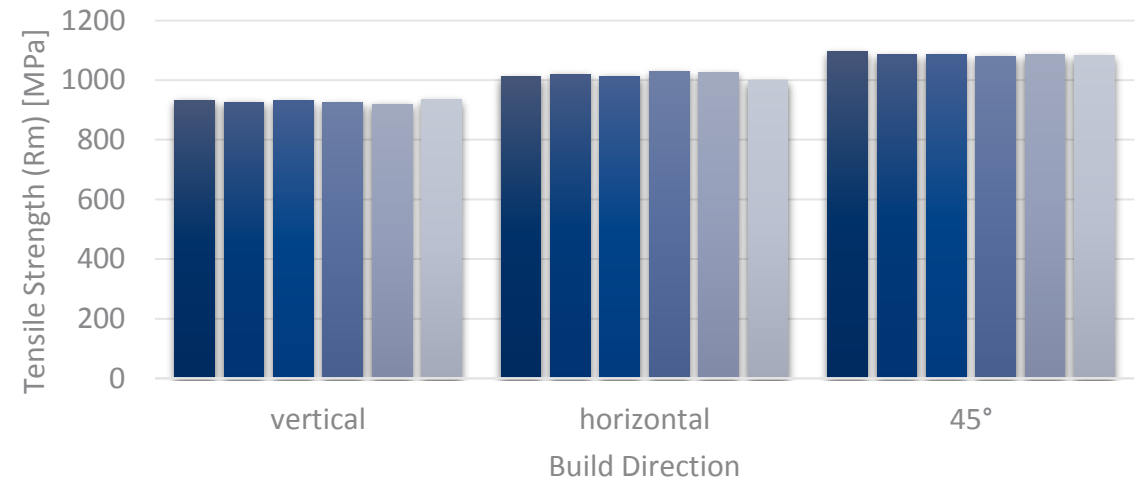
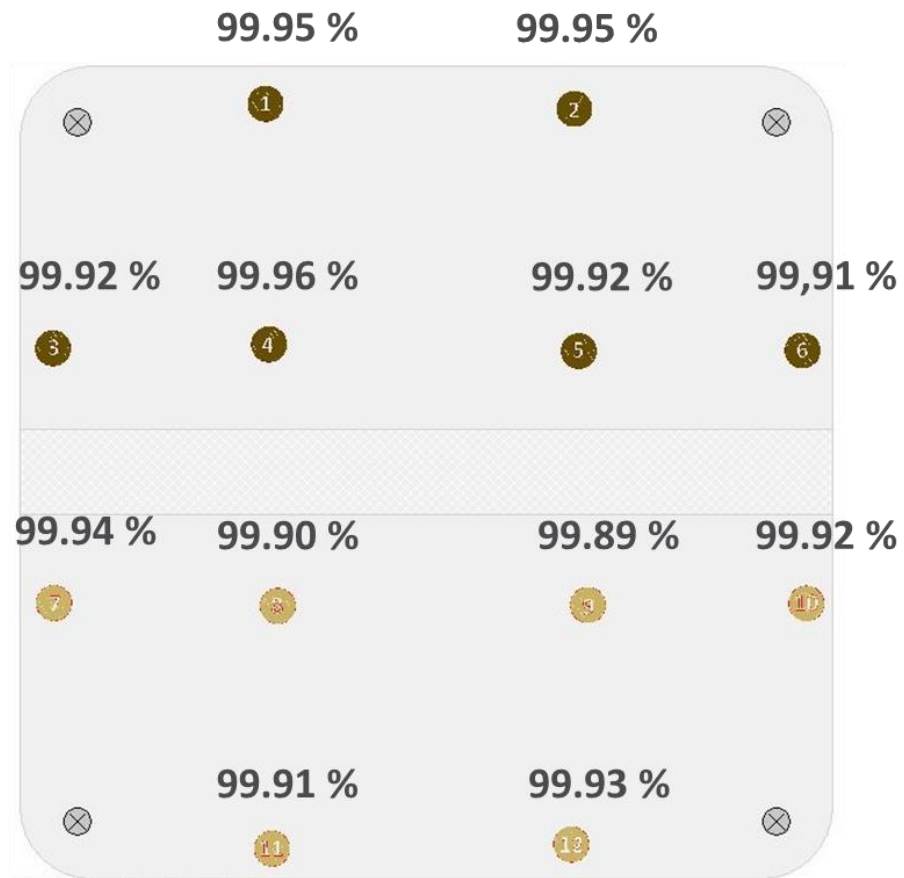
Build Speed: up to 105 cm³/h

○ SLM Solutions – New release: SLM 280 2.0



- Twin laser configurations with 2x 400W or 2x 700W for highest build rates in the industry
- At least 25% larger build envelope (280mm x 280mm) than other mid-size machines
- Patented overlap technology ensures seamless build of large parts with both lasers
- New unique gas flow system for extremely low variation of material properties and faster processing

○ SLM Solutions – Performances: IN625 in 50μm layer thickness

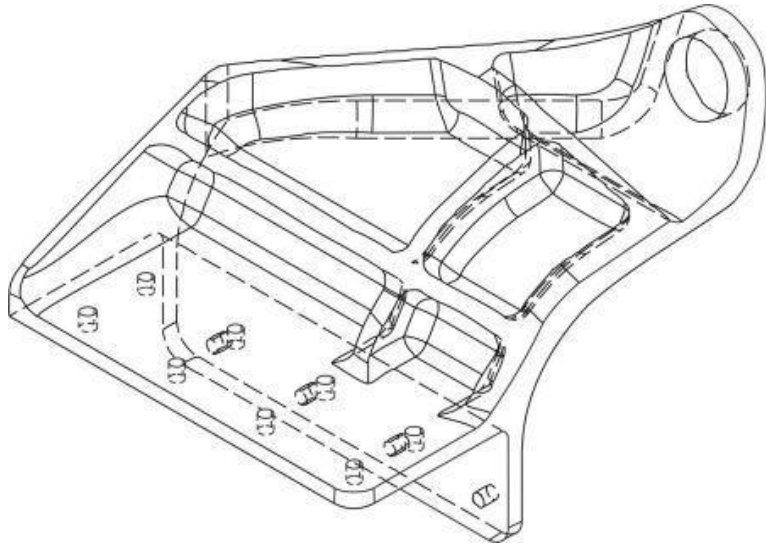


	Relative Density [%]	Tensile Strength Rm [MPa]		
		Vertical	Horizontal	45°
Mean Value	99.925	928	1016	1085
Standard deviation	0.021	4.80	10.20	4.37



○ Aerospace – Bionic cabin bracket

Conventional design



Source: Airbus

- Machined from solid block
- Buy-To-Fly Ratio: 13 (17kg/1,3kg)
- High set-up & span times
- 7000 Al Alloy

Bionic design



Source: Laser Zentrum Nord

- **50% Weight reduction**
- **Improved Buy-To-Fly Ratio: ~1-2**
- Build time for 2 parts: 41:23h
- AlSi10Mg

Application

- Aircraft:
Airbus A380
- Upper deck cabin
bracket
- Connecting crew
rest with stringers
- Lot size:
1 part per aircraft

○ Aerospace – Gooseneck bracket

AFLoNext

asco



■ Application

- Kruger flap actuation mechanism
- Research Project: FP7 AFLONEXT EU program
- Objectives: reduce weight, drag, noise

■ Build Job Data

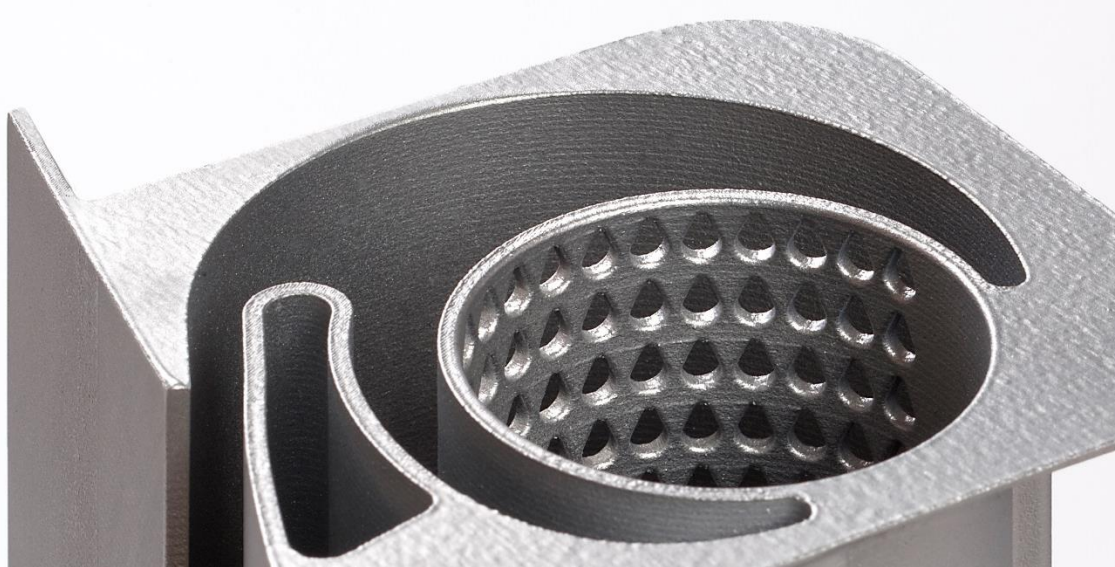
- SLM 280 Twin, 2 pcs/job
- Build time: 48h 27m
- Material: Ti6Al4V



■ Benefits of SLM Process

- Enabler for new topology optimized design

○ Aerospace – Steady blow actuator



■ Application

- Actuator for active flow control
- Complex assembly with long lead time
- Prototype part

■ Build job data

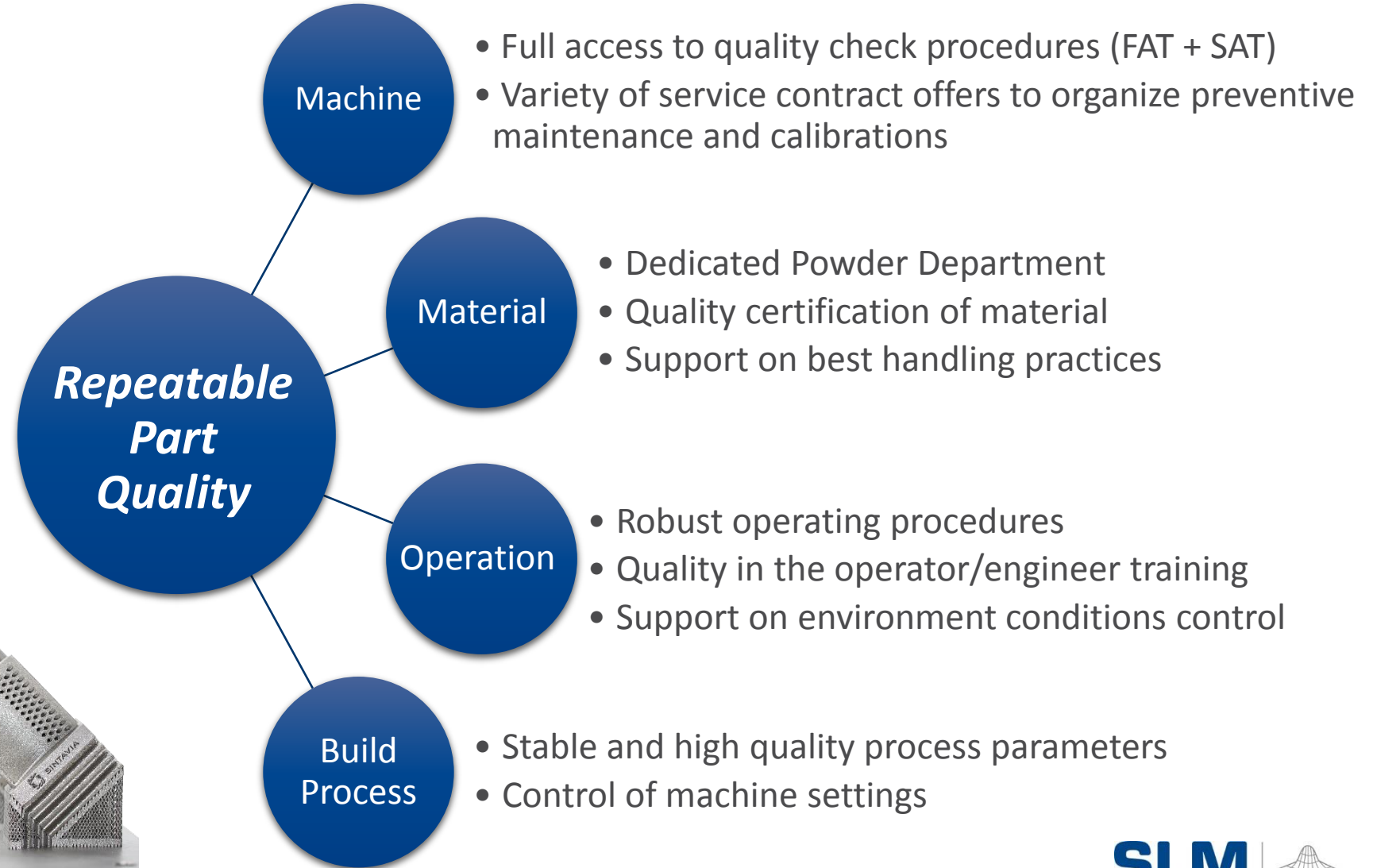
- SLM 280 Twin, 4 pcs/job
- Build time: 5d 3h 27m
- Material: AlSi10Mg



■ Benefits of SLM process

- Lead time reduction
- Integration of many piece parts into one part
- Reduction of assembly complexity
- Rapid prototype at low cost

○ Qualification process – 4 axis of support from SLM Solutions



○ Qualification process – Model IQ, OQ, PQ

Installation Qualification	Operational Qualification	Performance Qualification
<ul style="list-style-type: none">▪ Verify the equipment's design features▪ Ensure that the equipment was installed correctly▪ Basis : design specification with installation requirements▪ Verify availability of all necessary documents, drawings and manuals▪ Establish equipment inspection, maintenance and calibration schedules & procedures▪ Inspect & Calibrate equipment before and after process validation	<ul style="list-style-type: none">▪ Verify that manufacturing process is achieving its operational requirements▪ Test runs will determine highest, lowest and medium operating parameters▪ Use process parameters to set control limits and actions limits▪ Ensure process reproducibility▪ Challenge the process by using worst case conditions	<ul style="list-style-type: none">▪ Last phase of validation process▪ Demonstrate consistent results over time▪ Run equipment several times under normal operating conditions▪ Verify statistical process performance (e.g. 4 Sigma)▪ Challenge equipment functions

○ Qualification process – Process control and documentation

Restricted access to process parameters

- Operator/Engineer access levels
- Process parameter setting under Engineer access
- Support on jobs documentation during training program

Protocol and Sensor logging

- Monitoring of manual operations and sensor data (every 2 seconds)
- Notification of critical values via e-mail
- Documentation post-process

Layer Controlling

- Image documentation after powder application and after exposure
- Automatic analysis of the captured image data
- Error detection and automatic correction according to defined limits

Process Monitoring

- Vector-based Laser Power Measurement and Melt Pool Monitoring Measurement
- Correlation of measured patterns with defects
- Real-time measurement and plotting
- Documentation of the full manufacturing process

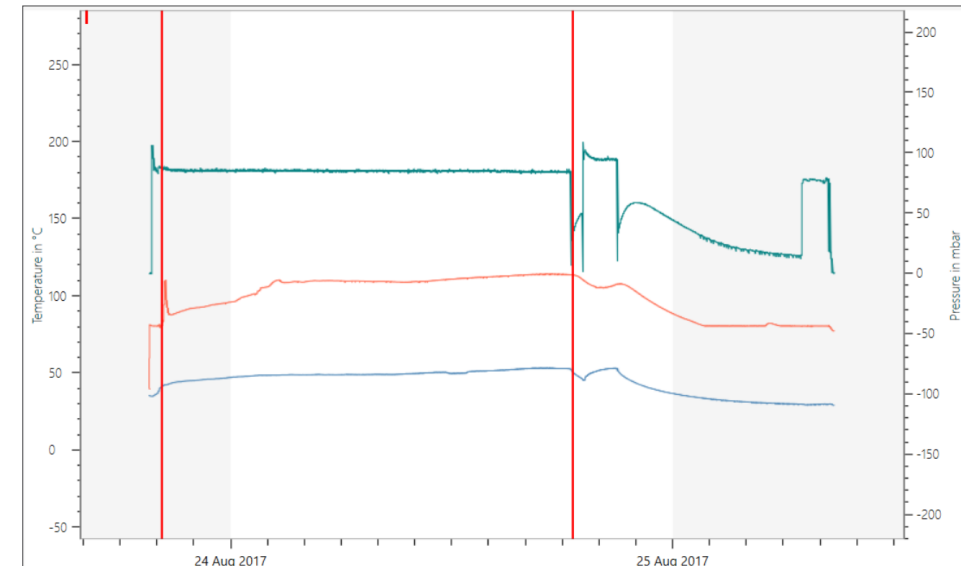
Qualification process – Process control and documentation

Protocol and Sensor logging

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	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AI	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ
1	Time	Platform	Build Chamber	Pump1	Cabinet	Cabinet	Optical E	Collimat	Ambiano	Dew point	Oxygen 1	Oxygen 2	Pressur	Filter Statu	T_LL	T_LF	T_MI	T_Mf	T_U	T_R	Li	-	-	R_Lf	R_L	B_f	B_F	-	Cyclont	S_MA	S_MIN	VSTG1	VSTG2	Gas flow speed	MemTotal	MemProcess	Galvo X0	Galvo Y0	Galvo X1	Galvo Y1	Galvo X2	Galvo Y2	Galvo X3
11	08/23/17 19:34:42	42.2	34.9	42914	42945	32.4	26. Apr	42942	42879	-67.50	22.17	2124	81.4	0.0	1	1	1	1	1	1	0			0	0	0	0	0	1	0	0	0	0	0.05	24	247	24.52	2181	23.59	24.19	24.18	23.36	24.70
12	08/23/17 19:34:44	42.5	34.9	42914	42915	32.4	26. Apr	42942	42879	-67.50	22.19	2128	82.2	0.0	1	1	1	1	1	1	0			0	0	0	0	0	1	0	0	0	0	0.04	24	247	24.52	2181	23.58	24.17	24.17	23.37	24.69
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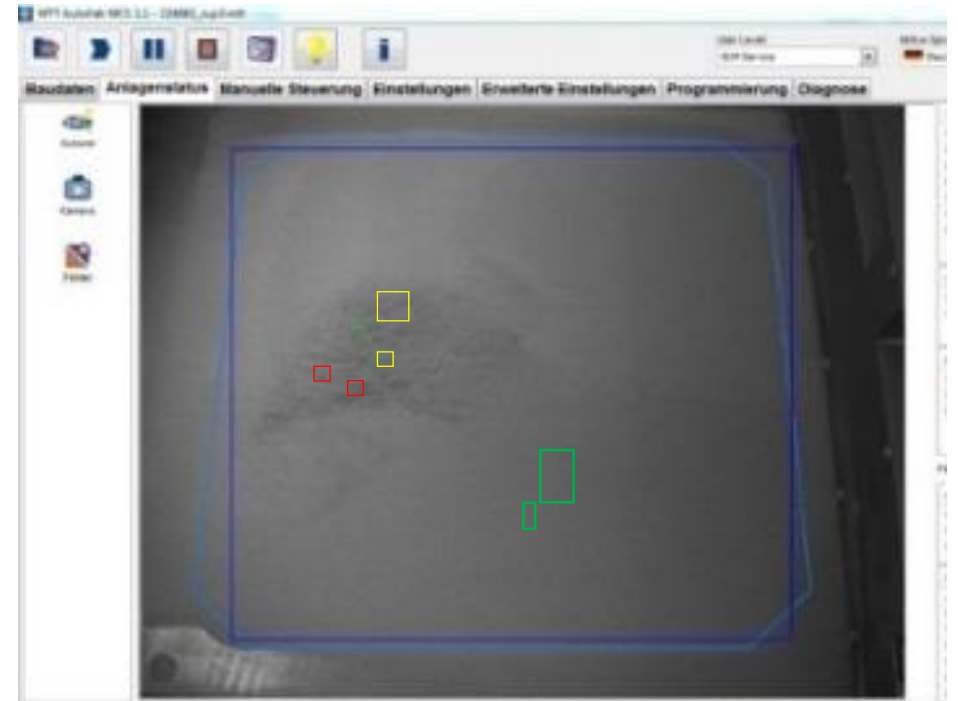
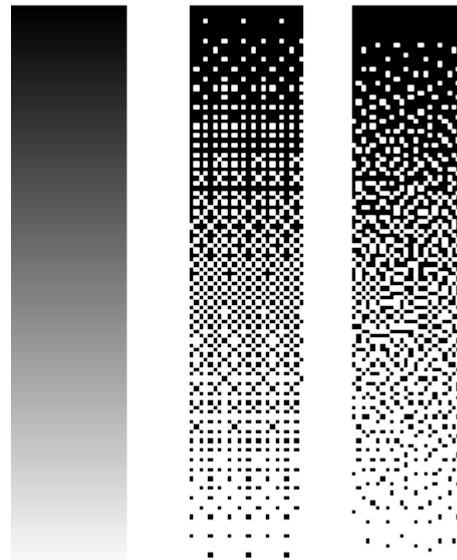
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Datei Bearbeiten Format Ansicht ?
09/01/17 16:57:08: Number of back way chambers used: 5
09/01/17 16:57:08: -----
09/01/17 16:57:08: Starting exposure (layer 2 at 0.05 mm)
09/01/17 16:57:08: TableType = 1.0, TableNo = 731.000000
09/01/17 16:57:08: Coefficients: A=-17151.000000, B=4.482422, C=-0.000030
09/01/17 16:57:08: RTC5 Correction file: C:\ProgramData\SLM Config\SLM280\03_31_2801326_02.ct5
09/01/17 16:57:08: TableType = 1.0, TableNo = 731.000000
09/01/17 16:57:08: Coefficients: A=-17151.000000, B=4.482422, C=-0.000030
09/01/17 16:57:08: RTC5 Correction file: C:\ProgramData\SLM Config\SLM280\03_31_2801326_01.ct5
09/01/17 16:57:39: Exposure finished (layer 2 at 0.05 mm)
09/01/17 16:57:39: -----
09/01/17 16:57:39: Starting recoating (layer 3 at 0.1 mm)
09/01/17 16:57:39: Script: 5
09/01/17 16:57:39: Script: Start recoating
09/01/17 16:57:39: Script: RecoaterV2 Steps 10
09/01/17 16:57:39: Script: Recoating: Moving platform to 100 microns (-31871 steps)
09/01/17 16:57:41: Script: Recoating: Moving recoater from 433.995
09/01/17 16:57:52: Script: Recoating: to 0
09/01/17 16:57:52: Script: Script Ende
09/01/17 16:57:52: Recoating finished (layer 3 at 0.1 mm)
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○ Qualification process – Process control and documentation

Layer Controlling

- Image documentation after powder application and after exposure
- Automatic analysis of the captured image data
- Error detection and automatic correction according to defined limits



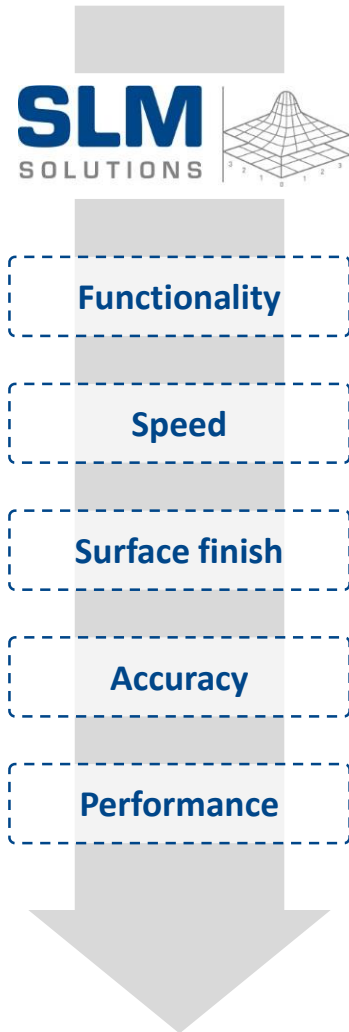
○ Qualification process – Process control and documentation

Process Monitoring

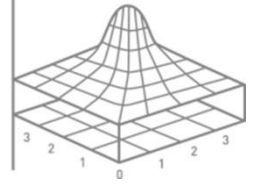
- Vector-based Laser Power Measurement and Melt Pool Monitoring Measurement
- Correlation of measured patterns with defects
- Real-time measurement and plotting
- Documentation of the full manufacturing process



○ Future outlook – Research & Development focus areas



- Enlarged build envelope
- Higher build rate – faster recoating & multilaser
- Robustness 24/7
- New powder cassette
- Tailored microstructure production
- Melt pool temperature monitoring
- Laser power management and control
- Process monitoring & control
- Optimized powder and build part handling
- Data management – storage & export
- User friendliness
- Easy maintenance
- Cost of machine and associated peripherals
- Standardization, modularization and flexible customization
- Remote operation and service



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