Optimizing cost with Simulation and Digital Twins

Carl Wouters

DID YOU KNOW?

Every third car in the world
is assembled with
products and solutions
from Atlas Copco.

DID YOU KNOW?

Oil-free compressors
from Atlas Copco
are used to process coffee*
with the highest demands
on purity and energy efficiency.

*(*We helped making the mug too)*

DID YOU KNOW?

Compressors from Atlas Copco
are used to brew 50% of
all industrially produced beer
in the world.

Atlas Copco in figures

Customers in **180** countries

34000 employees in **90** countries

Established in **1873** Stockholm, Sweden

Turnover of nearly **86** BSEK / **9** BEURO

A decentralized Group with **4** business areas

Organization

BOARD OF DIRECTORS

PRESIDENT AND CEO

GROUP MANAGEMENT
BUSINESS AREAS AND CORPORATE FUNCTIONS

COMPRESSOR TECHNIQUE

- Compressor Technique Service
- Industrial Air
- Oil-free Air
- Professional Air
- Gas and Process
- Medical Gas Solutions
- Airtec

VACUUM TECHNIQUE

- Vacuum Technique Service
- Semiconductor Service
- Semiconductor
- High Vacuum
- Industrial Vacuum

INDUSTRIAL TECHNIQUE

- Industrial Technique Service
- MVI Tools and Assembly Systems
- General Industry Tools and Assembly Systems
- Chicago Pneumatic Tools
- Industrial Assembly Solutions

POWER TECHNIQUE

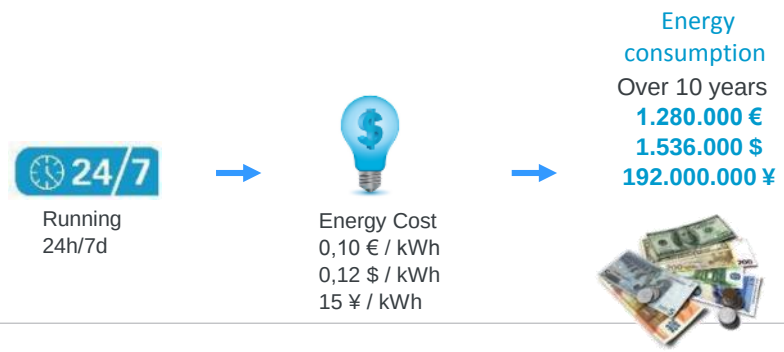
- Power Technique Service
- Specialty Rental
- Portable Air
- Power and Flow

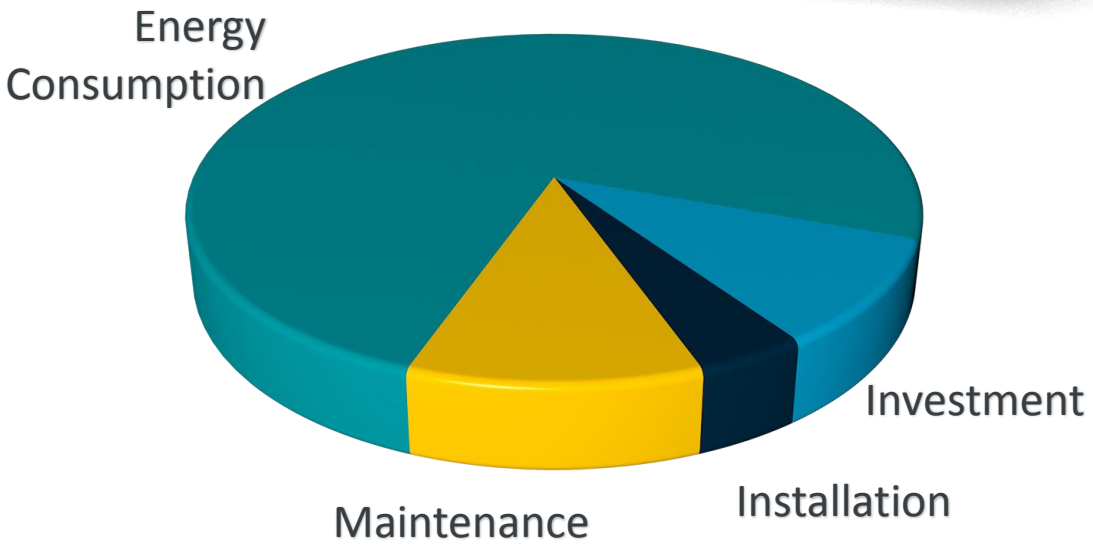
Atlas Copco


Atlas Copco
ZR 160 VSD+

The ZR 160 VSD+

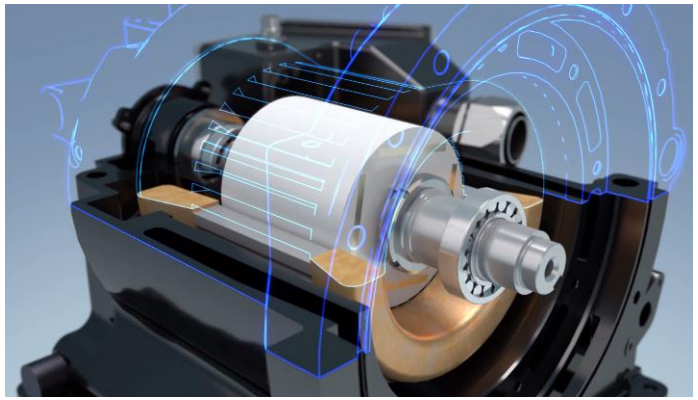
- One of the **most efficient** Oil-free screw compressor in the world in its power range
- **Hundreds of Atlas Copco employees** are involved in development, production, service and marketing
- All key components are completely **engineered by Atlas Copco** (i.e. Compressor Elements, Coolers, PM motors, Converters…)
- **> 50 sensors** for control, reliability, safety, predictive maintenance
- Able to operate **24/7**

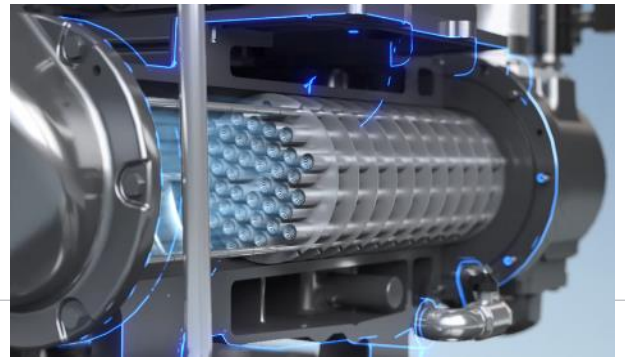




Challenges

- **Mature market**
- **Shorter Time to Market**
- **Cross divisional** development
- Almost **all components are redesigned** to improve reliability and efficiency while keeping total development, production and service costs in account
- **Self adaptive controller algorithm** to optimize efficiency in full working range
- **High product variability**, tens of thousands possible configuration options in Oil-free screw compressor portfolio
- **High product reliability**, > 60.000 running hours

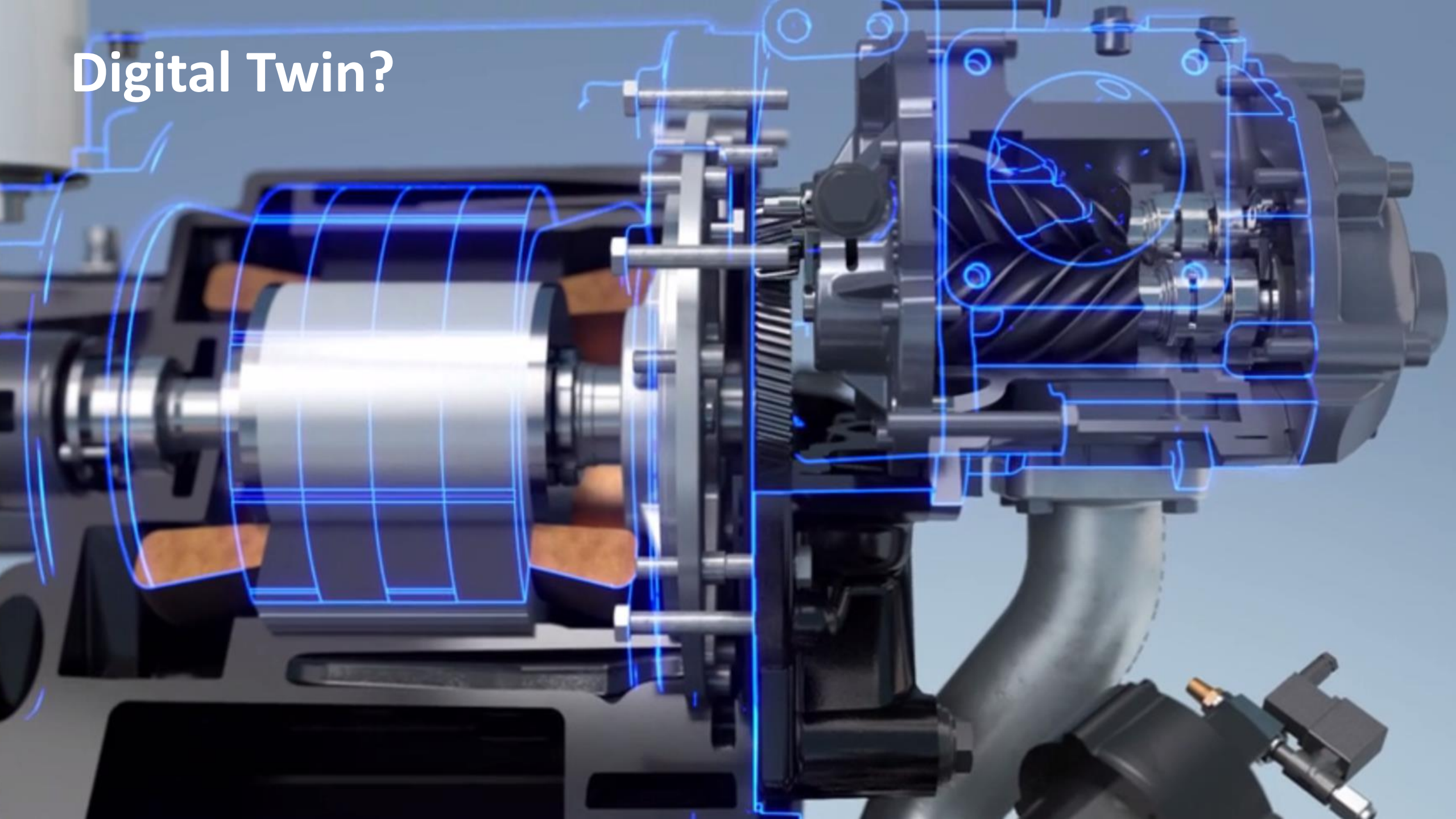




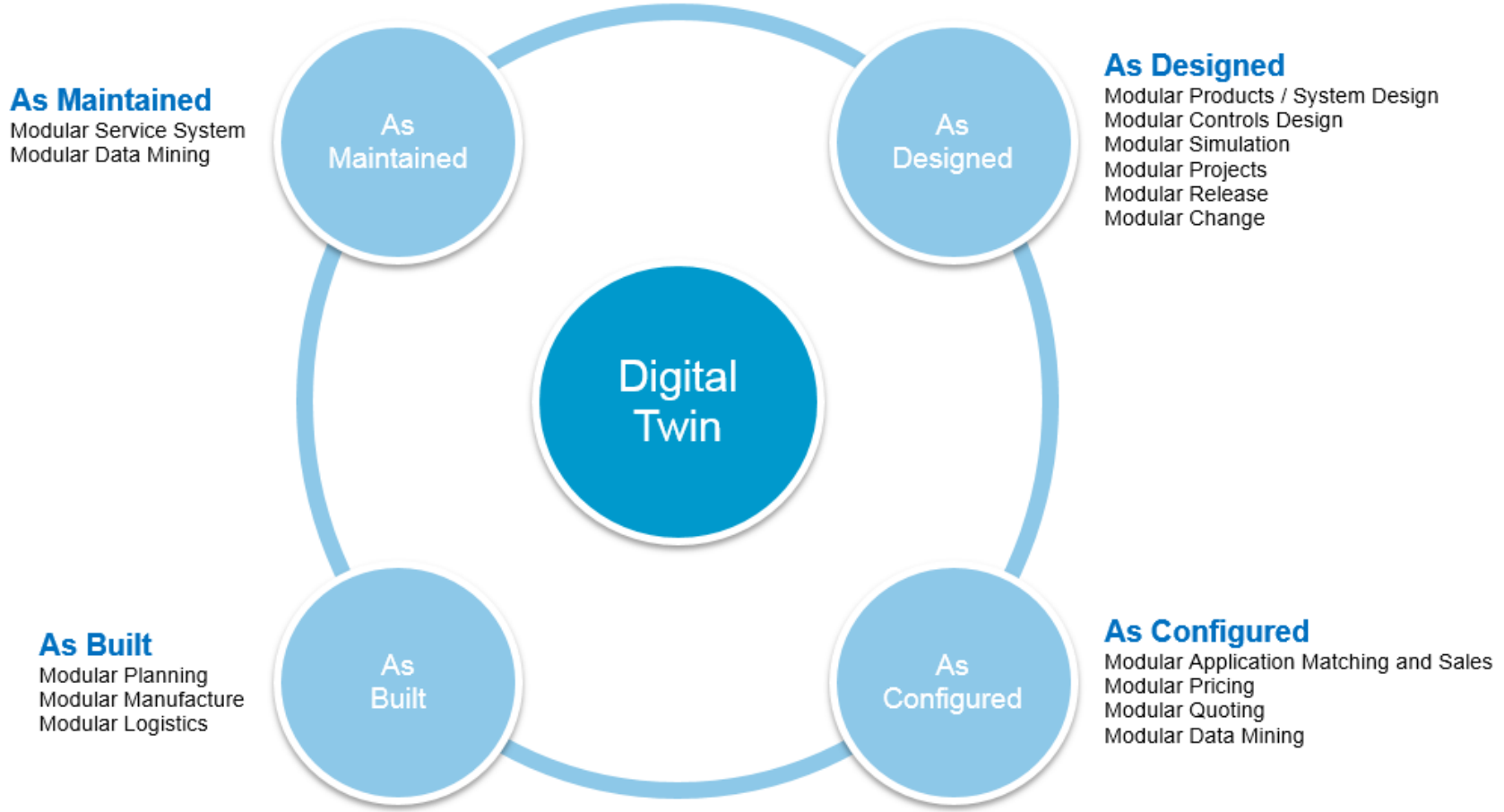
Innovation

Increase customer energy efficiency by 20% by 2020

Digital Twin?



Digital Twin in Atlas Copco and Single source of truth



As Maintained
Modular Service System
Modular Data Mining

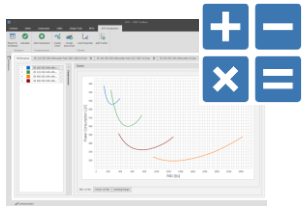
As Designed
Modular Products / System Design
Modular Controls Design
Modular Simulation
Modular Projects
Modular Release
Modular Change

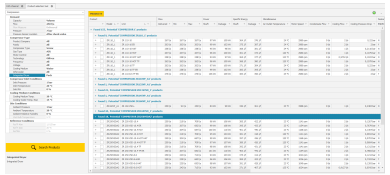
As Built
Modular Planning
Modular Manufacture
Modular Logistics

As Configured
Modular Application Matching and Sales
Modular Pricing
Modular Quoting
Modular Data Mining

Atlas Copco Model Based Engineering Platform

MBE Applications





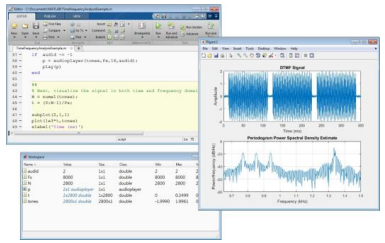
Digital Twin Storage

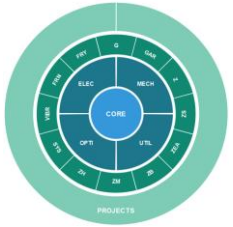
Digital Twin Processing

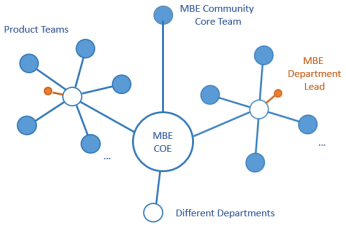
External Data Sources

MBE Community of Excellence

MathWorks®

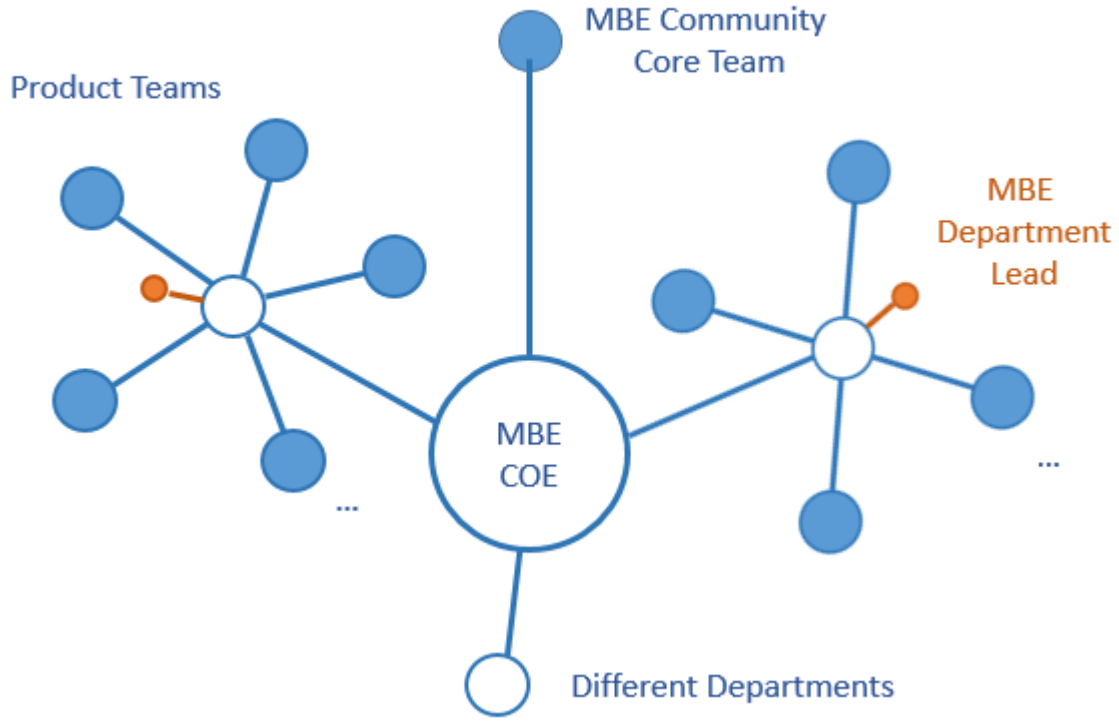






Atlas Copco

As Designed: MBE Community of Excellence



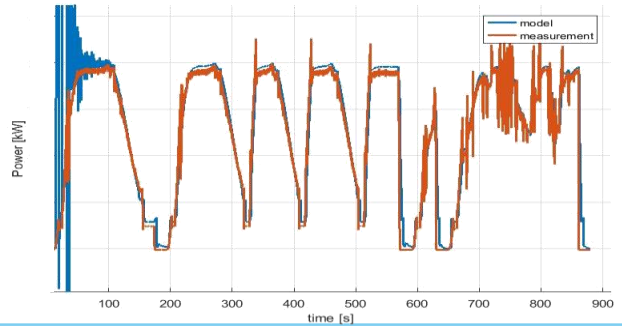
- Open information sharing mentality within Compressor Technique, using MATLAB as a platform
- Community wants to be integrated in all product teams worldwide
- Knowledge sharing platform for Calculations, Simulations, Data Analytics, Controller Algorithms
  - Object oriented MATLAB libraries
  - Integration of non-MATLAB code
  - GIT repositories, Source Control
  - Trainings
- Each product team is responsible and takes ownership for their implementations
- Standardization on tools

MathWorks® Atlas Copco

As Designed: MBE Framework

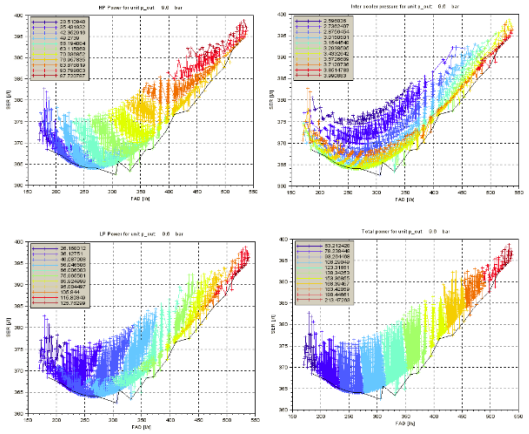
Physical Framework

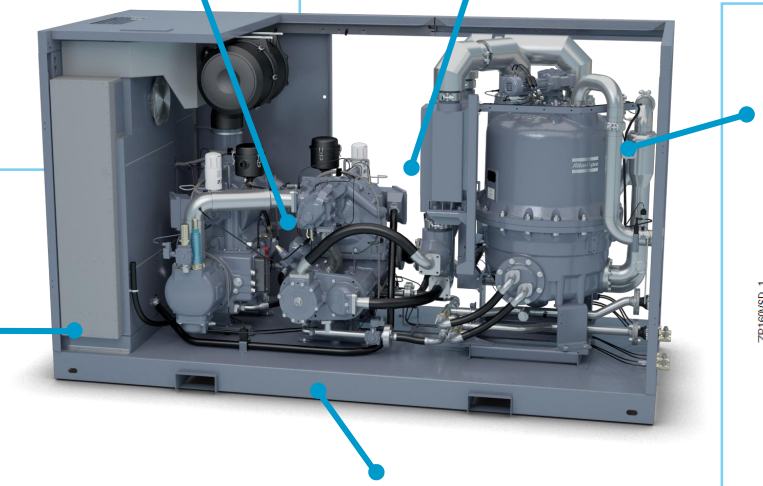
"As a calculation engineer, I want to simulate dynamic behaviour of my system to optimize my components."



Core Framework

"As a calculation engineer, I want to find optimal gear ratio's and element sizings."





Interface Framework

"As a marketeer, I want to have easy access to the validated engineering data to create my technical data sheets."

Technical data: ZR 160 VSD+-10.4

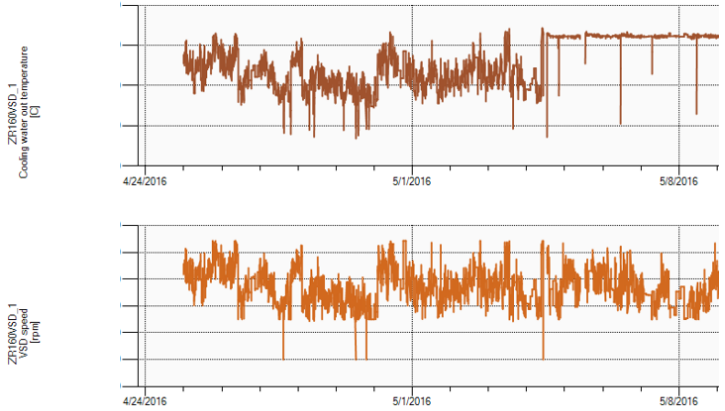
Product definition	
Model	ZR 160 VSD+
Pressure variant	10.4 bar
Integrated dryer	Pack
Frequency	50 Hz

Reference conditions	
Absolute inlet pressure	1 bar(a)
Relative humidity	0 %
Air inlet temperature	20 °C
Cooling water inlet temperature	20 °C
Cooling water temperature rise	15 °C
Effective working pressure	7 bar(g)
Motor shaft speed(rpm)	6316 rpm

Performance data*1	
Maximum working pressure	10.4 bar(g)
Free air delivery (at maximum volume flow rate)	
– Total electrical power input	
– Total specific energy requirements (SER)	
Free air delivery (at 75% of volume flow range)	
– Total electrical power input	
– Total specific energy requirements (SER)	
Free air delivery (at 50% of volume flow range)	
– Total electrical power input	
– Total specific energy requirements (SER)	
Free air delivery (at 25% of volume flow range)	
– Total electrical power input	
– Total specific energy requirements (SER)	
Free air delivery (at minimum volume flow rate)	
– Total electrical power input	
– Total specific energy requirements (SER)	
Effective working pressure (1)	
Free air delivery (at maximum volume flow rate)	

Controller Framework

"As a control engineer, I want to simulate the effect of my control strategy on the system."



Community Tools

Software platform enabling community development
Wiki, bug trackers, source control,…

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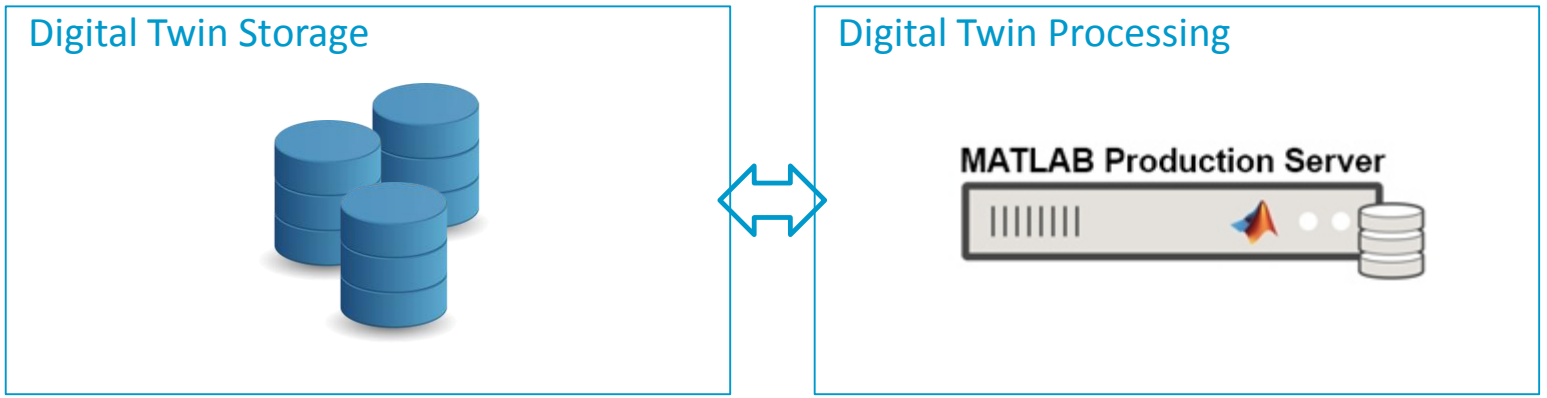
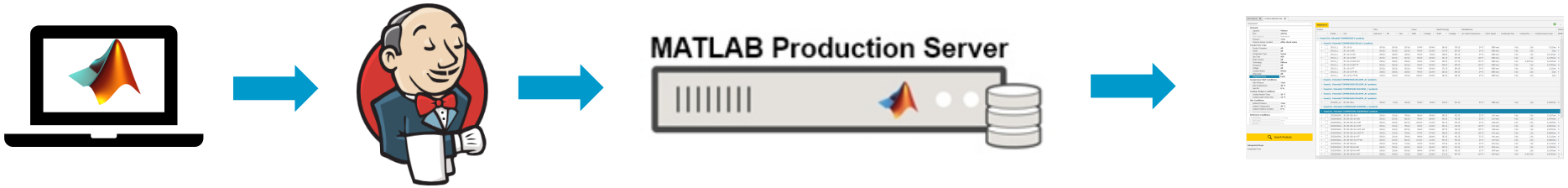
As Designed: Digital Twin

Thomas Kaiser, SAP Senior Vice President of IoT: “Digital twins are becoming a business imperative, covering the entire lifecycle of an asset or process and forming the foundation for connected products and services.”



Model Integration



MBE CoE | Nightly CI | Deployment | Application Integration

Info channel | Product selection tool

Compressors

As Configured

Demand	
Capacity	Volume
Flow	250 l/s
Flow Measu	Delivered
Pressure	7 bar
Pressure Sensor Location	After check valve
Compressor Type	
Product Company	All
Family	All
Compressor Type	Screw
Gas Type	AIR
Motor Control	All
Technology	OilFree
Frequency	All
Voltage	All
Cooling Medium	Water
Aftercooler	All
Integrated Dryer	Pack
Compressor Inlet Conditions	
Inlet Pressure	1 bar
Inlet Temperature	20 °C
Inlet RH	0 %
Cooling Medium Conditions	
Cooling Medium Temp.	20 °C
Cooling Water Temp. Rise	15 °C
Site Conditions	
Ambient Pressure	1 bar
Ambient Temperature	20 °C
Ambient Relative Humidity	0 %
Wet Bulb Temperature	5 °C
Reference Conditions	
Ref P Atm	1,013 bar
Ref T Atm	20 °C
Ref RH	0 %

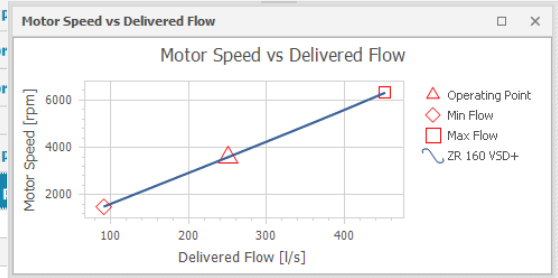
Search Products

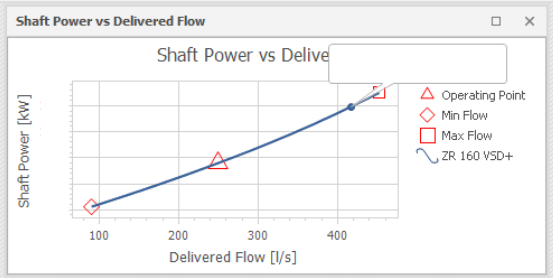
Integrated Dryer

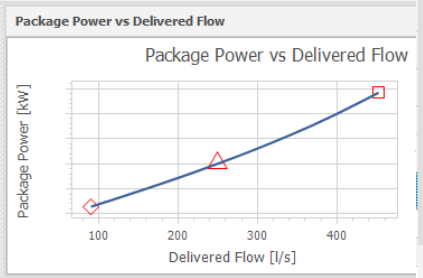
Integrated Dryer

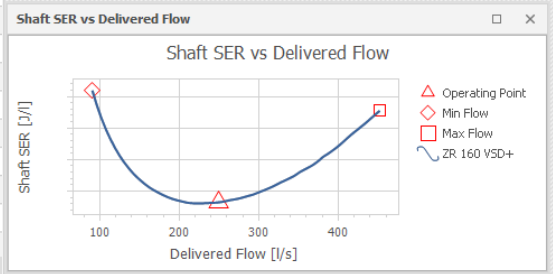
PRODUCTS

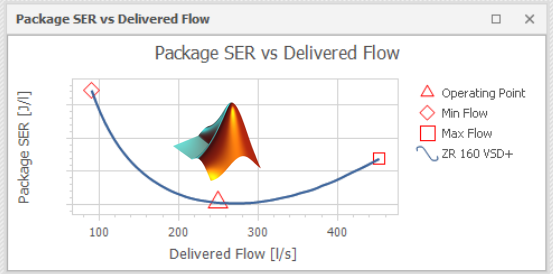
Product			Flow			Power		Specific Energy		Miscellaneous					Featur
Model	Unit		Delivered	Min	Max	Shaft	Package	Shaft	Package	Air Outlet Temperature	Motor Speed	Condensate Flow	Cooling Flow	Cooling Pressure Drop	ENREC
Found 27, Potential 'COMPRESSOR 1' products															
Found 9, Potential 'COMPRESSOR ZR110_1' products															
ZR110_1	ZR 110-10		267 l/s	267 l/s	267 l/s					24 °C	2980 rpm	0 l/s	2 l/s	0,22 bar	N
ZR110_1	ZR 110-10 ER		263 l/s	263 l/s	263 l/s					24 °C	2980 rpm	0 l/s	2 l/s	2 bar	Y
ZR110_1	ZR 110-10 HAT		258 l/s	258 l/s	258 l/s					24 °C	2980 rpm	0 l/s	1 l/s	0,2116 bar	N
ZR110_1	ZR 110-10 HOT		267 l/s	267 l/s	267 l/s					120 °C	2980 rpm	0 l/s	1 l/s	0,1079 bar	N
ZR110_1	ZR 110-10 HOT HAT		258 l/s	258 l/s	258 l/s					123 °C	2980 rpm	0 l/s	0,9752 l/s	0,1022 bar	N
ZR110_1	ZR 110-10 HOT TF		262 l/s	262 l/s	262 l/s					120 °C	2980 rpm	0 l/s	1 l/s	0,1079 bar	N
ZR110_1	ZR 110-10 TF		262 l/s	262 l/s	262 l/s					24 °C	2980 rpm	0 l/s	2 l/s	0,22 bar	N
ZR110_1	ZR 110-10 TF ER		258 l/s	258 l/s	258 l/s					24 °C	2980 rpm	0 l/s	2 l/s	2 bar	Y
ZR110_1	ZR 110-8.6 TF ER		276 l/s	276 l/s	276 l/s					24 °C	2980 rpm	0 l/s	2 l/s	2 bar	Y
Found 1, Potential 'COMPRESSOR ZR110VP_A1' products															
Found 1, Potential 'COMPRESSOR ZR132VP_A1' products															
Found 21, Potential 'COMPRESSOR ZR132VSD_1' p															
Found 1, Potential 'COMPRESSOR ZR145VP_A1' pr															
Found 1, Potential 'COMPRESSOR ZR160VP_A1' pr															
ZR160VP_A1	ZR 160 VSD+														
Found 44, Potential 'COMPRESSOR ZR160VSD_1' p															
Found 18, Potential 'COMPRESSOR ZR250VSDA2' p															
ZR250VSDA2	ZR 250 VSD-10.4														
ZR250VSDA2	ZR 250 VSD-10.4 ER														
ZR250VSDA2	ZR 250 VSD-10.4 HAT														
ZR250VSDA2	ZR 250 VSD-10.4 HOT														
ZR250VSDA2	ZR 250 VSD-10.4 HOT HAT														
ZR250VSDA2	ZR 250 VSD-10.4 HOT TF														
ZR250VSDA2	ZR 250 VSD-10.4 TF														
ZR250VSDA2	ZR 250 VSD-10.4 TF ER														
ZR250VSDA2	ZR 250 VSD-8.6														
ZR250VSDA2	ZR 250 VSD-8.6 ER														
ZR250VSDA2	ZR 250 VSD-8.6 HAT														
ZR250VSDA2	ZR 250 VSD-8.6 HOT														

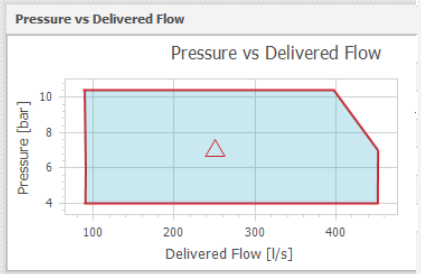


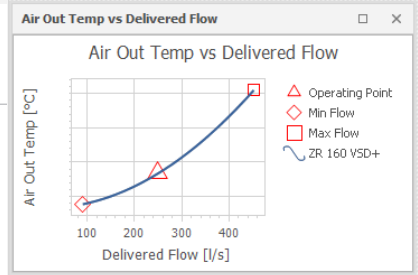


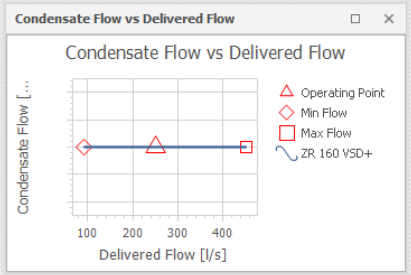


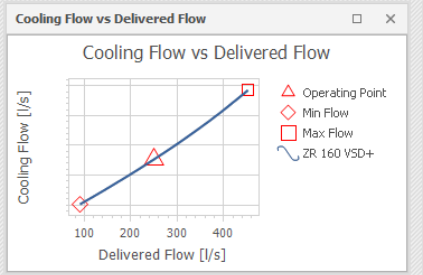


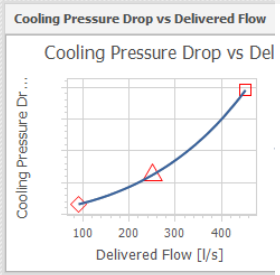












Basic product | General Options | Request article numbers and instruction book

Model	ZR 160 VSD+
Integrated dryer PDP sensor is delivered as standard	Pack
Frequency	50 Hz
Supply voltage	400V
Electrical approval	IEC
Working pressure	10.4 bar
Pressure vessel approval	CE
Flanged connection	DIN flanges

Next

Basic product | General Options | Request article numbers and instruction book

Request article numbers

Instruction Book

Technical Datasheet

Product Description

Previous

ZR 90-160 VSD+

Country of destination	Belgium
Model	ZR 160 VSD+
Integrated dryer	Pack
Frequency	50 Hz
Supply voltage	400V
Electrical approval	IEC
Working pressure	10.4 bar
Pressure vessel approval	CE

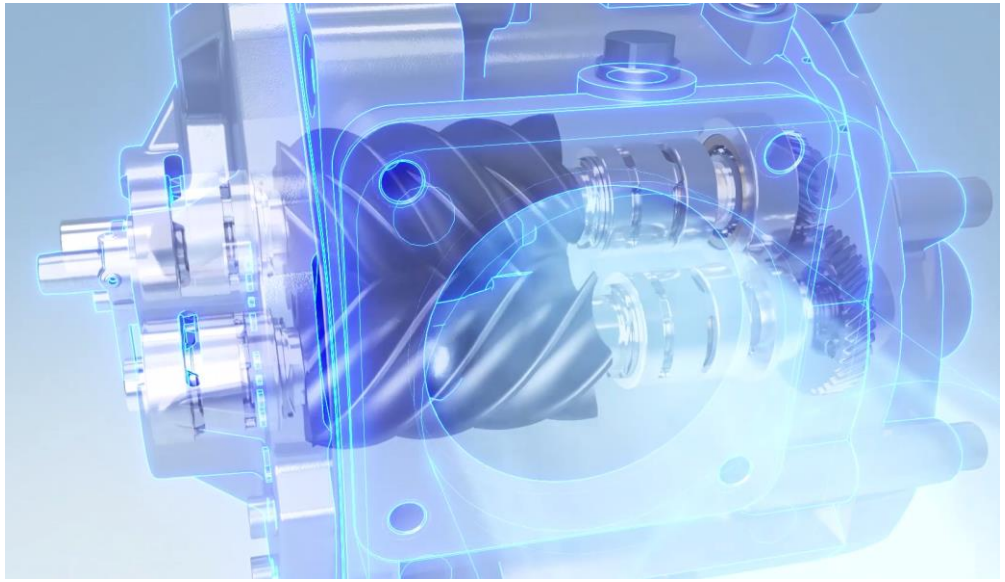
Technical data: ZR 160 VSD+-10.4

Product definition	
Model	ZR 160 VSD+
Pressure variant	10.4 bar
Integrated dryer	Pack
Frequency	50 Hz

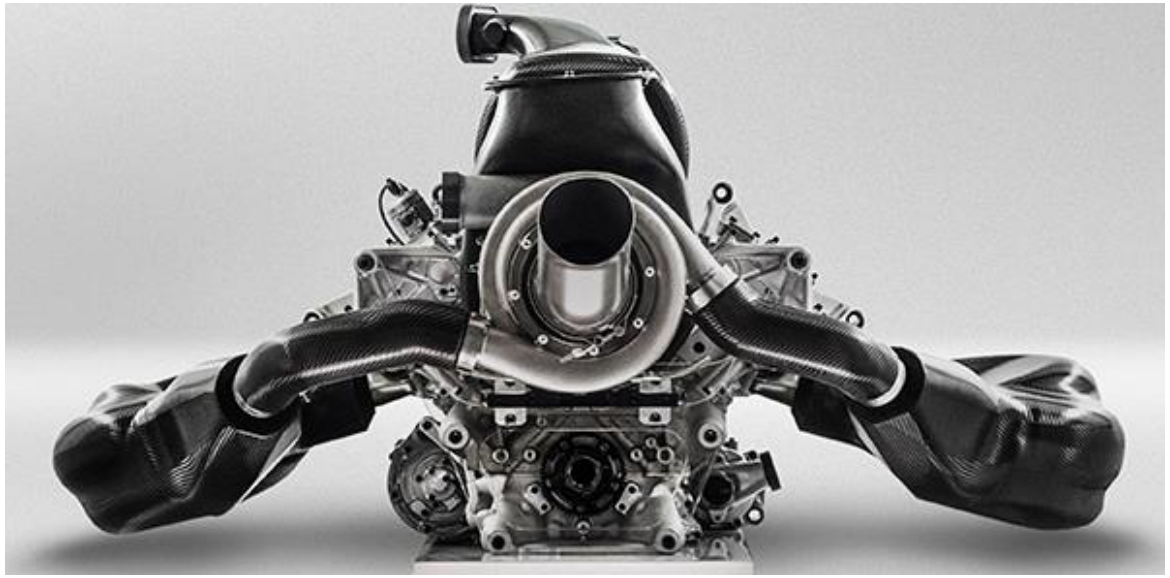
Reference conditions	
Absolute inlet pressure	1 bar(a)
Relative humidity	0 %
Air inlet temperature	20 °C
Cooling water inlet temperature	20 °C
Cooling water temperature rise	15 °C
Effective working pressure	7 bar(g)
Motor shaft speed(rpm)	6316 rpm

Performance data*1	
Maximum working pressure	10.4 bar(g)
Free air delivery (at maximum volume flow rate)	
– Total electrical power input	
– Total specific energy requirements (SER)	
Free air delivery (at 75% of volume flow range)	
– Total electrical power input	
– Total specific energy requirements (SER)	
Free air delivery (at 50% of volume flow range)	
– Total electrical power input	
– Total specific energy requirements (SER)	
Free air delivery (at 25% of volume flow range)	
– Total electrical power input	
– Total specific energy requirements (SER)	
Free air delivery (at minimum volume flow rate)	
– Total electrical power input	
– Total specific energy requirements (SER)	
Effective working pressure (1)	
Free air delivery (at maximum volume flow rate)	

As Produced



- **Revolutions:** 3.000 – 35.000 rpm
- **Tolerances:** 10 – 20 micrometer
- **Power Density:** 0.62 kilogram / kilowatt
- **Lifetime:** > 60.000 running hours



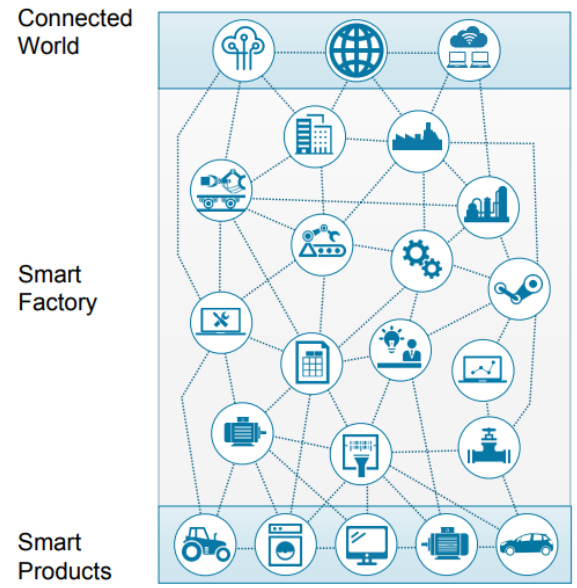
- **Revolutions:** < 18.000 rpm
- **Tolerances:** micrometers
- **Power Density:** 0.18 kilogram / kilowatt
- **Lifetime:** +/- 20 running hours

*Racecar Engineering

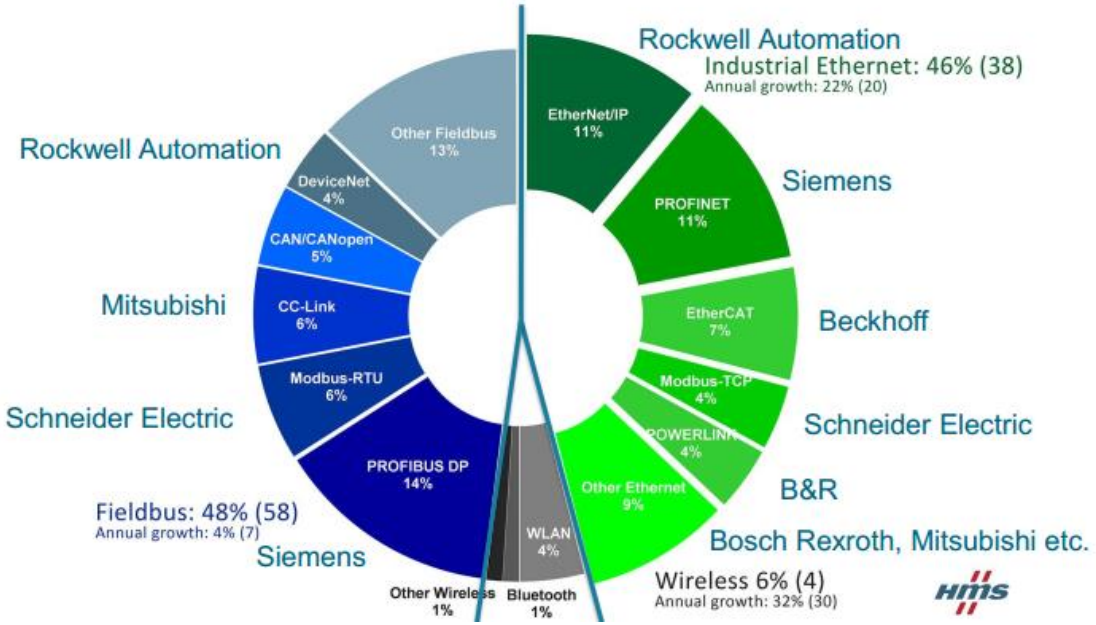
As Produced: Connectivity

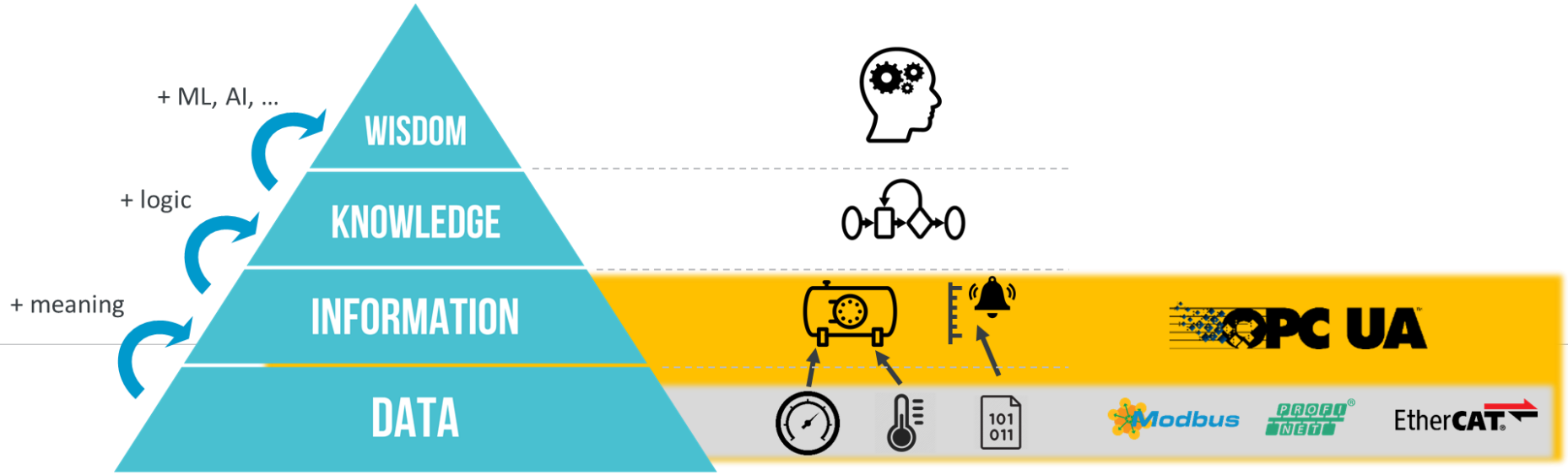
The New World: Industrie 4.0

- Flexible systems and machines
- Functions are distributed throughout the network
- Participants interact across hierarchy levels
- Communication among all participants
- Product is part of the network



M2M Communication Landscape

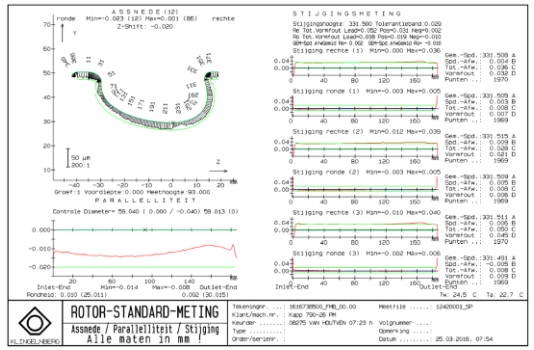




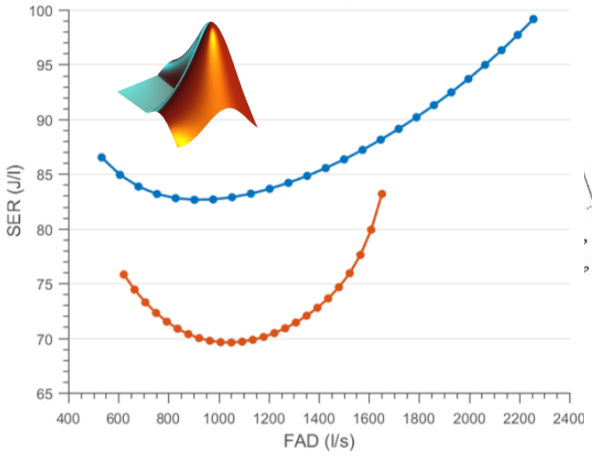
As Produced: Industry 4.0

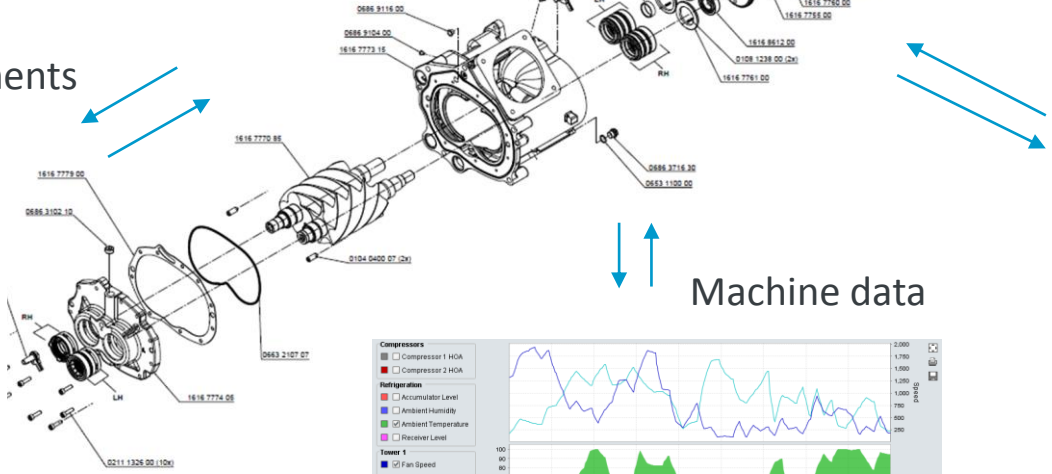
Bill of Material

Tactile measurement

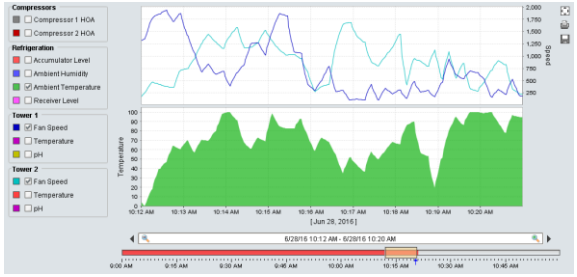


Performance Models & Measurements

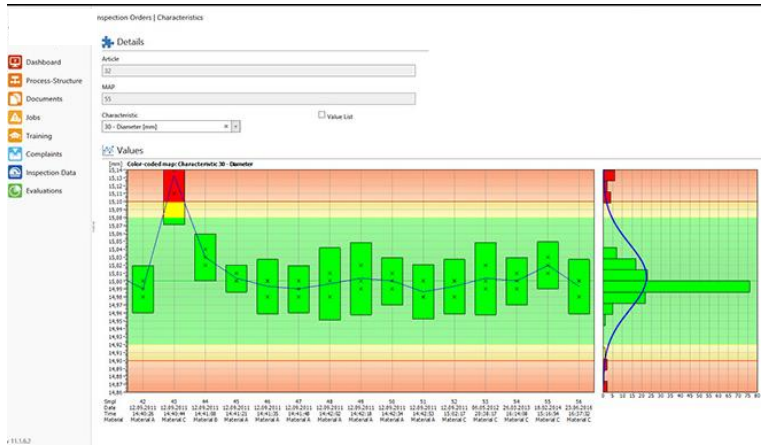




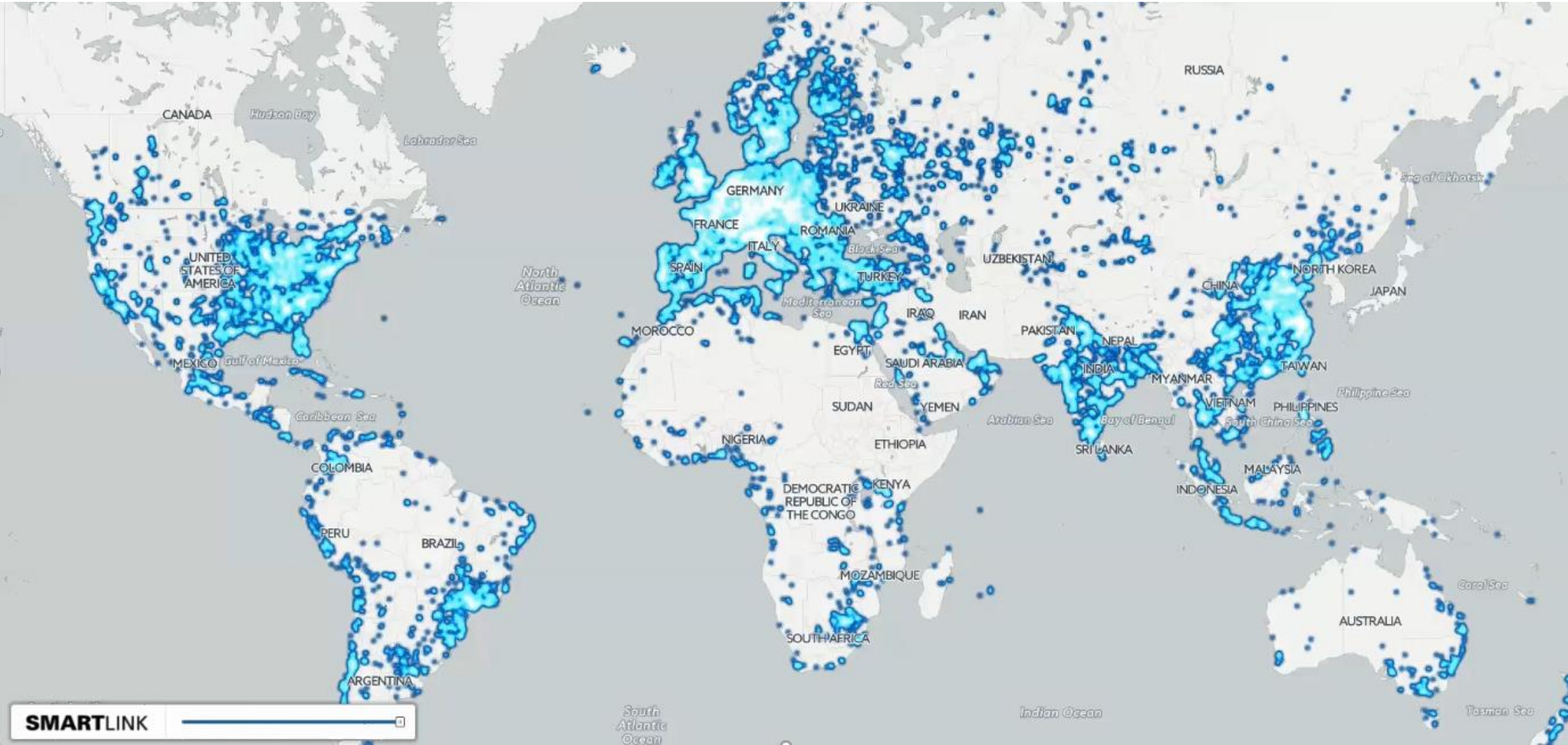
Machine data



Quality

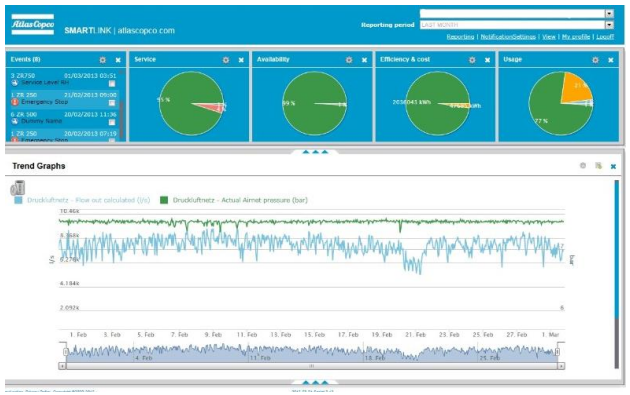


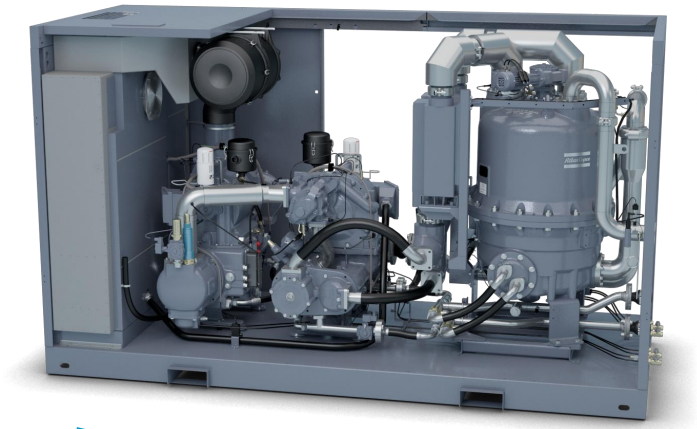
As Maintained: > 120.000 Machines Connected



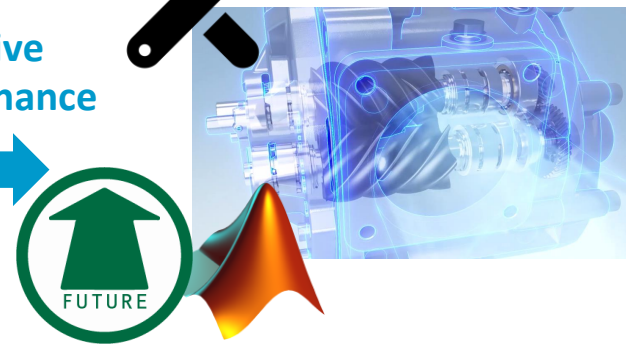
As Maintained: > 120.000 Machines Connected

Condition Monitoring

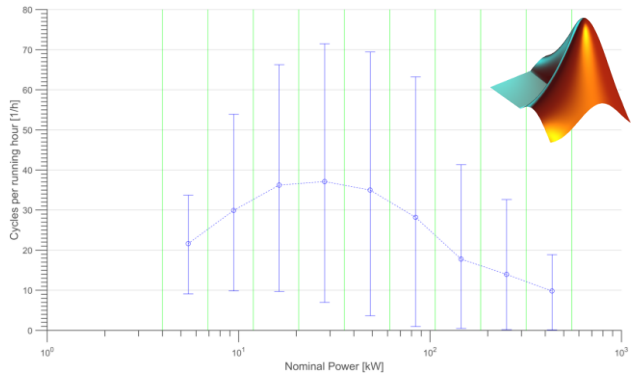




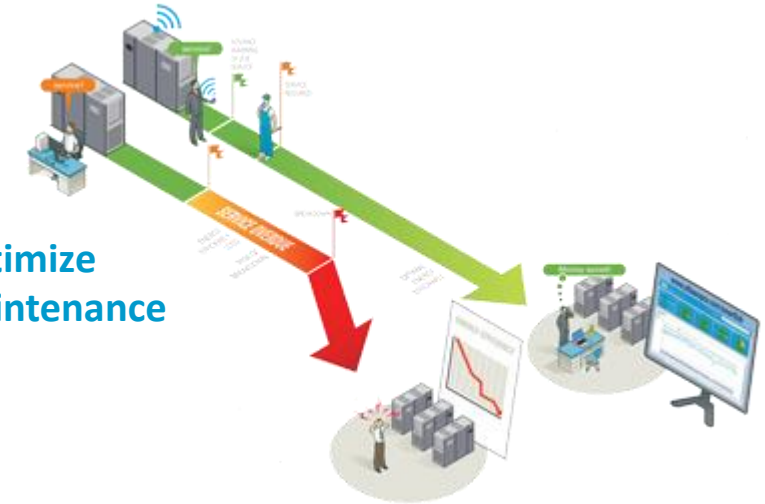
Predictive maintenance



Data analytics to improve Design

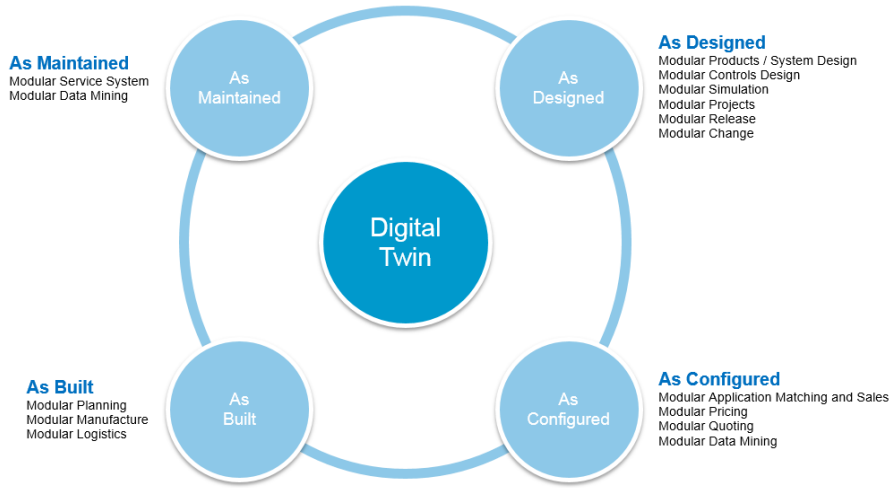


Optimize maintenance



As Achieved: Standardized Atlas Copco Model Based Engineering Platform

- Company-wide workflow preventing design errors and mistakes
- Collaboration platform for efficient communication and quick implementation of upgrades
- High quality continuously updated digital twins used throughout product lifecycle
- Standardized accurate configuration tool used by global sales
- Optimized maintenance and Data Analytics platform for 120k+ connected machines
- Re-establishing Atlas Copco as undisputed global market leader in high quality compressor technology

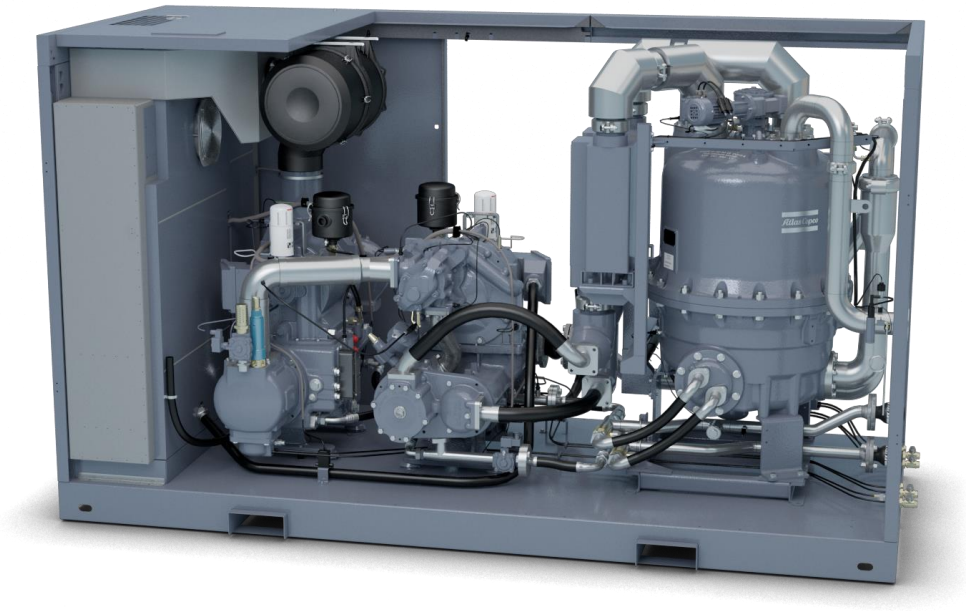


The new ZR160VSD+ shows how value can be created on the path towards the digital twin.

Challenges & Outlook

- Still a long road to take to connect all valuable data
- Labor intensive to clean and structure data
- Databases and Processing engines need to be easily scalable, strong requirement to move to cloud and make software products scalable
- Strong competition in cloud processing and data analytics, fast pace market, MathWorks needs to strengthen their presence
- Integration of Engineering models are key in a succesfull Digital Twin. It can deliver deep insights for product enhancements and new business models

Questions & Answers



Atlas Copco