





# 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

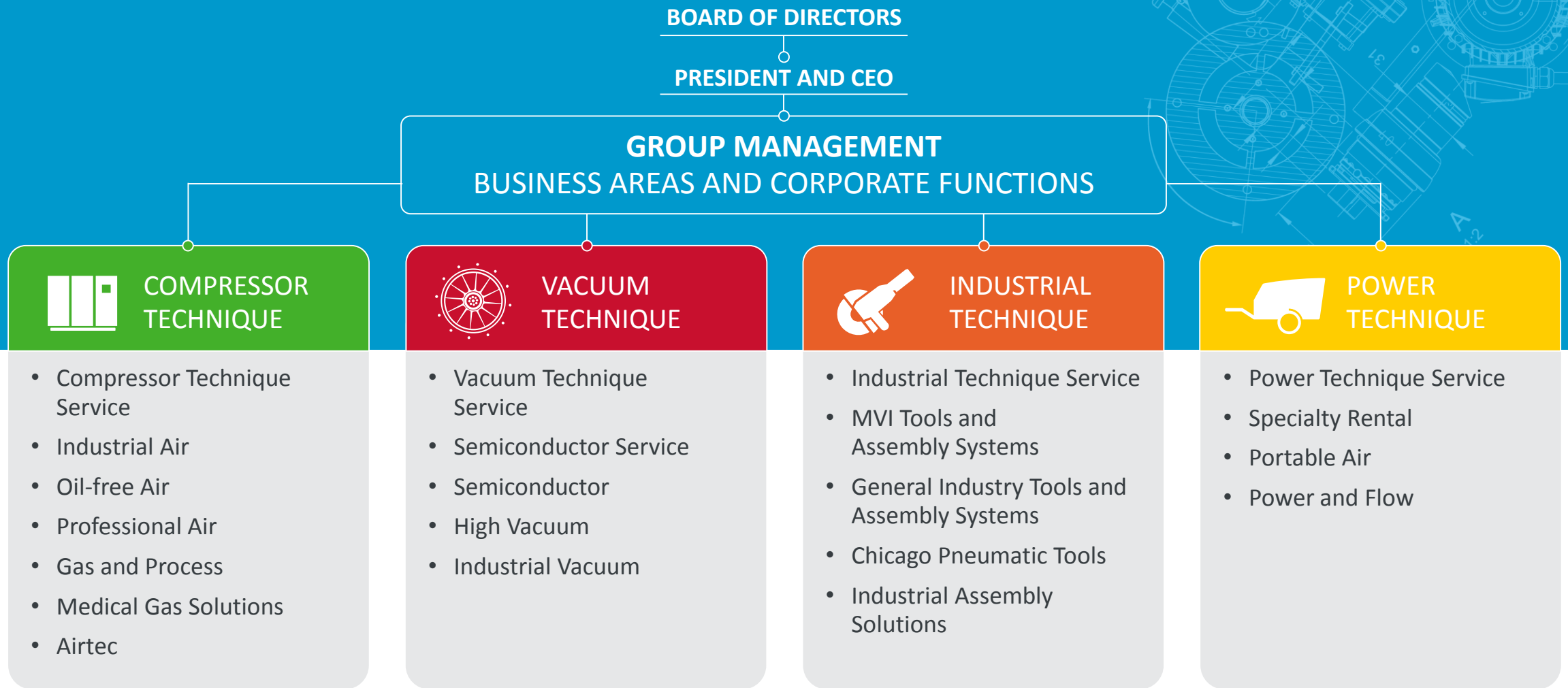


Turnover of nearly **86** BSEK / **9** BEURO



A decentralized Group with **4** business areas

# Organization





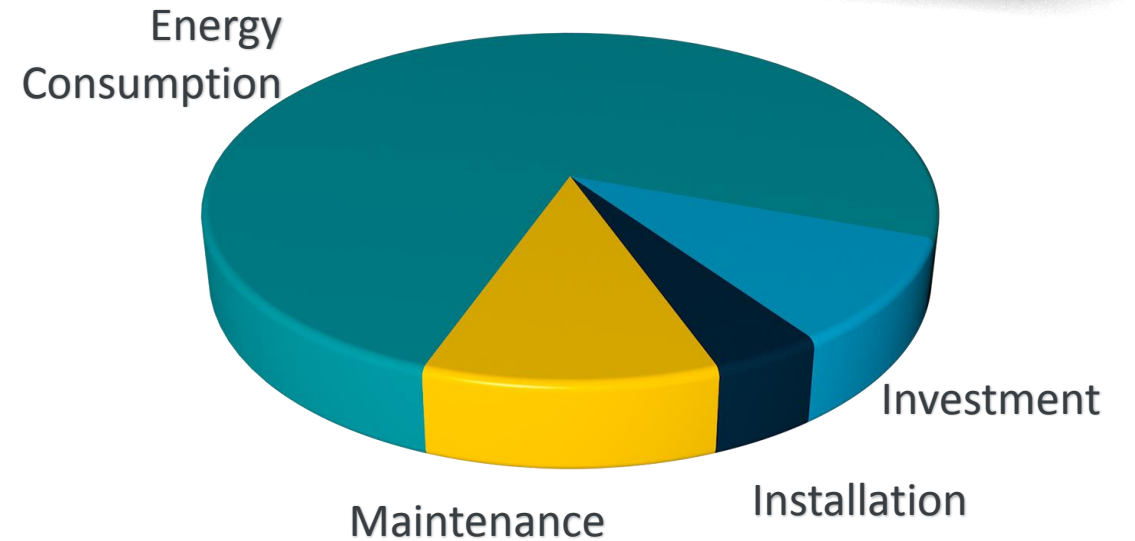
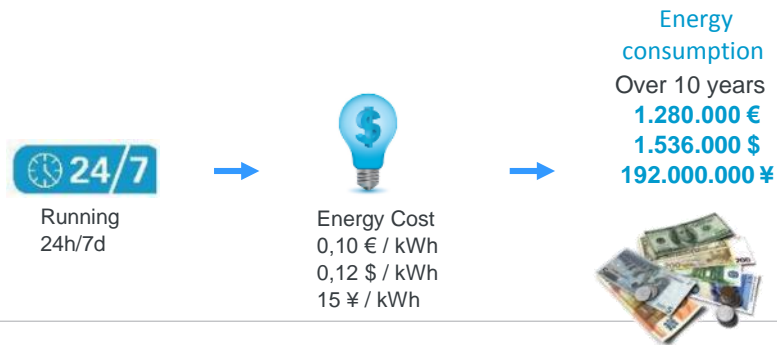
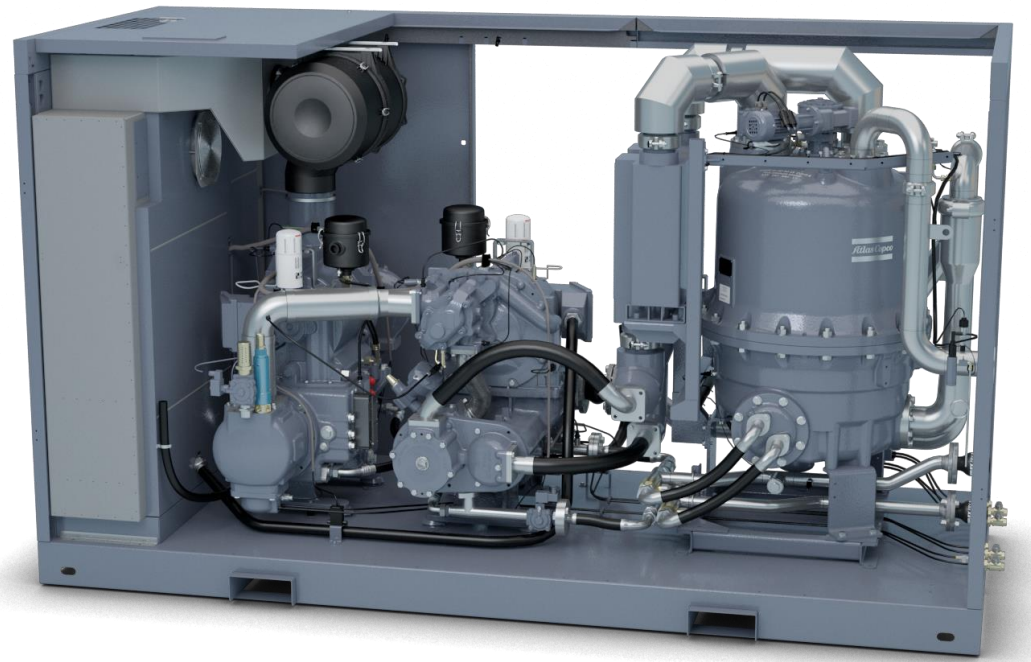
Atlas Copco

ZR 160 VSD+



# The ZR 160 VSD+

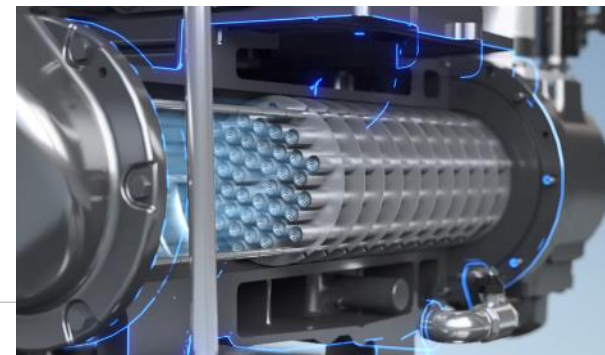
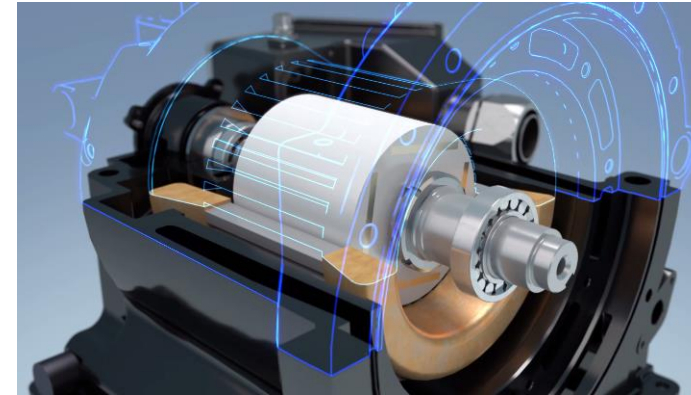
- One of the **most efficient** Oil-free screw compressor in the world in its power range
- **Hundreds of Atlas Copco employees** are involved in development, production, service and marketing
- All key components are completely **engineered by Atlas Copco** (i.e. Compressor Elements, Coolers, PM motors, 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

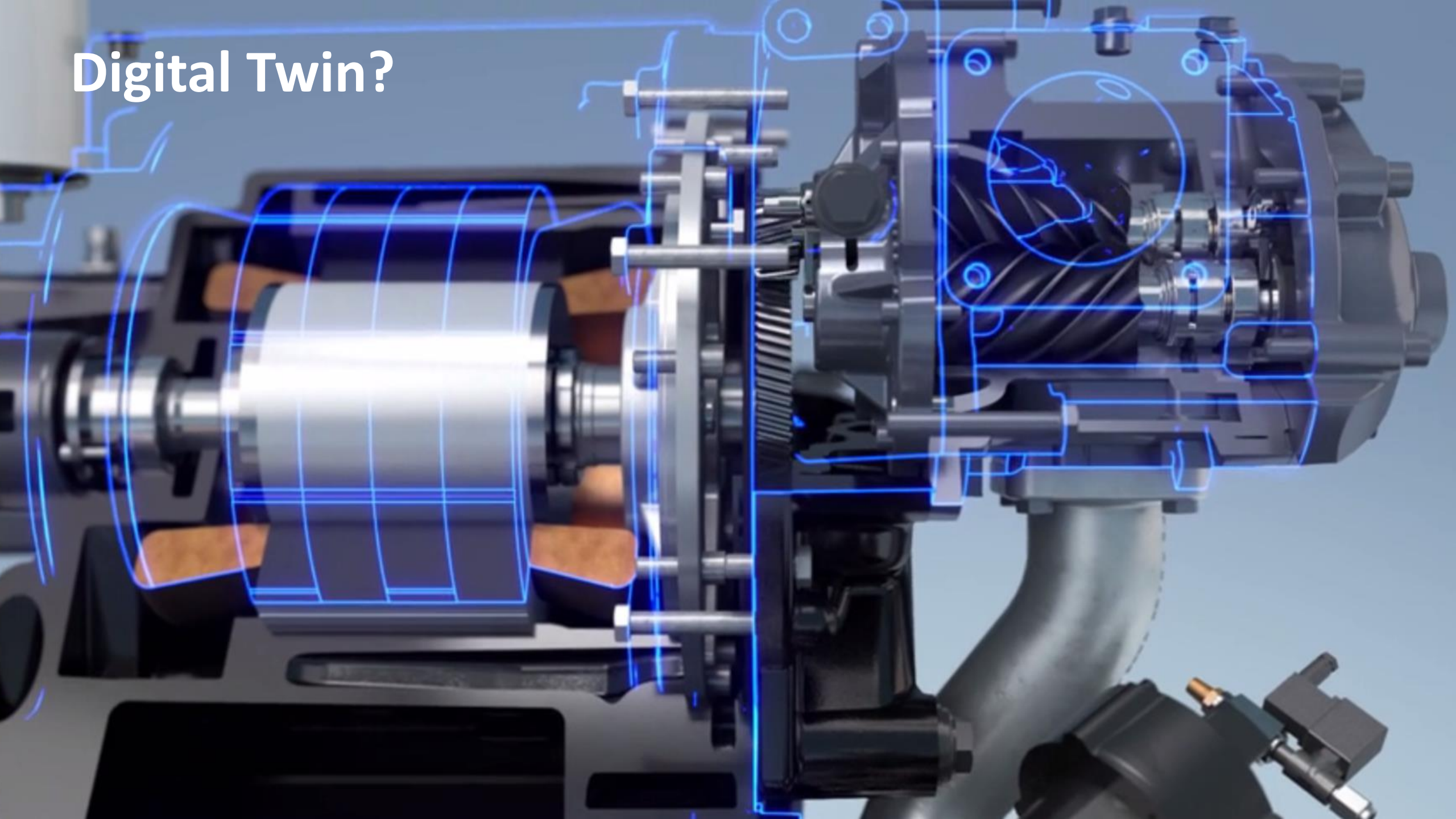


## Innovation

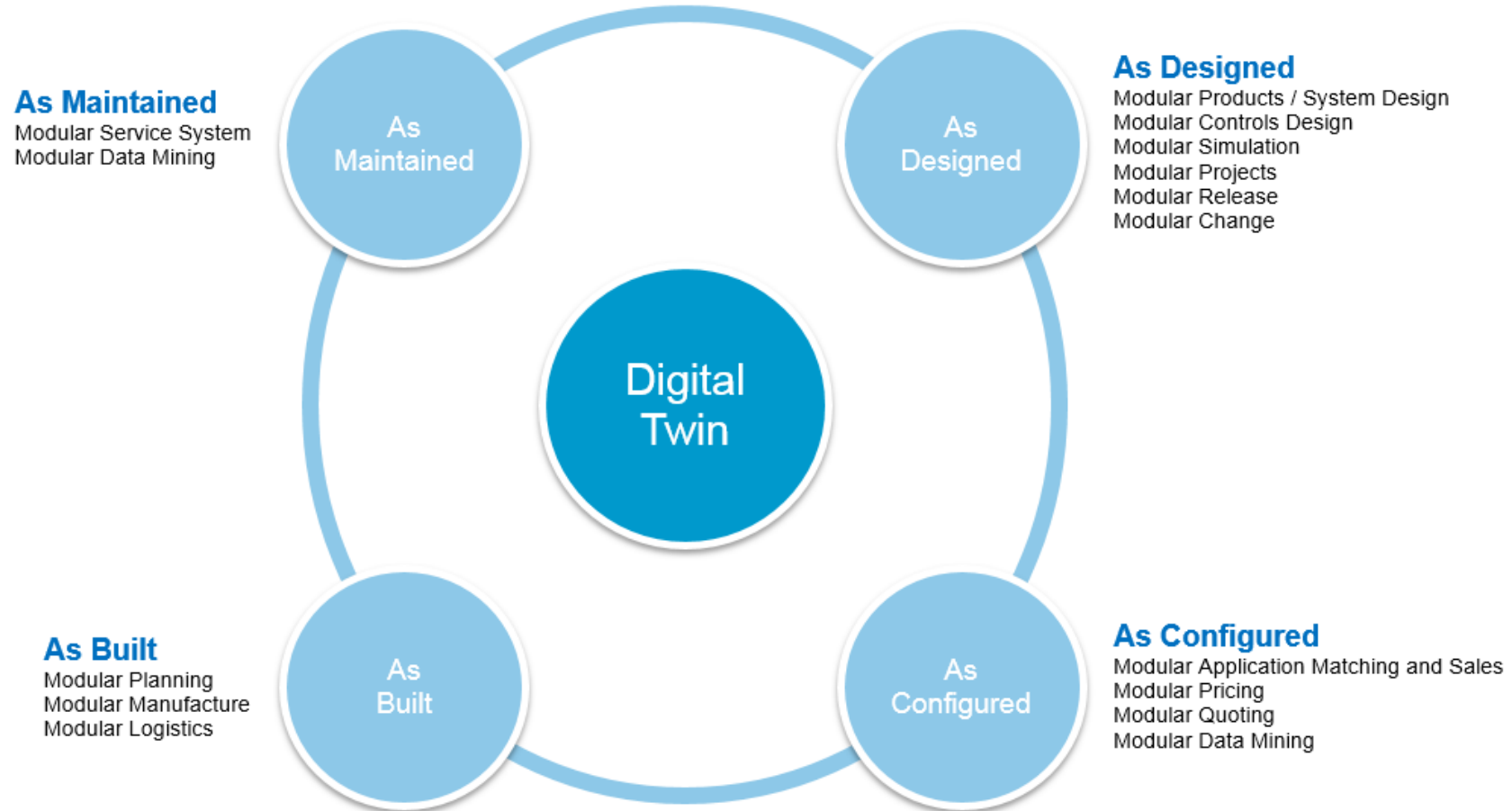


Increase customer energy efficiency by 20% by 2020

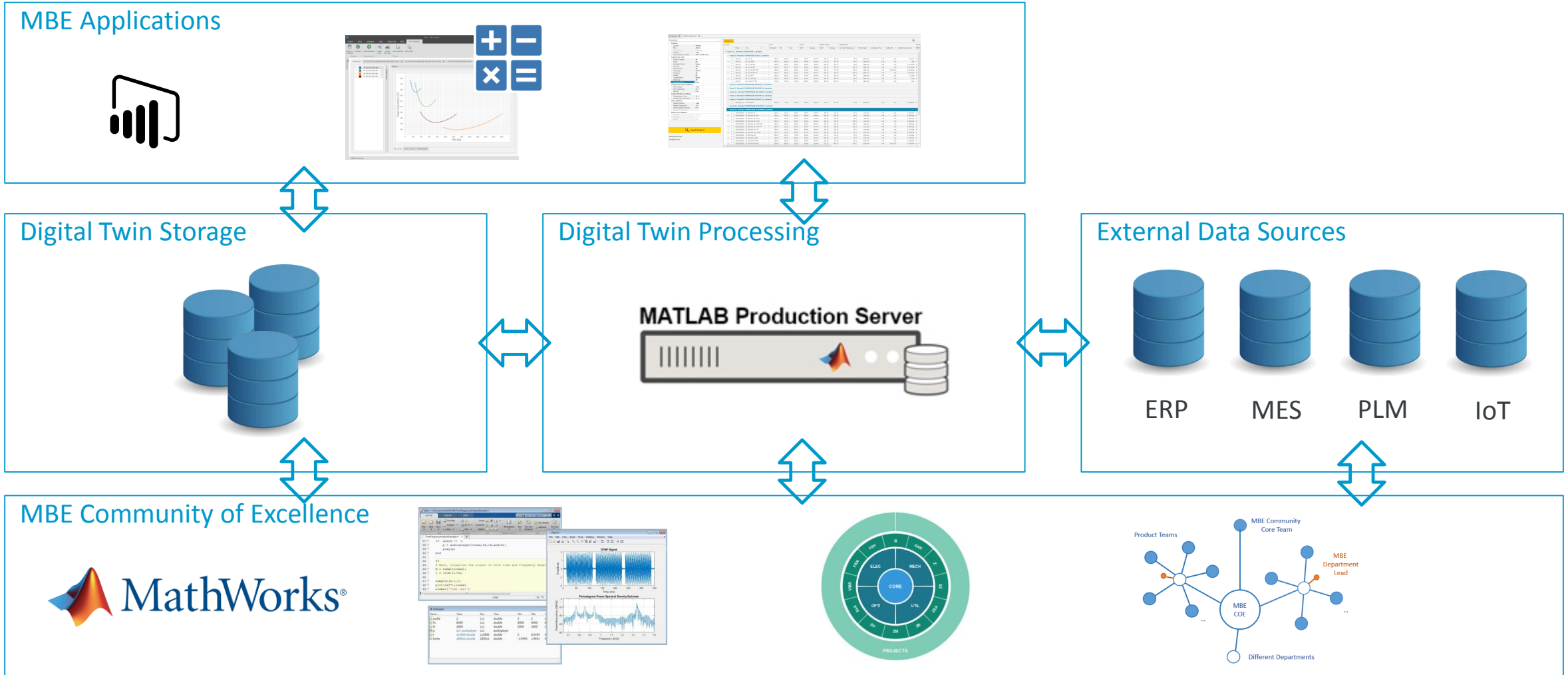
Digital Twin?



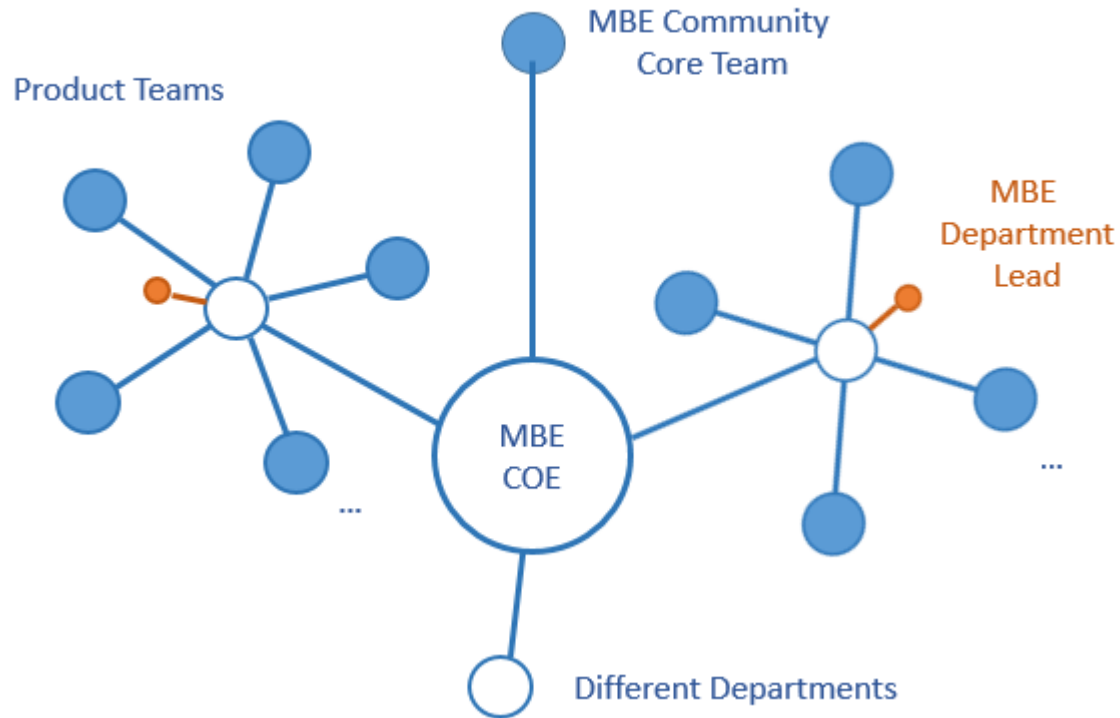
# Digital Twin in Atlas Copco and Single source of truth



# Atlas Copco Model Based Engineering Platform



# As Designed: MBE Community of Excellence

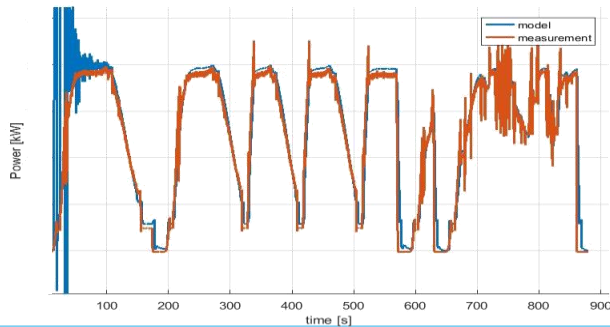


- **Open information sharing** mentality within Compressor Technique, using **MATLAB** as a platform
- Community **wants** to be integrated in **all product teams worldwide**
- **Knowledge sharing platform** for Calculations, Simulations, Data Analytics, Controller Algorithms
  - Object oriented MATLAB 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

# As Designed: MBE Framework

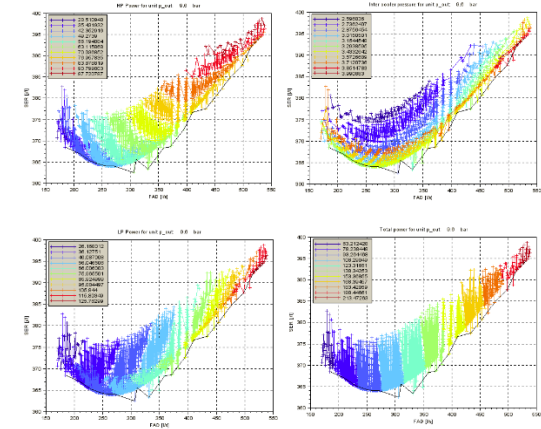
## Physical Framework

“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.”

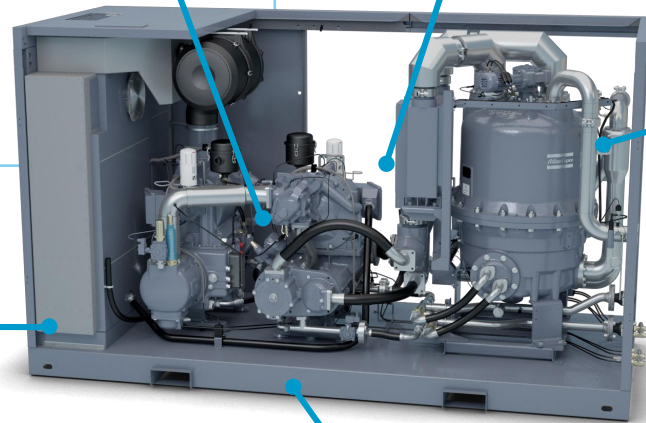


## Interface Framework

“As a marketer, I want to have easy access to the validated engineering data to create my technical data sheets.”

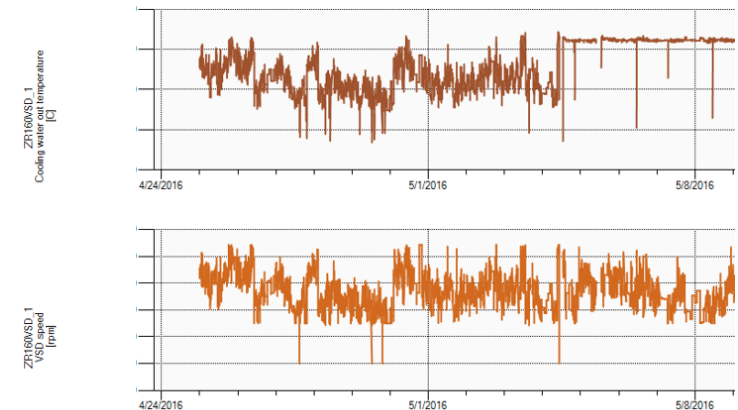
Technical data: ZR 160 VSD+10.4

| Product definition                              |             |
|---|-------------|
| Model   | ZR 160 VSD+ |
| Pressure variant                                | 10.4 bar    |
| Integrated dryer                                | Flack       |
| 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 <sup>1)</sup>                  |             |
| 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 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 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.”

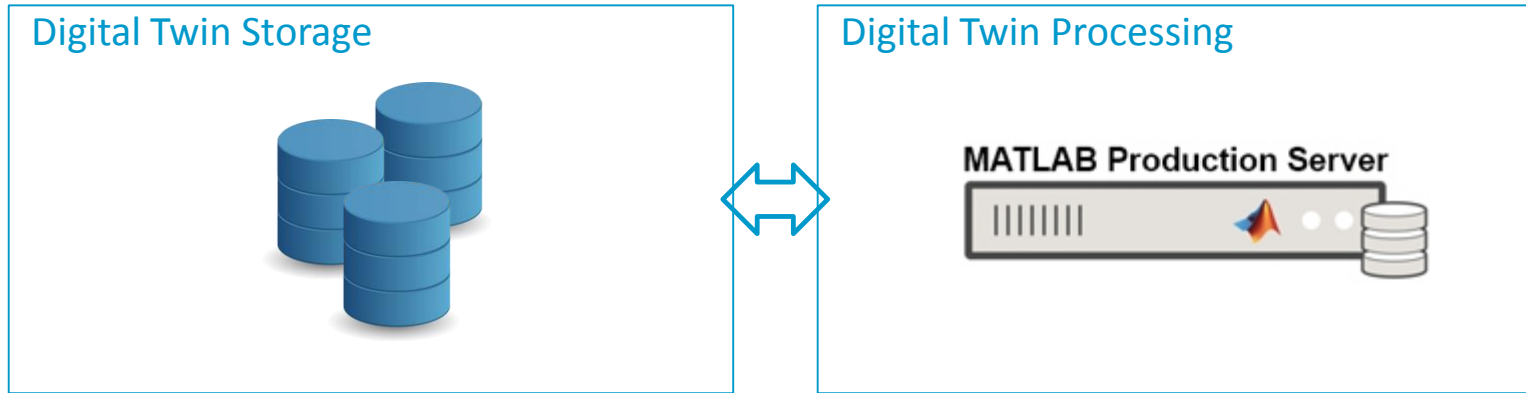


## Community Tools

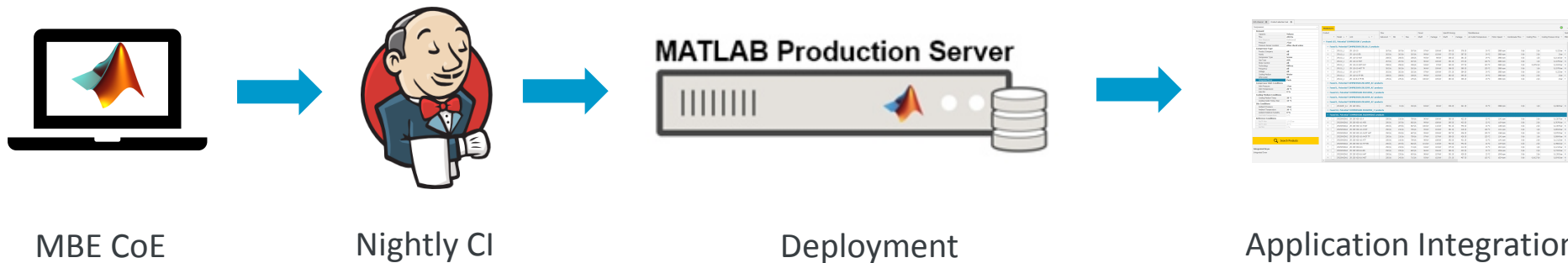
Software platform enabling community development  
Wiki, bug trackers, source control,...

# 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





**Compressors**

**Demand**

Capacity: 250  
 Flow: 250 / bar  
 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 %

As Configured

**PRODUCTS**

| Product  | Model   | Unit              | Flow      |         |         | Power |         | Specific Energy |         | Miscellaneous          |             |                 |              | Feature    |                       |
|--|---------|-------------------|-----------|---------|---------|-------|---------|-----------------|---------|------------------------|-------------|-----------------|--------------|------------|-----------------------|
|  |         |                   | Delivered | Min     | Max     | Shaft | Package | Shaft           | Package | Air Outlet Temperature | Motor Speed | Condensate Flow | Cooling Flow |            | Cooling Pressure Drop |
| <b>Potential 'COMPRESSOR 1' products</b>         |         |                   |           |         |         |       |         |                 |         |                        |             |                 |              |            |                       |
| Found 9, Potential 'COMPRESSOR ZR110_1' products |         |                   |           |         |         |       |         |                 |         |                        |             |                 |              |            |                       |
| + <input type="checkbox"/>                       | 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                     |
| + <input type="checkbox"/>                       | 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                     |
| + <input type="checkbox"/>                       | 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                     |
| + <input type="checkbox"/>                       | 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                     |
| + <input type="checkbox"/>                       | 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                     |
| + <input type="checkbox"/>                       | 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                     |
| + <input type="checkbox"/>                       | 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                     |
| + <input type="checkbox"/>                       | 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                     |
| + <input type="checkbox"/>                       | 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' products

Found 1, Potential 'COMPRESSOR ZR145VP\_A1' products

Found 1, Potential 'COMPRESSOR ZR160VP\_A1' products

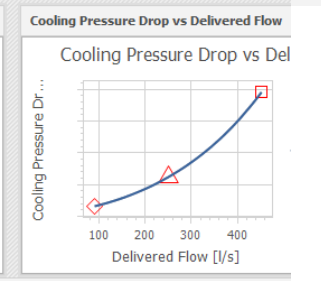
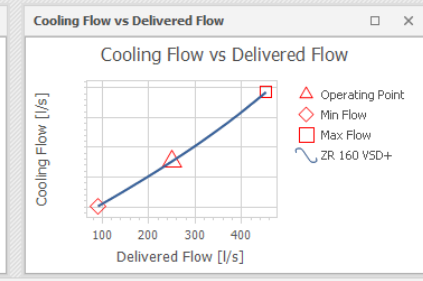
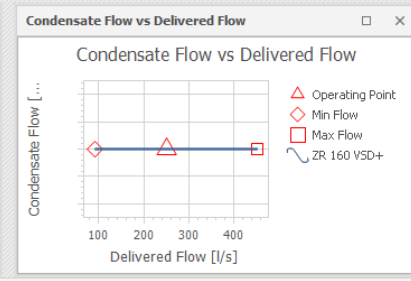
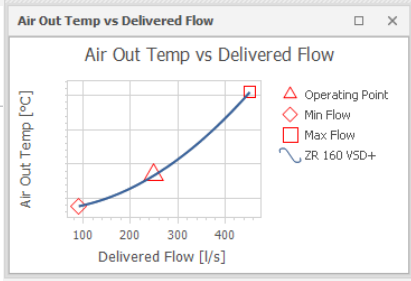
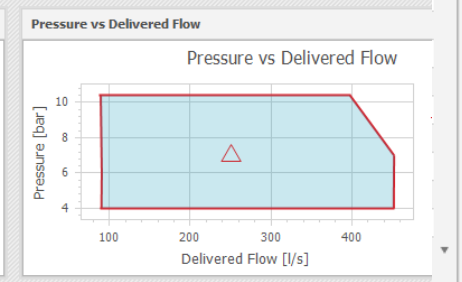
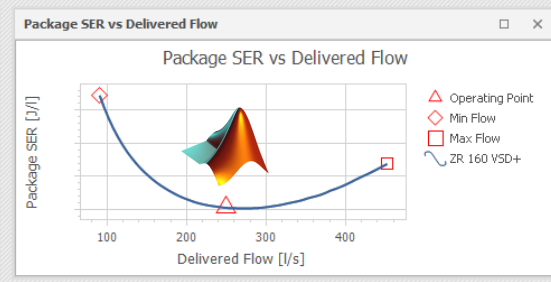
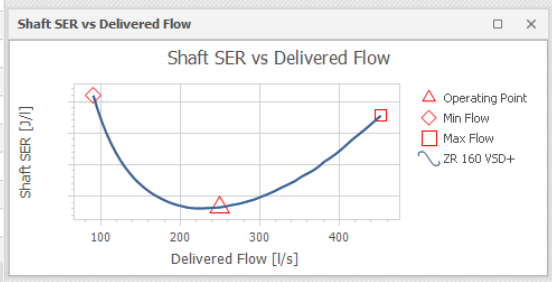
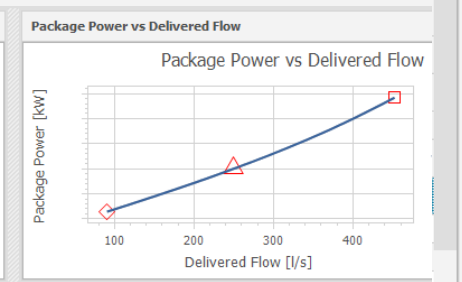
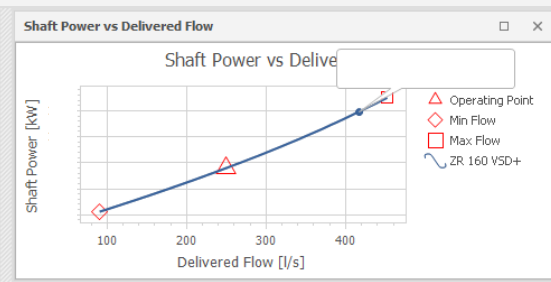
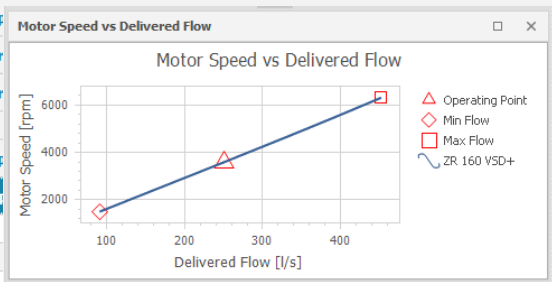
Found 44, Potential 'COMPRESSOR ZR160VSD\_1' products

Found 18, Potential 'COMPRESSOR ZR250VSDA2' products

|                            |            |                         |  |  |  |  |  |  |  |  |  |  |  |  |  |
|----------------------------|------------|-------------------------|--|--|--|--|--|--|--|--|--|--|--|--|--|
| + <input type="checkbox"/> | ZR250VSDA2 | ZR 250 VSD-10.4         |  |  |  |  |  |  |  |  |  |  |  |  |  |
| + <input type="checkbox"/> | ZR250VSDA2 | ZR 250 VSD-10.4 ER      |  |  |  |  |  |  |  |  |  |  |  |  |  |
| + <input type="checkbox"/> | ZR250VSDA2 | ZR 250 VSD-10.4 HAT     |  |  |  |  |  |  |  |  |  |  |  |  |  |
| + <input type="checkbox"/> | ZR250VSDA2 | ZR 250 VSD-10.4 HOT     |  |  |  |  |  |  |  |  |  |  |  |  |  |
| + <input type="checkbox"/> | ZR250VSDA2 | ZR 250 VSD-10.4 HOT HAT |  |  |  |  |  |  |  |  |  |  |  |  |  |
| + <input type="checkbox"/> | ZR250VSDA2 | ZR 250 VSD-10.4 HOT TF  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| + <input type="checkbox"/> | ZR250VSDA2 | ZR 250 VSD-10.4 TF      |  |  |  |  |  |  |  |  |  |  |  |  |  |
| + <input type="checkbox"/> | ZR250VSDA2 | ZR 250 VSD-10.4 TF ER   |  |  |  |  |  |  |  |  |  |  |  |  |  |
| + <input type="checkbox"/> | ZR250VSDA2 | ZR 250 VSD-8.6          |  |  |  |  |  |  |  |  |  |  |  |  |  |
| + <input type="checkbox"/> | ZR250VSDA2 | ZR 250 VSD-8.6 ER       |  |  |  |  |  |  |  |  |  |  |  |  |  |
| + <input type="checkbox"/> | ZR250VSDA2 | ZR 250 VSD-8.6 HAT      |  |  |  |  |  |  |  |  |  |  |  |  |  |
| + <input type="checkbox"/> | ZR250VSDA2 | ZR 250 VSD-8.6 HOT      |  |  |  |  |  |  |  |  |  |  |  |  |  |

Search Products

Integrated Dryer  
 Integrated Dryer



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

|  |             |
|--|-------------|
| Model  | ZR 160 VSD+ |
| Integrated dryer<br><small>PDP sensor is delivered as standard</small> | 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](#)


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Request article numbers

[Product Description](#)

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< 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

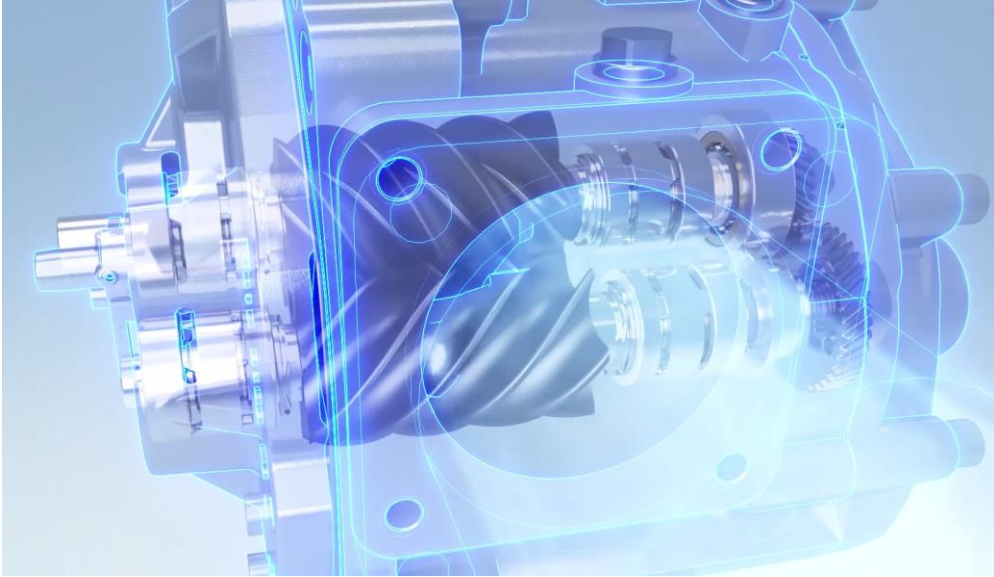
**Technical data: ZR 160 VSD+-10.4**

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

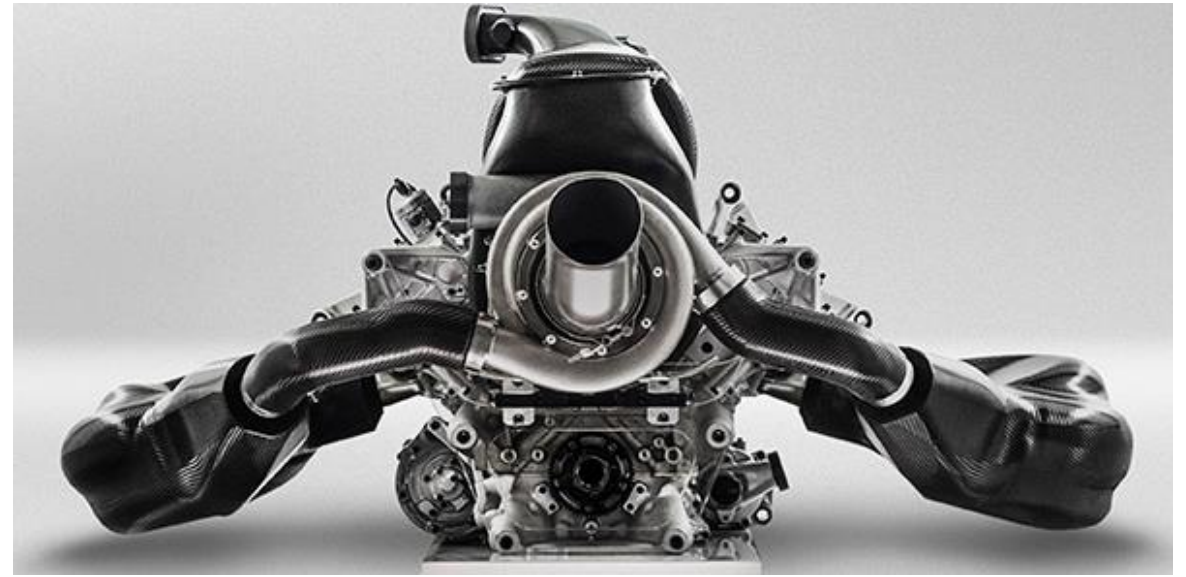
| Reference conditions            |          |
|---------------------------------|----------|
| Absolute inlet pressure         | 1 bar(a) |
| Relative humidity               | 0 %      |
| Air inlet temperature           | 20 °C    |
| Cooling water inlet temperature | 20 °C    |
| Cooling water temperature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

| Performance data*1                               |              |
|--|--------------|
| <b>Maximum working pressure</b>                  | 10.4 bar(g)  |
| Free air delivery (at maximum volume flow rate ) | 1000 l/min   |
| - Total electrical power input                   | 175.0 kW     |
| - Total specific energy requirements (SER)       | 0.175 kWh/m³ |
| Free air delivery (at 75% of volume flow range)  | 750 l/min    |
| - Total electrical power input                   | 130.0 kW     |
| - Total specific energy requirements (SER)       | 0.173 kWh/m³ |
| Free air delivery (at 50% of volume flow range)  | 500 l/min    |
| - Total electrical power input                   | 100.0 kW     |
| - Total specific energy requirements (SER)       | 0.170 kWh/m³ |
| Free air delivery (at 25% of volume flow range)  | 250 l/min    |
| - Total electrical power input                   | 70.0 kW      |
| - Total specific energy requirements (SER)       | 0.168 kWh/m³ |
| Free air delivery (at minimum volume flow rate ) | 100 l/min    |
| - Total electrical power input                   | 40.0 kW      |
| - Total specific energy requirements (SER)       | 0.165 kWh/m³ |
| <b>Effective working pressure (1)</b>            | 10.4 bar(g)  |
| Free air delivery (at maximum volume flow rate ) | 1000 l/min   |

## As Produced



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



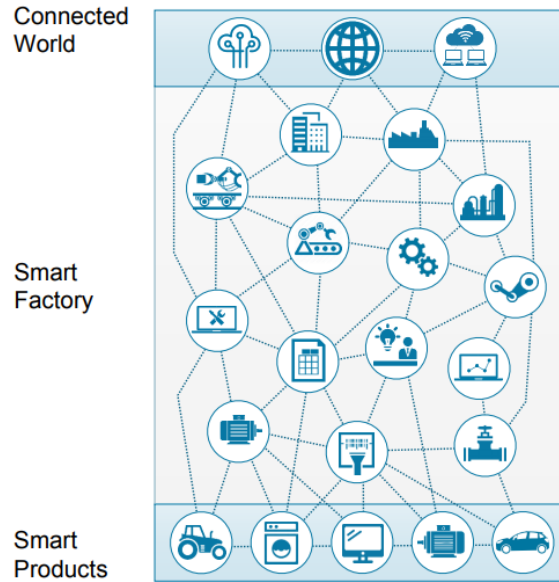
- **Revolutions:** < 18.000 rpm
- **Tolerances:** micrometers
- **Power Density:** 0.18 kilogram / kilowatt
- **Lifetime:** +/- 20 running hours

\*Racecar Engineering

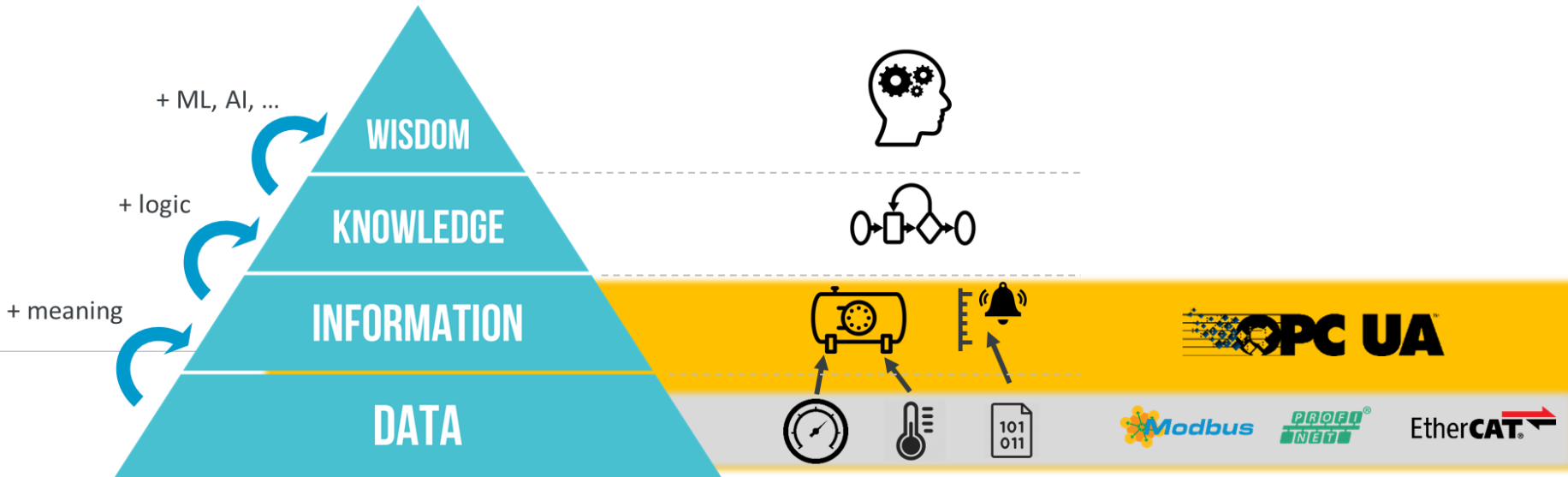
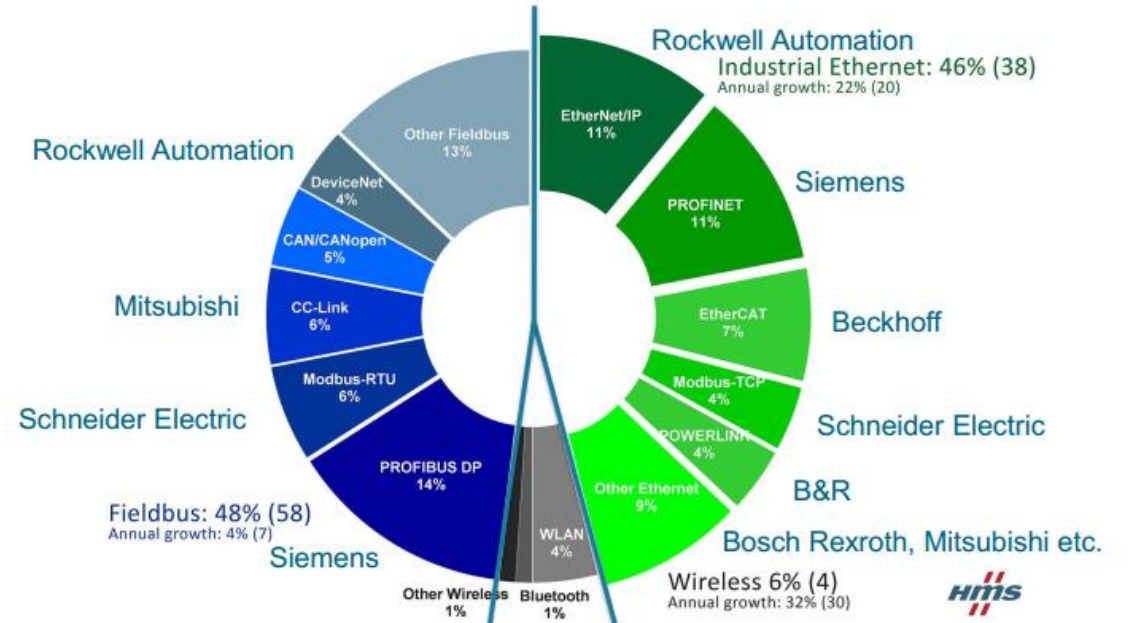
# As Produced: Connectivity

## 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

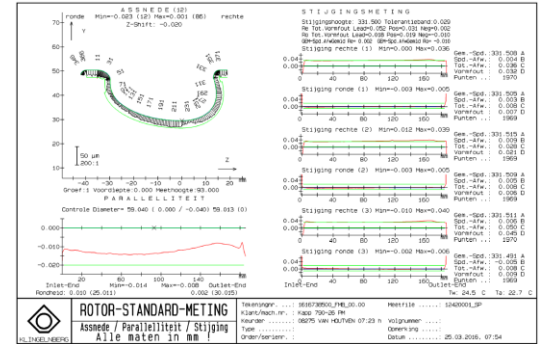


# As Produced: Industry 4.0

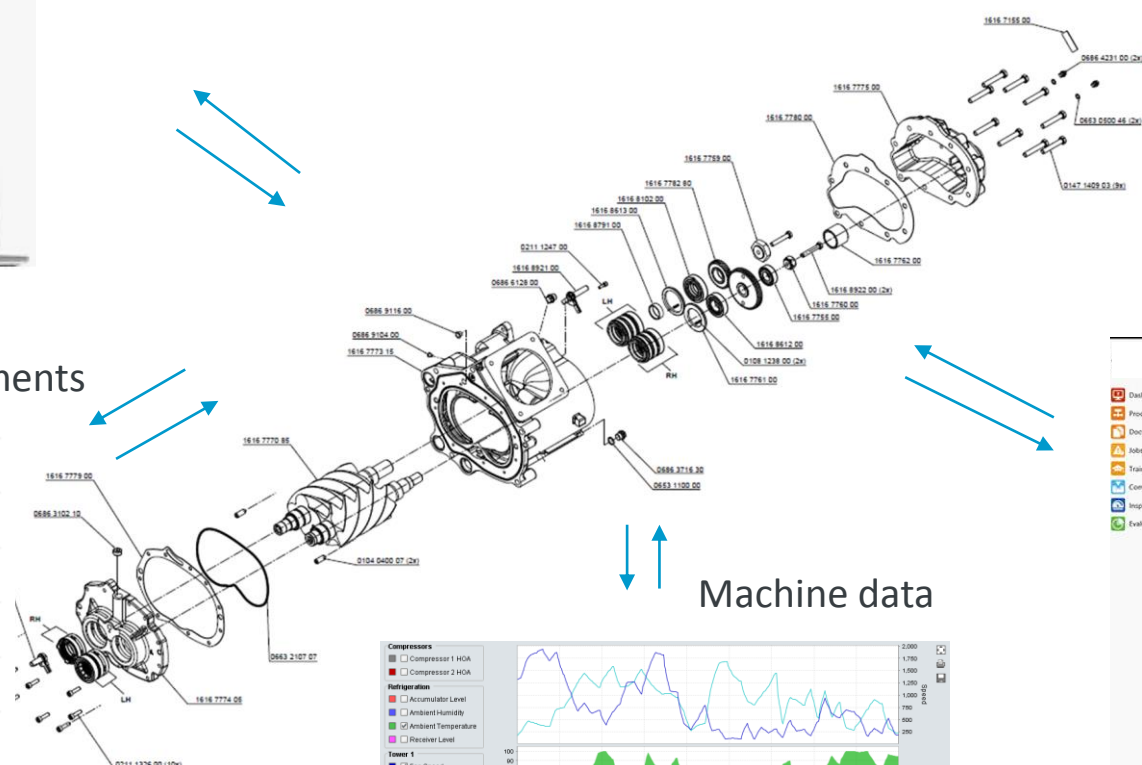
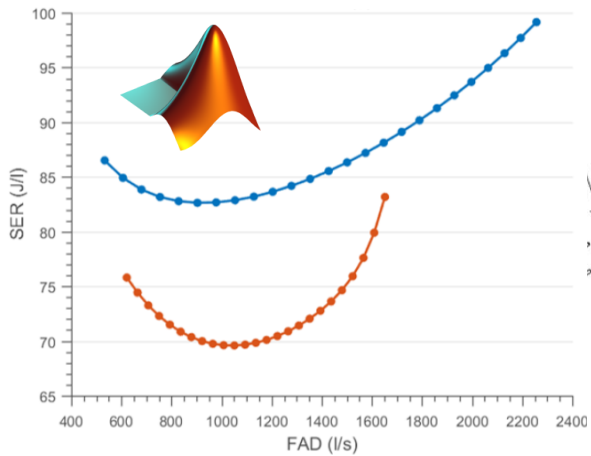
## Bill of Material



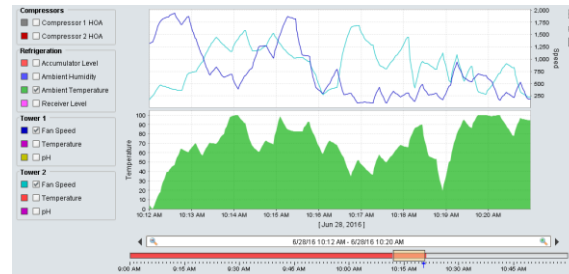
## Tactile measurement



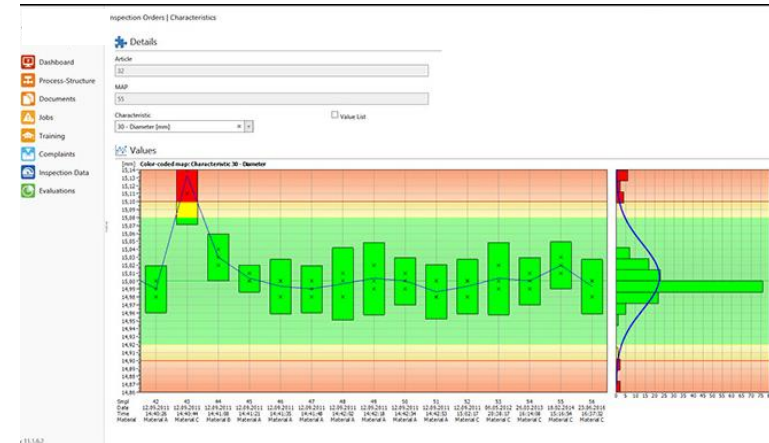
## Performance Models & Measurements



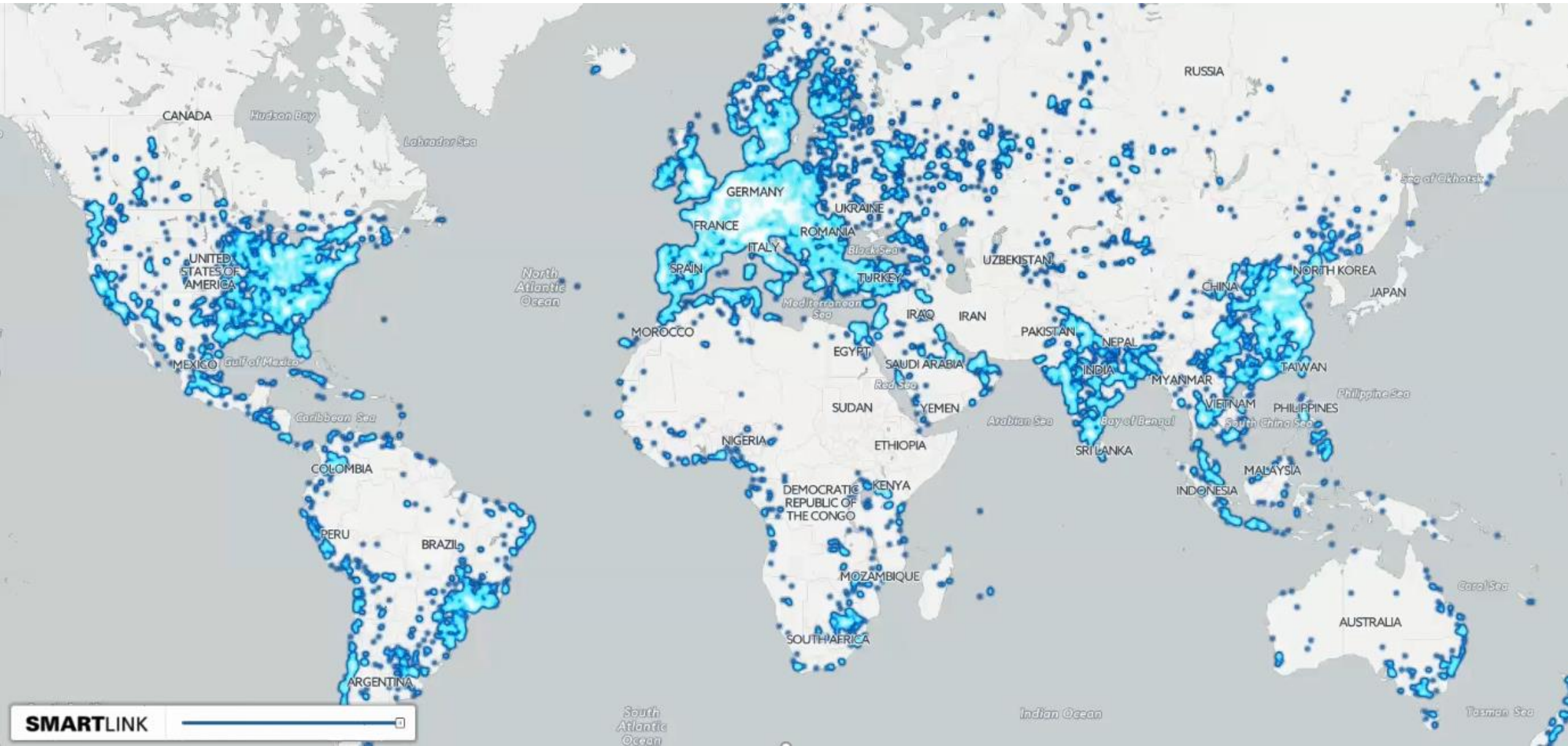
## Machine data



## Quality

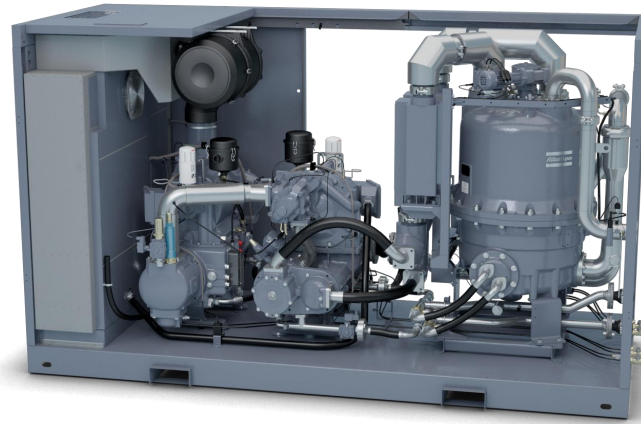


As Maintained: > 120.000 Machines Connected

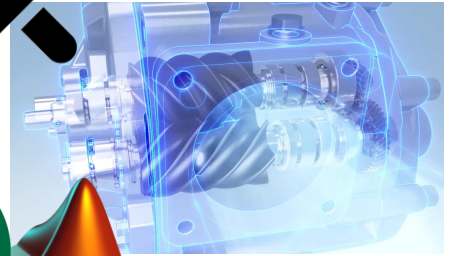


# As Maintained: > 120.000 Machines Connected

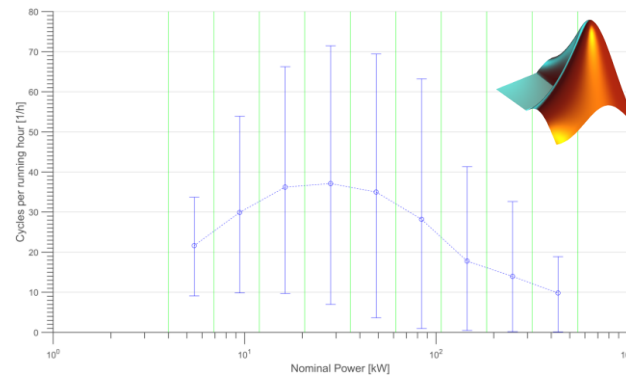
## Condition Monitoring



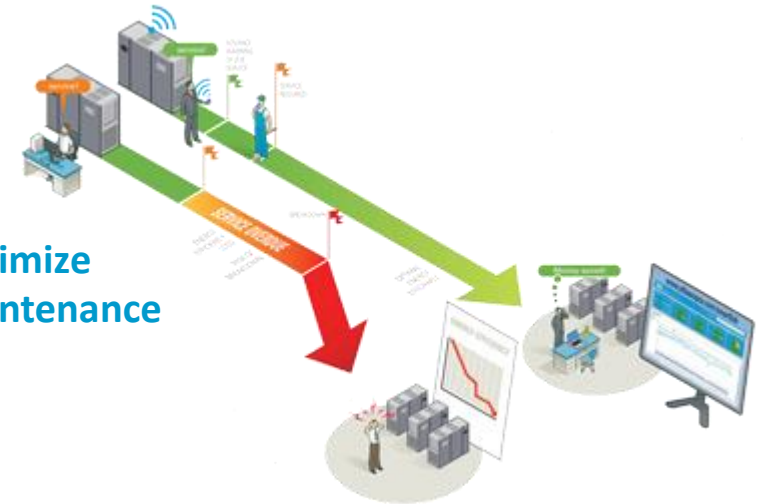
Predictive maintenance



Data analytics to improve Design

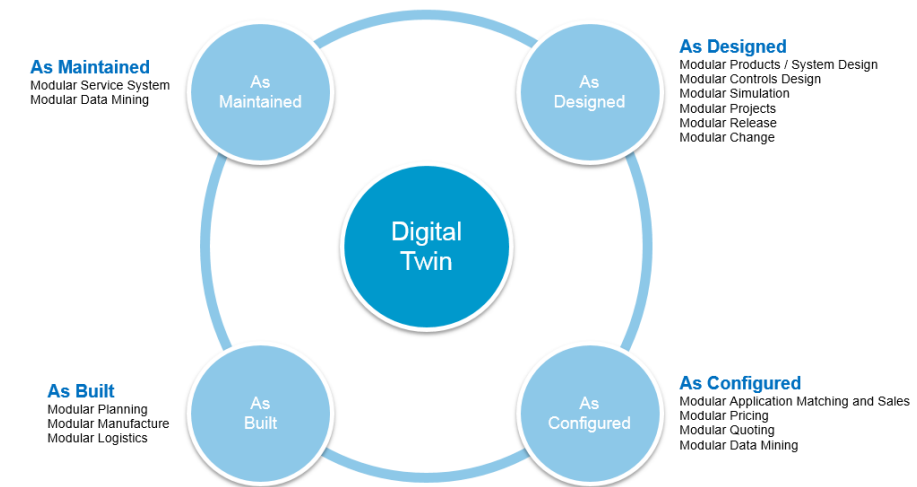


Optimize maintenance



# 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.

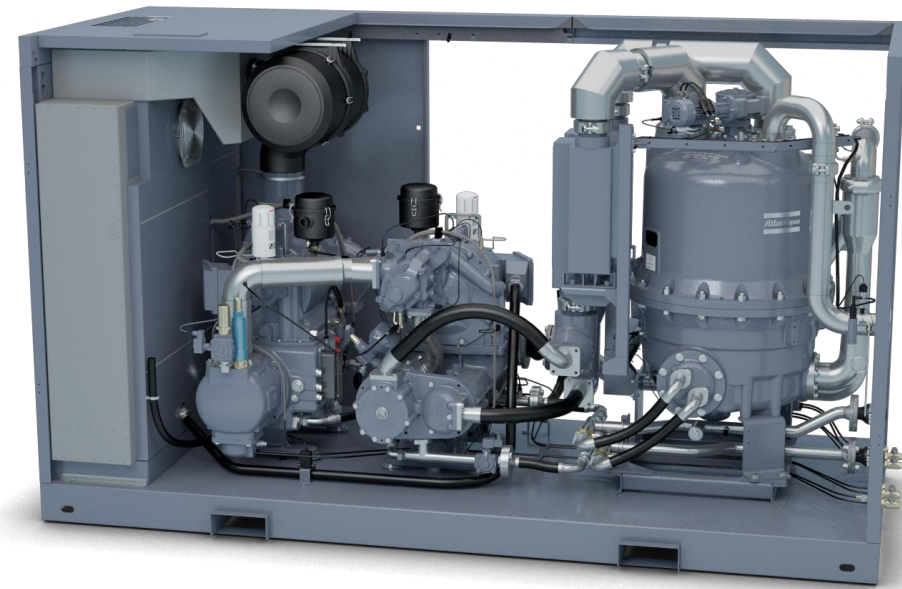


# Challenges & Outlook



- 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 successful Digital Twin. It can deliver deep insights for product enhancements and new business models

# Questions & Answers



*Atlas Copco*

