

# Motion Control: Solving Challenging Problems with new Technologies

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Atef Massoud, Greg Dieck and Richard Naddaf  
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# What we will cover today

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History & evolution of motion



Common challenges in applications



Technology solutions



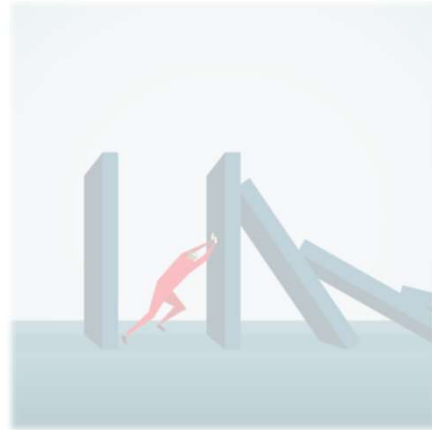
Future trends in motion

# What we will cover today

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History & evolution  
of motion



Common challenges  
in applications



Technology  
solutions



Future trends  
in motion

# Servo drives and motors

## Drives:

- Analog tuning -> Digital tuning
- Output for fault -> Full diagnostics

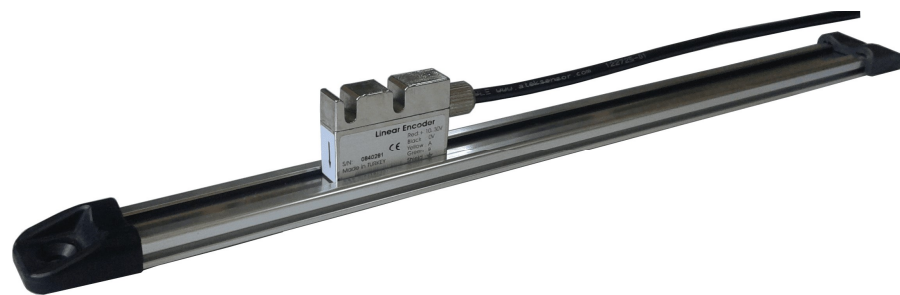
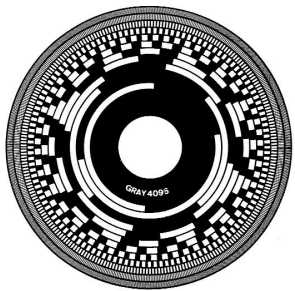
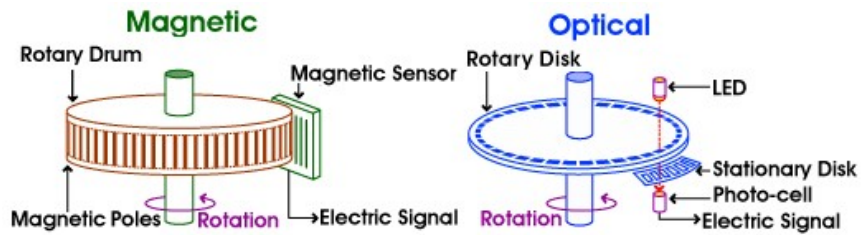
## Motors

- DC Brushed -> AC Synchronous

## More types of motors to choose from:

- Stepper
- Linear
- Direct Drive
- Hygienic





# Feedback devices

Started with:

- Low resolution
- Fragile

Moving towards:

- High resolution ( $\mu\text{m}$  accuracy)
- Durable
- Serial communication (not just position)
- Network communication

# Specialized tools

## Laser

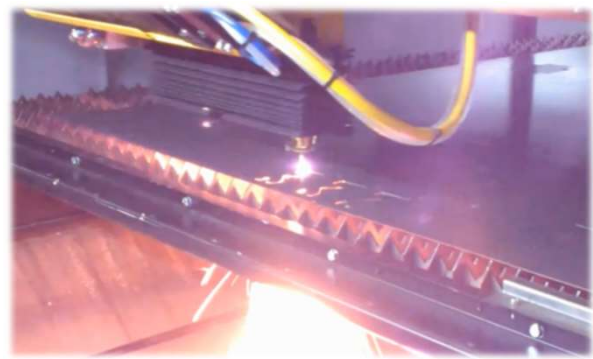
- Not just cutting anymore

## Mechanical systems

- High accuracy stages
- Hexapod

## Robots

- Custom design
- Combine mechanical systems (7<sup>th</sup> axis)
- Integration with conveyors, vision...



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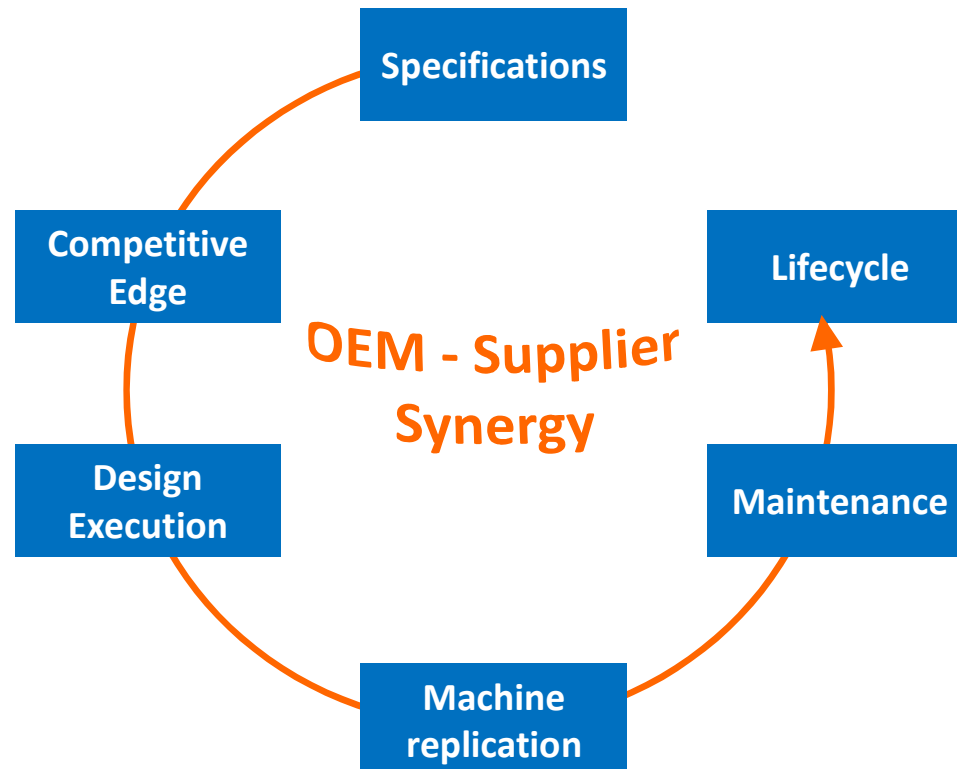


Technology solutions



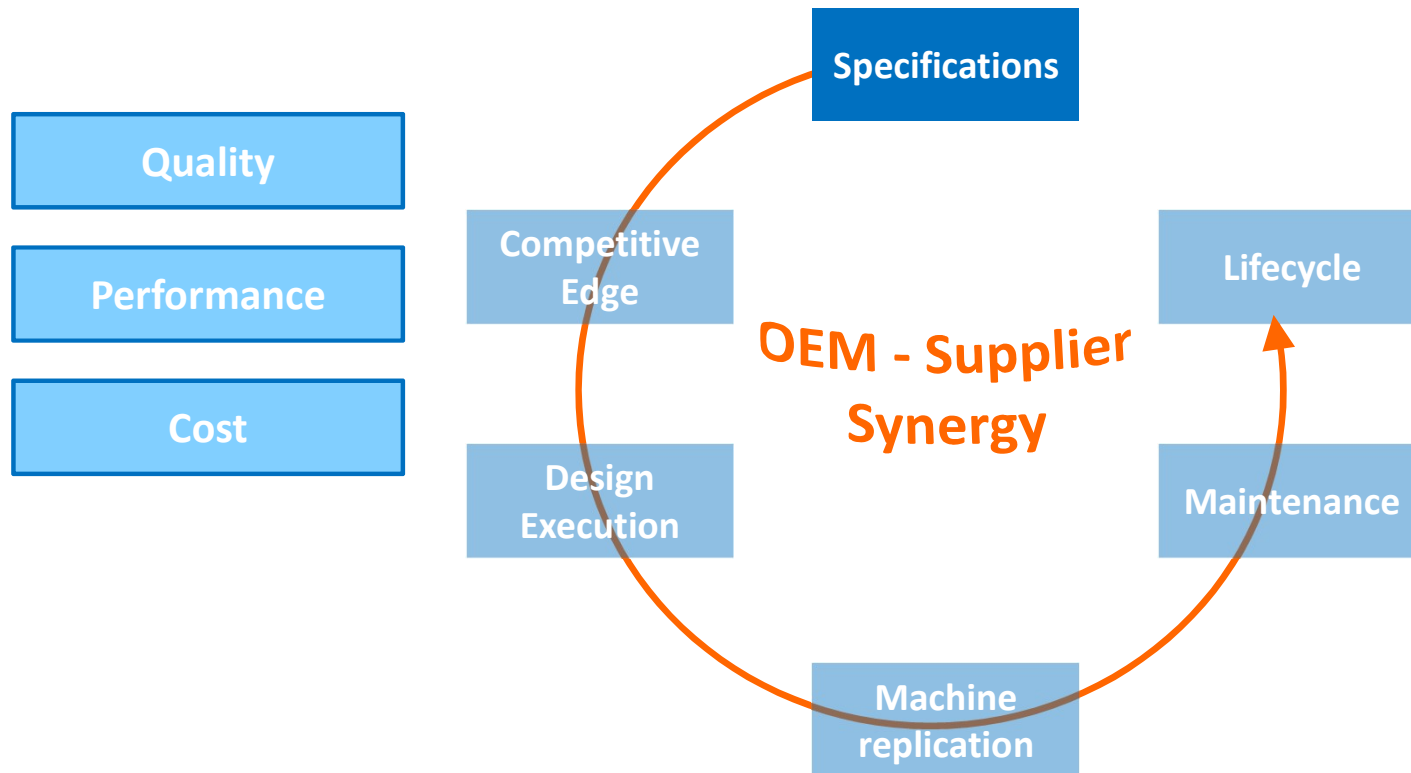
Future trends in motion

# Machine Builder Challenges & Expectations

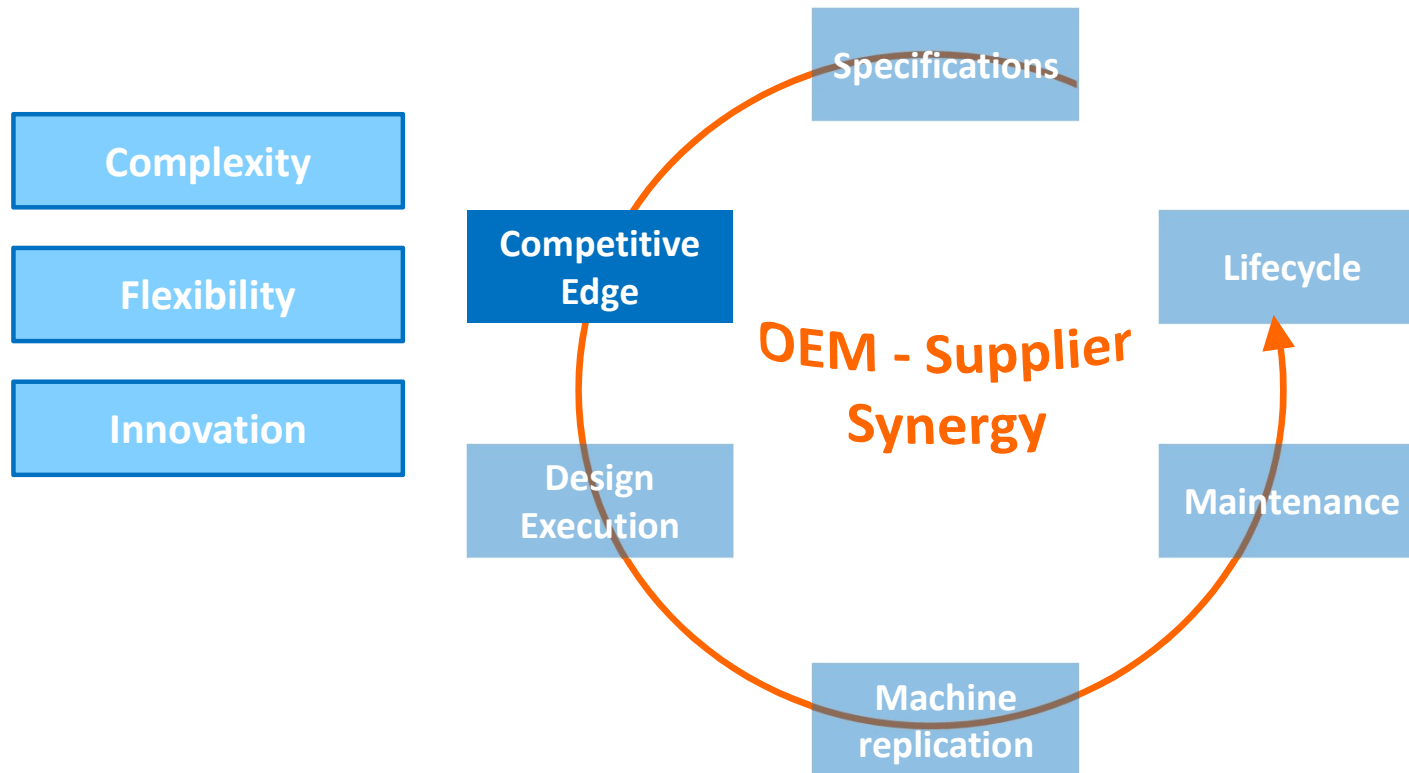




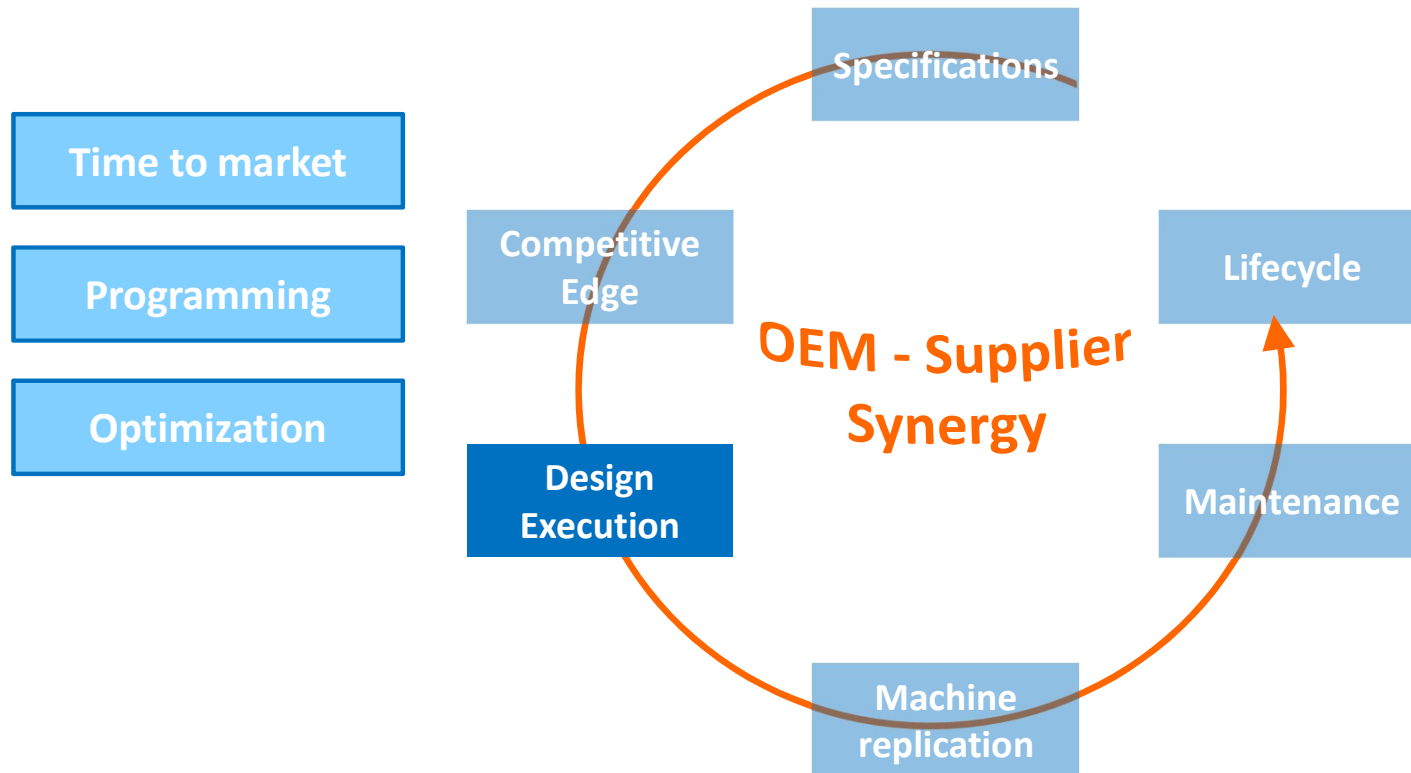
# Machine Builder Challenges & Expectations



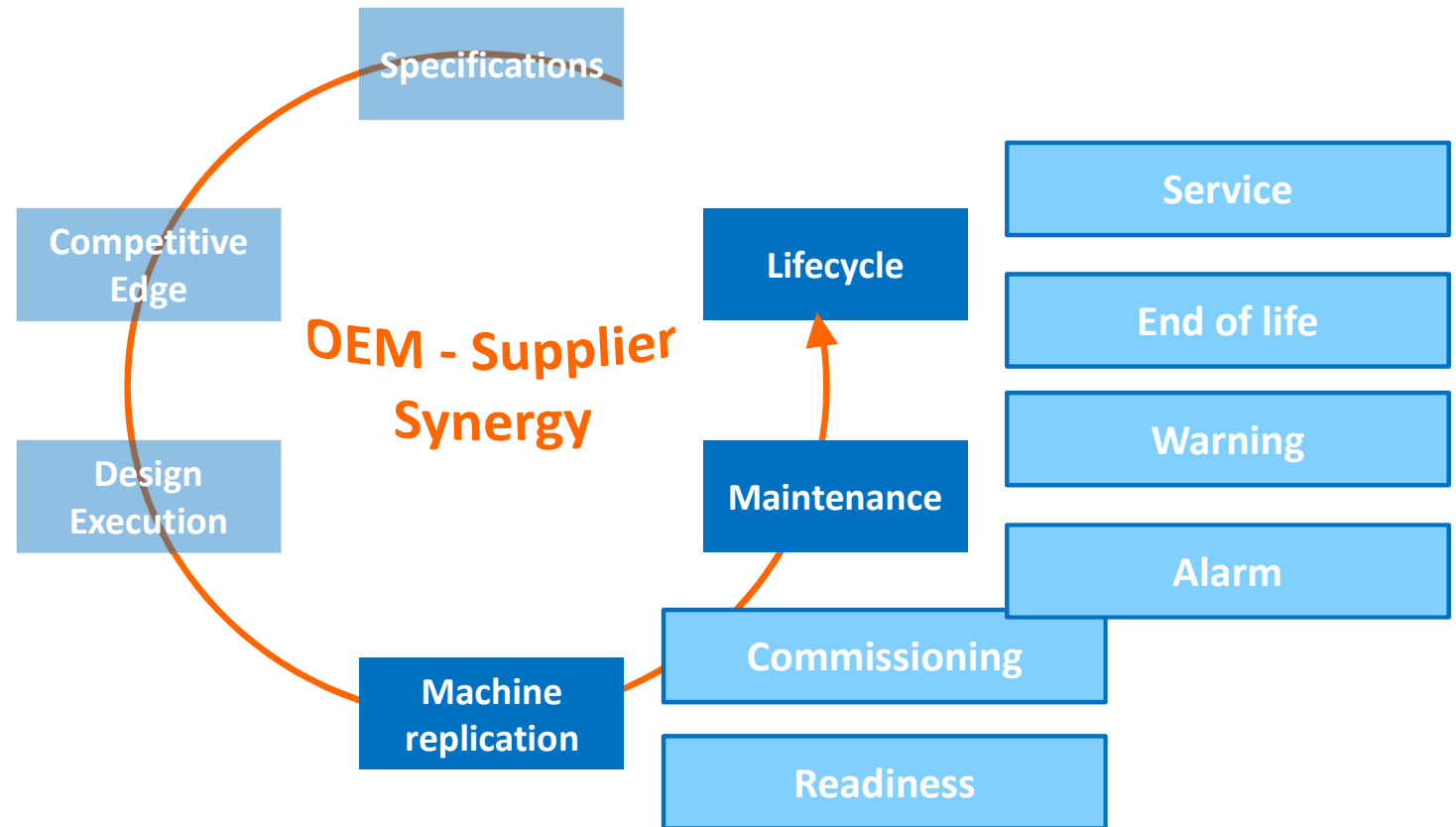
# Machine Builder Challenges & Expectations



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# Machine Builder Challenges & Expectations



# Synergy

## ❖ Core OEM Expectations

❖ Technical Specifications

❖ Competitive Edge

❖ Design Execution

❖ Machine replication

❖ Maintenance

❖ Lifecycle

## ❖ Successful Supplier Traits

○ Leading edge technology: hardware, firmware and software

○ Complete solution, flexibility, performance, innovative

○ Ease of use: design, configuration and programming

○ Software that can run the entire machine

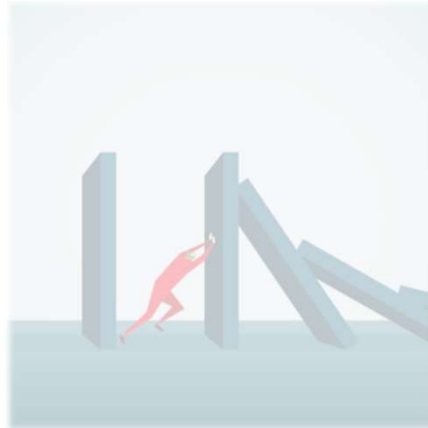
○ OEE, MTBF, MTTR...

○ Strong PLM strategy

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Common challenges in applications

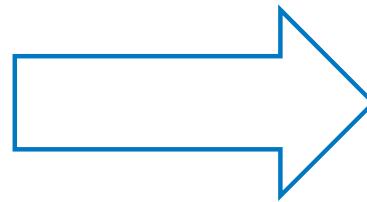
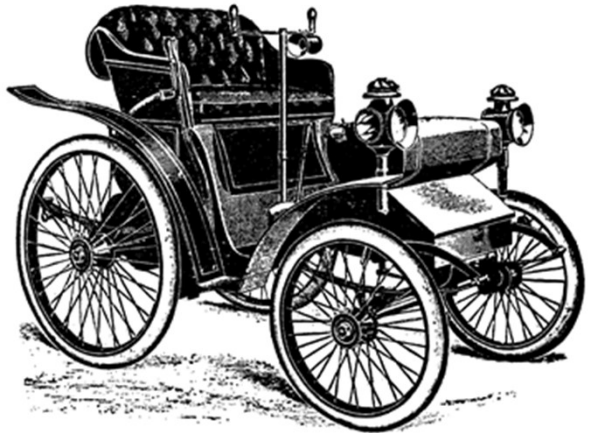


Technology solutions



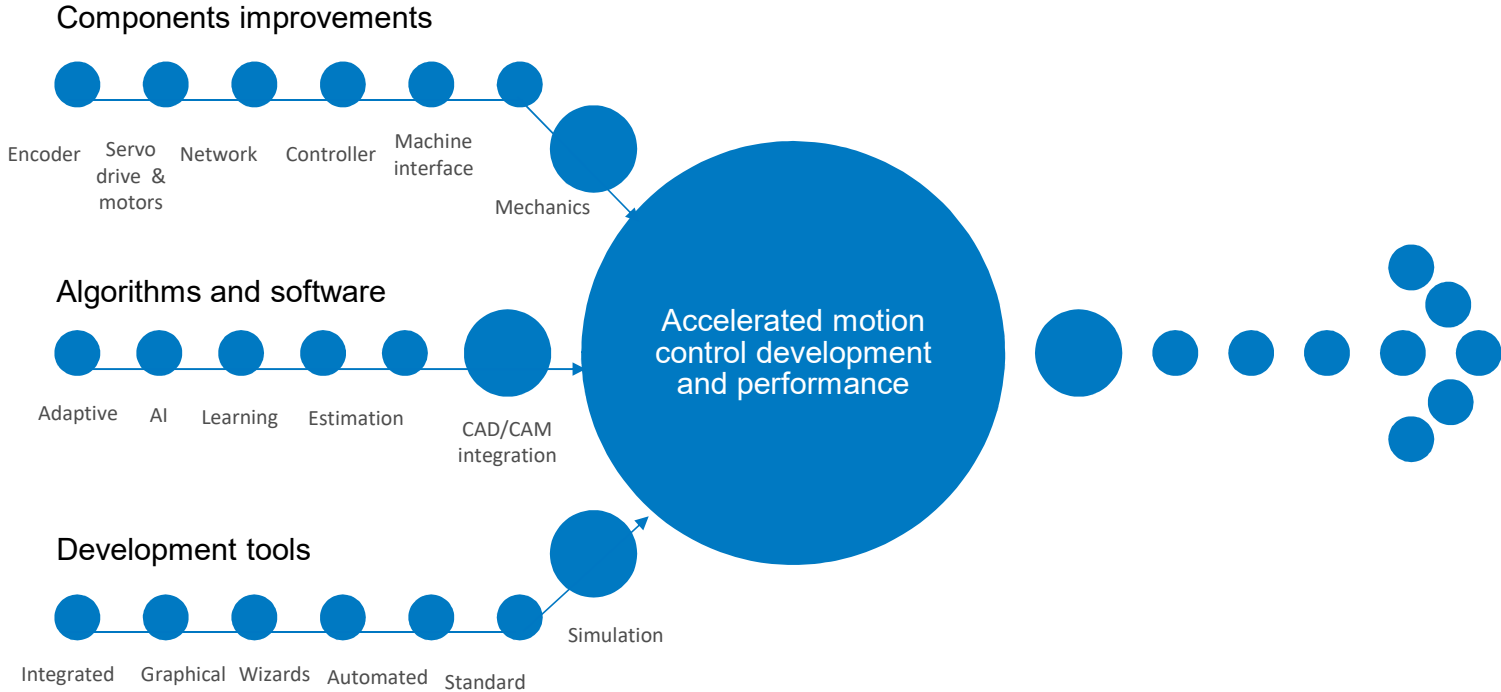
Future trends in motion

### 3- Technology Solutions



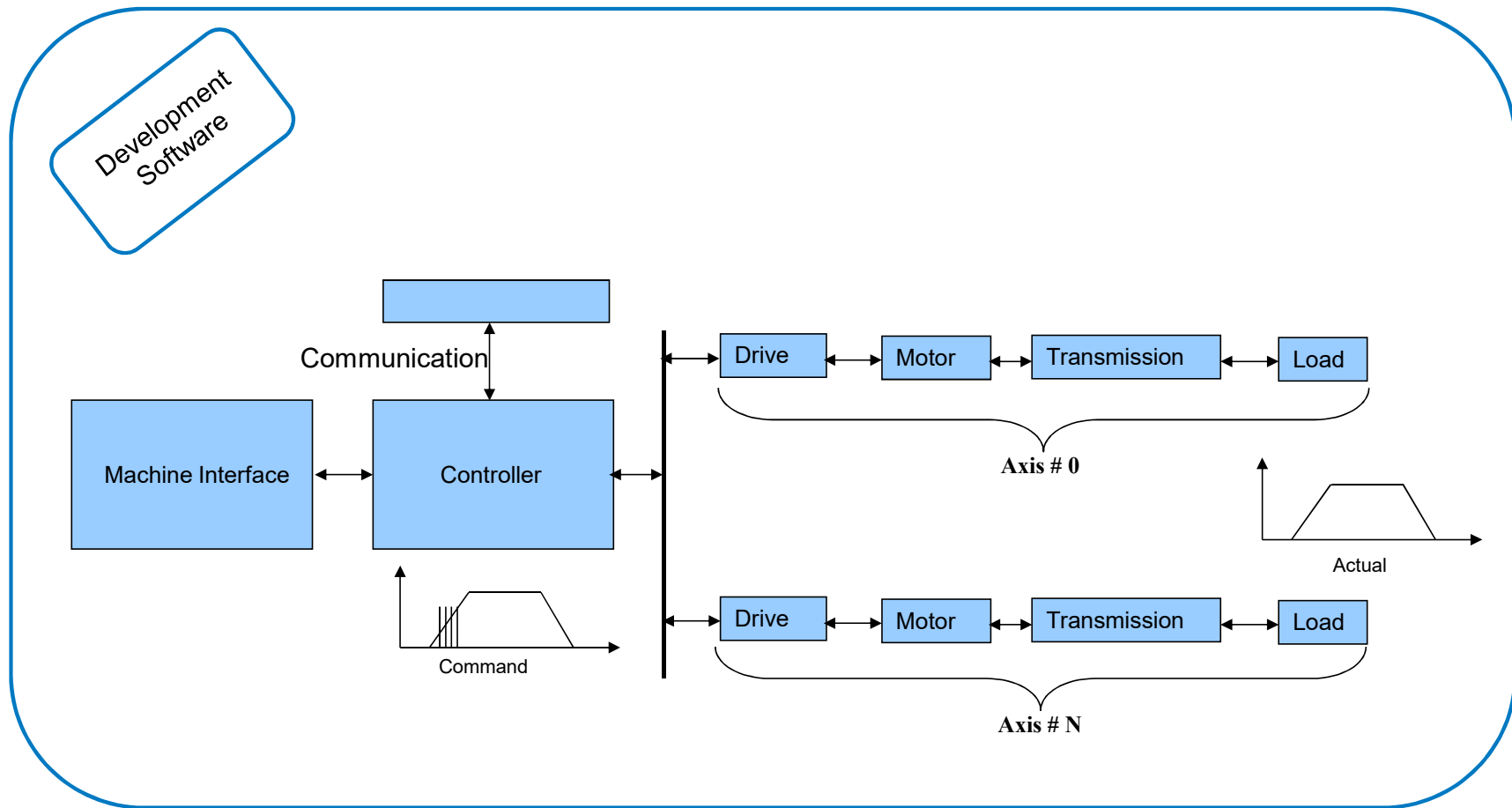
- To show concepts, algorithms, methods, technology, and practice to solve challenges and meet demand
- We need to consider the whole system because, in motion control, all elements are interconnected and act as a compound dynamic system

# The technology solutions spines





# Let us look at the complete System



# What makes Motion Control Systems

## Motion Control Types

- Setup
- Dynamic configuration
- Homing
- PTP
- PLS Control
- Gearing
- Camming
- Interpolation and Coordinated
- NC Integrated and G-Code
- Dynamic trajectories and custom kinematics
- Robotics

## Actuation

- 1.Servo, rotary and linear
- 1.AC drives and induction motors
- 1.Galvanometers, voice coil
- 1.Stepper
- 1.Specialty

## System Architecture and Integration

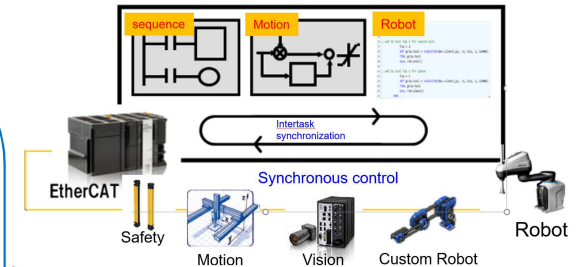
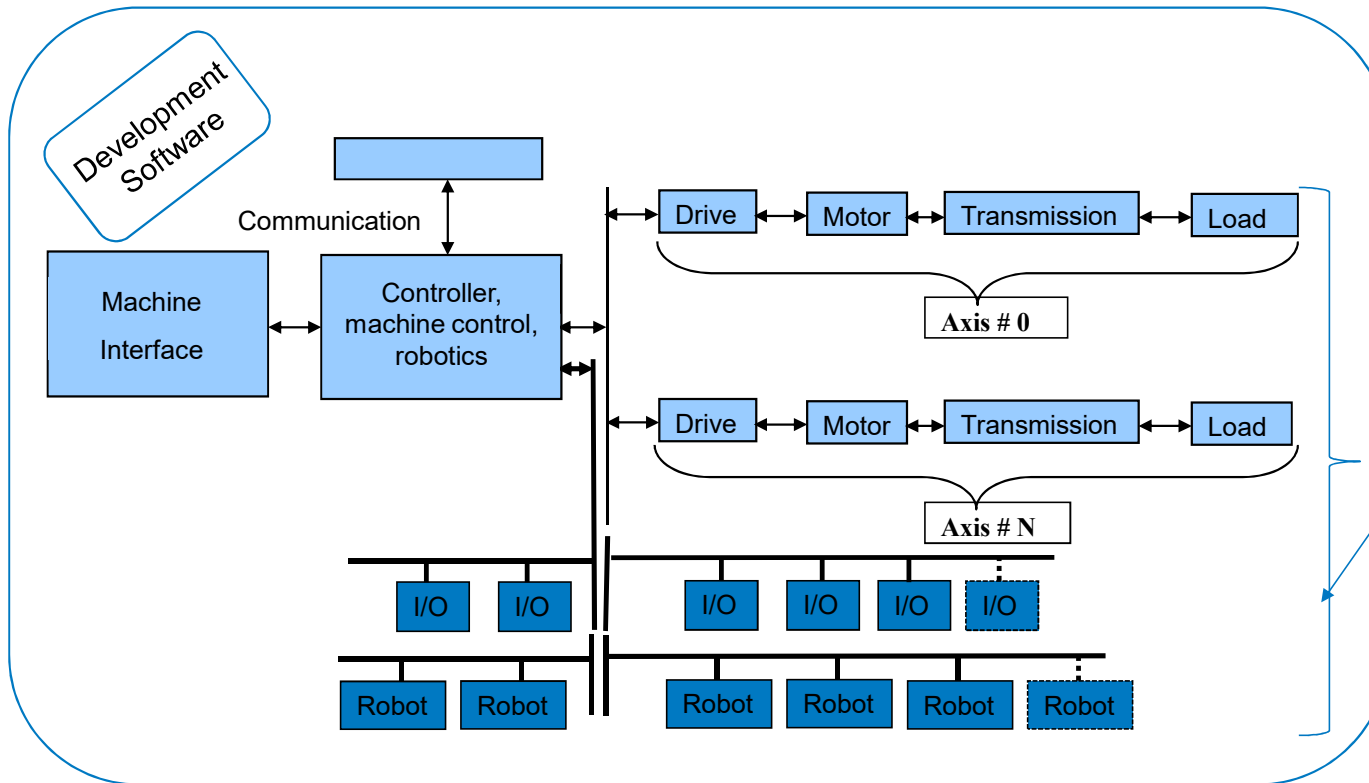
- Networks and interfaces
- EtherNet/IP , EtherCAT, ...
- Analog, PWM, ..
- Safety and vision
- Machine interface
- Communication protocols

## Software and Tools

- Servo Sizing
- Programming
- OS and Execution
- Trace Capabilities
- 3D simulation and digital twin
- Servo Setup and tune
- Sustaining, Updates, and Troubleshooting

# Machine Configurations, architecture, and Interfaces

## 1- Combining motion control, machine control, and robotics into one controller



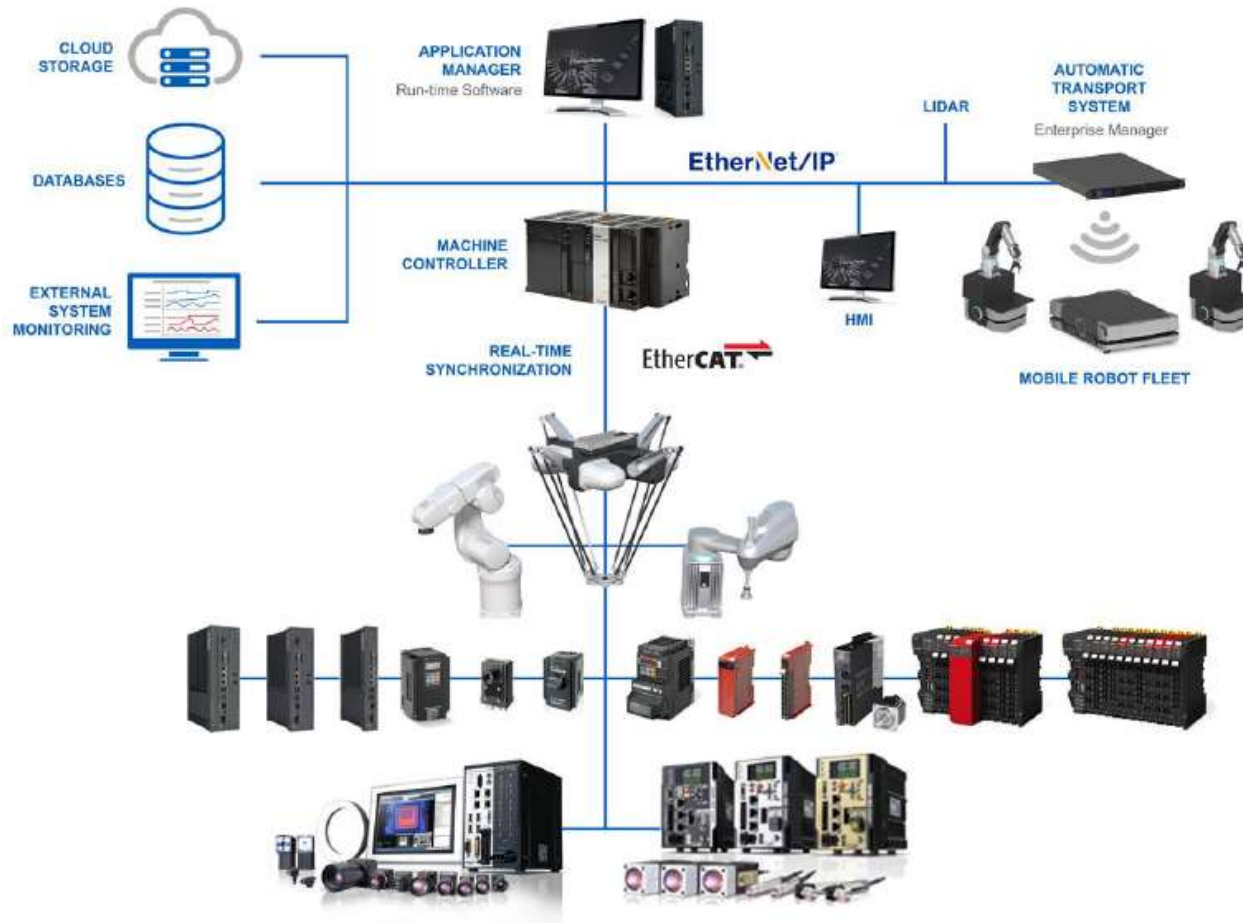
Motion, I/O, and robotics are in the same domain for network, programming, control, synchronization, and troubleshooting.

Gains:

- Development time and learning
- Throughput
- Build complex machines for complex automation
- Reduce troubleshooting and update times

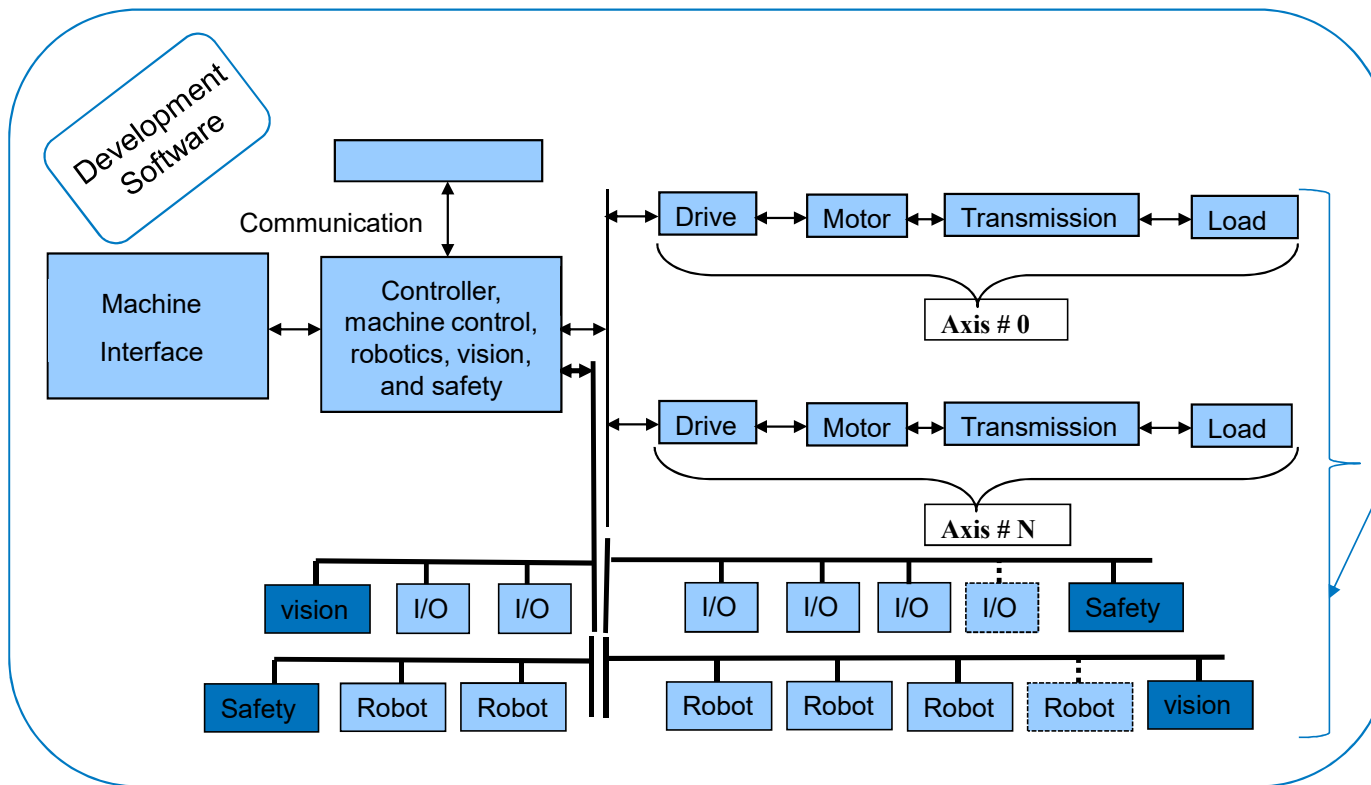
With the same controller, same network, same machine interface with the same development tools

# Expanding the architecture with integrated vision and safety



# Machine Configurations, architecture, and Interfaces

## 2- Expand machine and automation by integrating vision and safety



Motion, I/O, robotics, vision and safety are in the same domain for network, programming, control, synchronization, and troubleshooting.

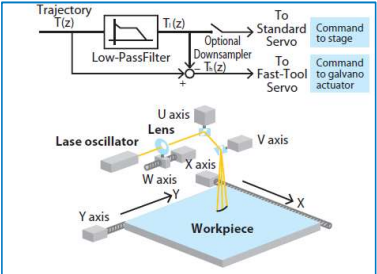
Gains:

- Development time and learning
- Throughput increase
- Build safe, scalable, flexible, and complex machines for complex automation
- Reduce troubleshooting and update times

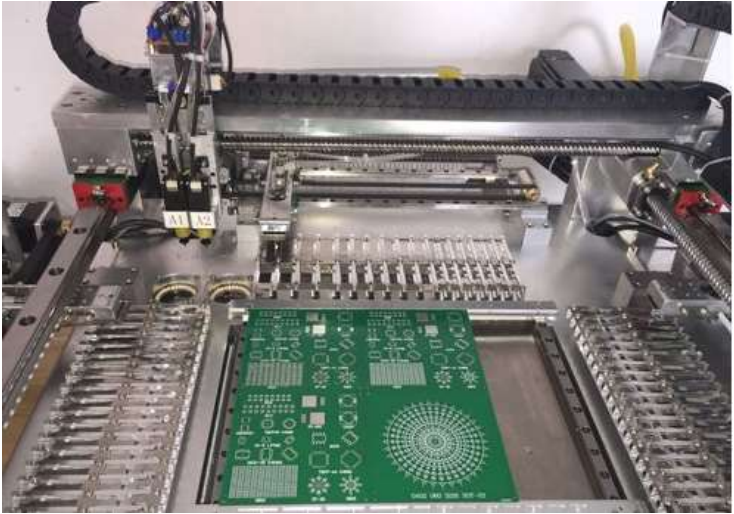
With the same controller, same network, same machine interface with the same development tools

# Application examples:

Hybrid fast and standard tool control



- Laser processing
- Micromachining
- Laser marking
- + more



# Example Improvements in components

These will focus on speed, resolution, rates, and power....

Component	Improvement in
Encoder	Resolutions, speed, size, durability, connections, protocols, ...
Servo Drive	I/O, communication, diagnostics, compensation, algorithms, speed, computation, range and flexibility
Servo Motor	Torque or force/weight, ranges, dynamic response, range
Network, Protocol and connectivity	Stability, resolution, speed and bandwidth, flexibility, the mix of devices and protocols, redundancy, dynamic configuration,
Controllers, Real-time OS and Execution	Computations, multi-core, robust, multitasking,

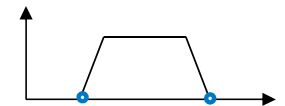


Improved response, precision, and control of current, velocity, and position

Improved<sup>+</sup> development and performance, and expanded (do more)



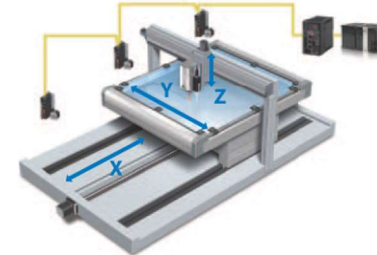
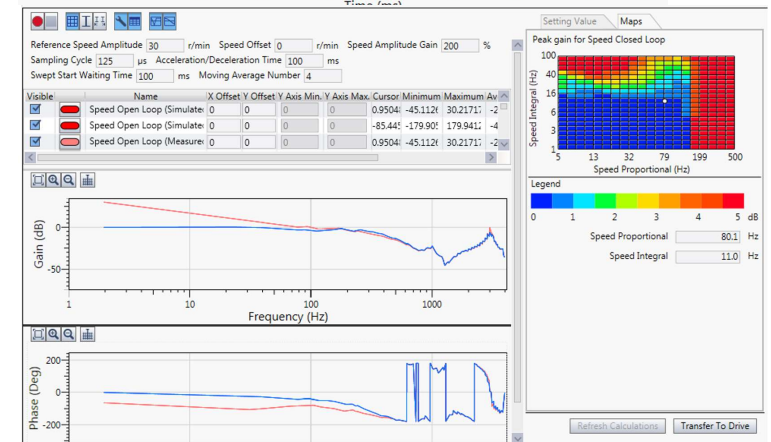
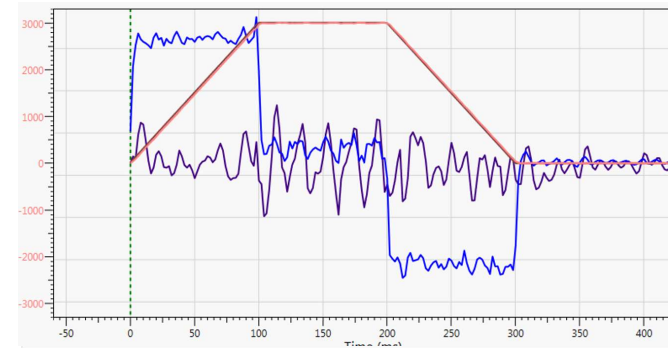
Faster, Precision machines and precise productions.



# Algorithms and software

## Servo

- Load, friction, resonance, backlash, velocity real-time estimation
- Velocity and acceleration Feedforward
- Vibration control of resonance and structure
- Adaptive filters
- On the fly switching among torque, velocity, and position control
- Linear and quadratic interpolation
- Control gains switching
- Multi-axes servo tuning
- Dual feedback



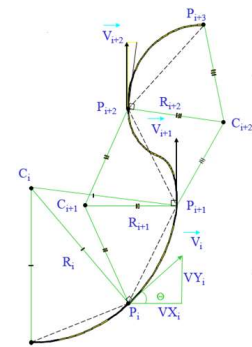


# Algorithms and software

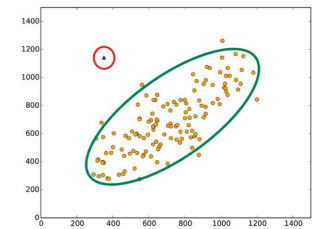
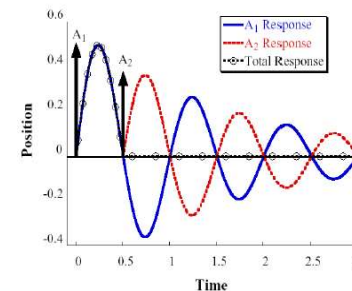
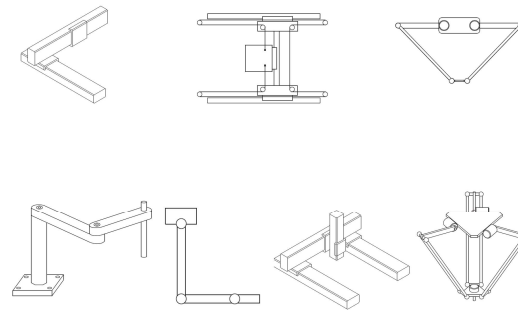
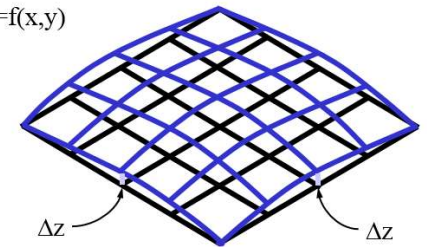


## Controller

- Curve fitting and lookahead
- AI anomaly detection in real-time
- Dynamic trajectory generation
- Custom kinematics
- Advance servo position loop control in the controller
- 1 D, and Multi-dimensional compensation
- Cross coupling and dynamic compensation
- Single resonance and multi resonance control using trajectory for single axis or a 6 dof robot
- High speed and high precision



$$\Delta Z = f(x, y)$$



# Development and Tools

Graphical interactive, digital twin, simulation, Sample application, wizard, automated deployment, tuning, ...



```
1 rCos,q2=FWC_X*WC_K+WV_Y*WC_Y+rKin_L1*rKin_L1/r2*rKin_L1*rKin_L1*WV_Y;
2 rSin,q2=SQR(1-rCos,q2);
3 rC_A2=ATAN2_FN(x=rCos,q2,y=rSin,q2);
4 T1=rWC_X*rKin_L2*COS(rC_A2)+rKin_L1+WV_Y*rKin_L2*SIN(rC_A2);
5 T2=rWC_Y*rKin_L2*COS(rC_A2)+rKin_L1+WV_X*rKin_L2*SIN(rC_A2);
6 rCos,q1=T1/SQR(T1*1+T2*12);
7 rSin,q1=T2/SQR(T1*1+T2*12);
8 rC_A1=ATAN2_FN(x=rCos,q1,y=rSin,q1);
9 rC_A1d=RadToDeg(rC_A1);
10 rC_A2d=RadToDeg(rC_A2);
```

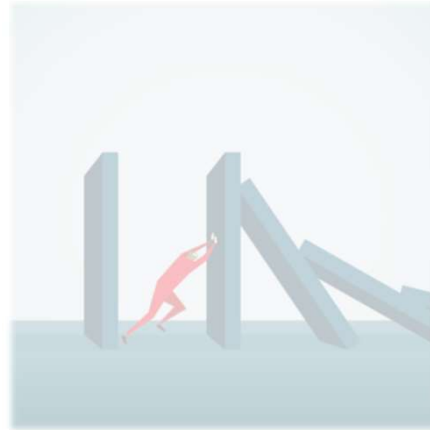
Parameter	Value
Gain	1.000
Proportional	1.000
Integral	1.000
Derivative	1.000
Filter	1.000
...	...

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# New demands and trends

## Industrial Networks

- Higher speed network (GBS)
- Wireless
- Data collection and transfer

## Higher accuracy encoders

## Demand for smaller products

- Smaller machines
- Smaller tooling
- Extreme accuracy





# Artificial Intelligence in Motion

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## Machine learning

- Collect analyze and utilize data
- Anomaly detection
- Predicting failure before it happens

## Samples of failures that is can predict

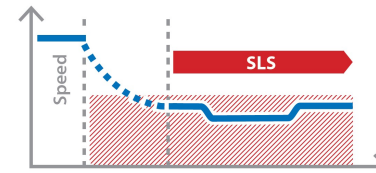
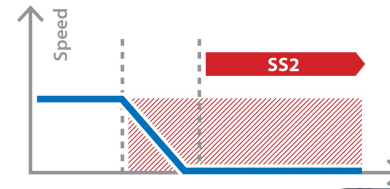
- Ball screw
  - Guide broken
  - Ball Bearings falling out
  - Contamination
- Conveyor
  - Contamination
  - Belt loosen
  - Belt broken
  - Pulley broken

# Safety in Motion Control

Help to create a safe environment for both people and machines

Eliminate machine down time by not stopping

- Adjustments while running
- Load/unload without stopping
- Utilize safe work zones
- Maintain coordinated motion during stops





# Summary

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## History & evolution

## Challenges & Expectations

- Performance, flexibility, innovation
- Close partnership, communication of collaboration

## Technology Solutions

- High performance and complete solution
- Flexible, Intelligent, and Integrated

## Future trends

- Smaller, faster, and safe

# Thank you

