



An MTConnect[®]-Based Approach for Machine Monitoring

Radu Pavel, Ph.D.

Vice President, Chief Technology Officer

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TechSolve, Inc. - Overview



- A process improvement and machining services organization located in Cincinnati, OH
- State and Federal Manufacturing Extension Partnership (MEP) Center
- Founded as IAMS in 1982 ; rebranded as TechSolve, Inc. in 2000
- 40+ Member Team: Engineers, MBA's, PhD's, and former business owners
- Fully instrumented machining laboratory

Fully-Instrumented Machining Laboratory

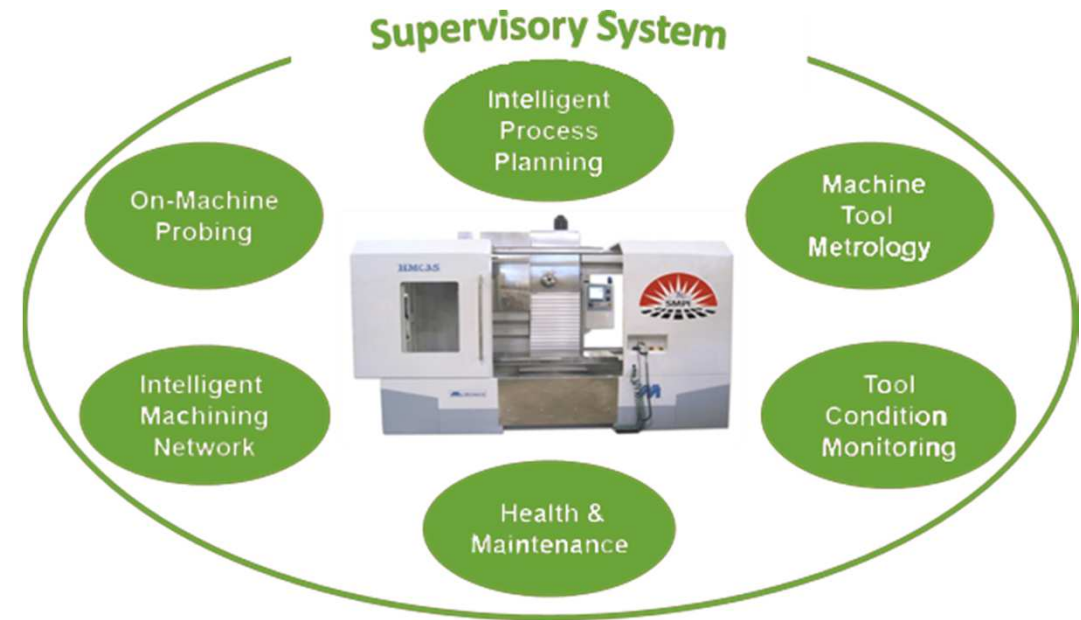
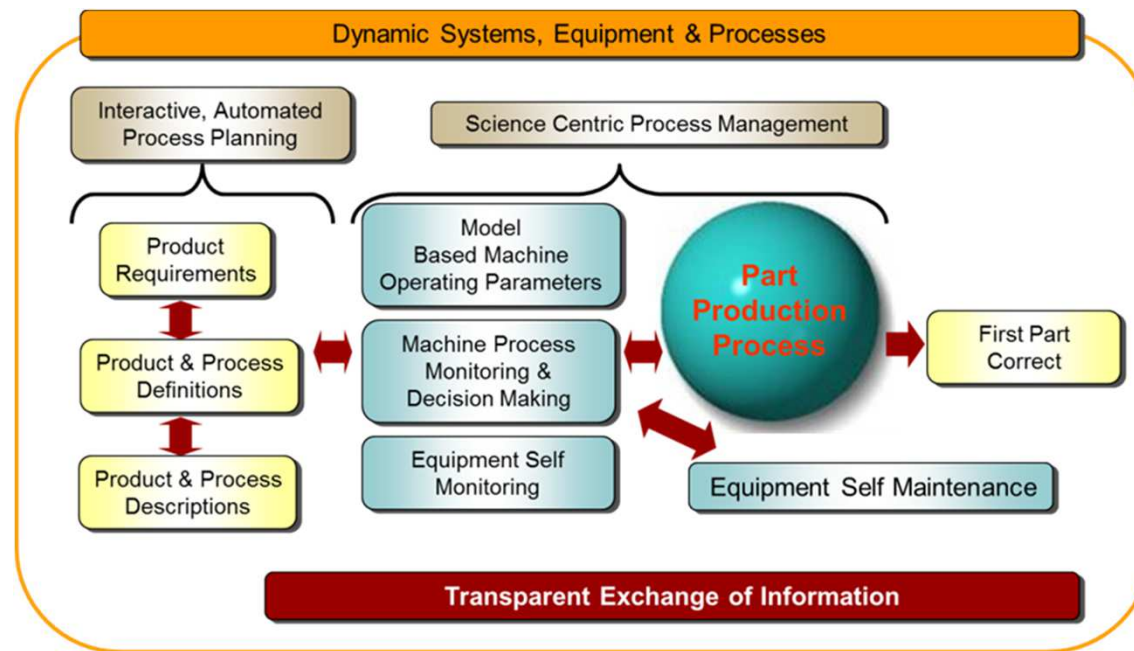
Equipment Highlights:

- Mazak Integrex i200S Mill Turn
- Makino V55 - 3 Axis VMC w/20K spindle
- DMG DMU-50 - 3+2 Axis VMC w/Siemens 840D CNC & through-spindle coolant
- DMG DMU-70 eVo Linear - 5 Axis VMC w/ Siemens 840D & 580 psi through-spindle coolant
- Hardinge Cobra 65 - 2 Axis turning center w/Fanuc 21T & Bar Feed
- Milltronics HMC35 - 4 Axis HMC w/Fanuc 0iMC
- Chevalier Smart B1224II CNC Surface Grinder
- Sheffield Cordax D-8 CMM
- Kistler Turning, Milling, and Drilling Dynamometers
- Keyence VHX Digital 3D Microscope
- Smart Manufacturing test-beds
- Fluids Lab



Smart Machine Platform Initiative

Be the framework for the identification, development, and transition of technologies that recognize the goal of “First Part Correct” manufacturing.



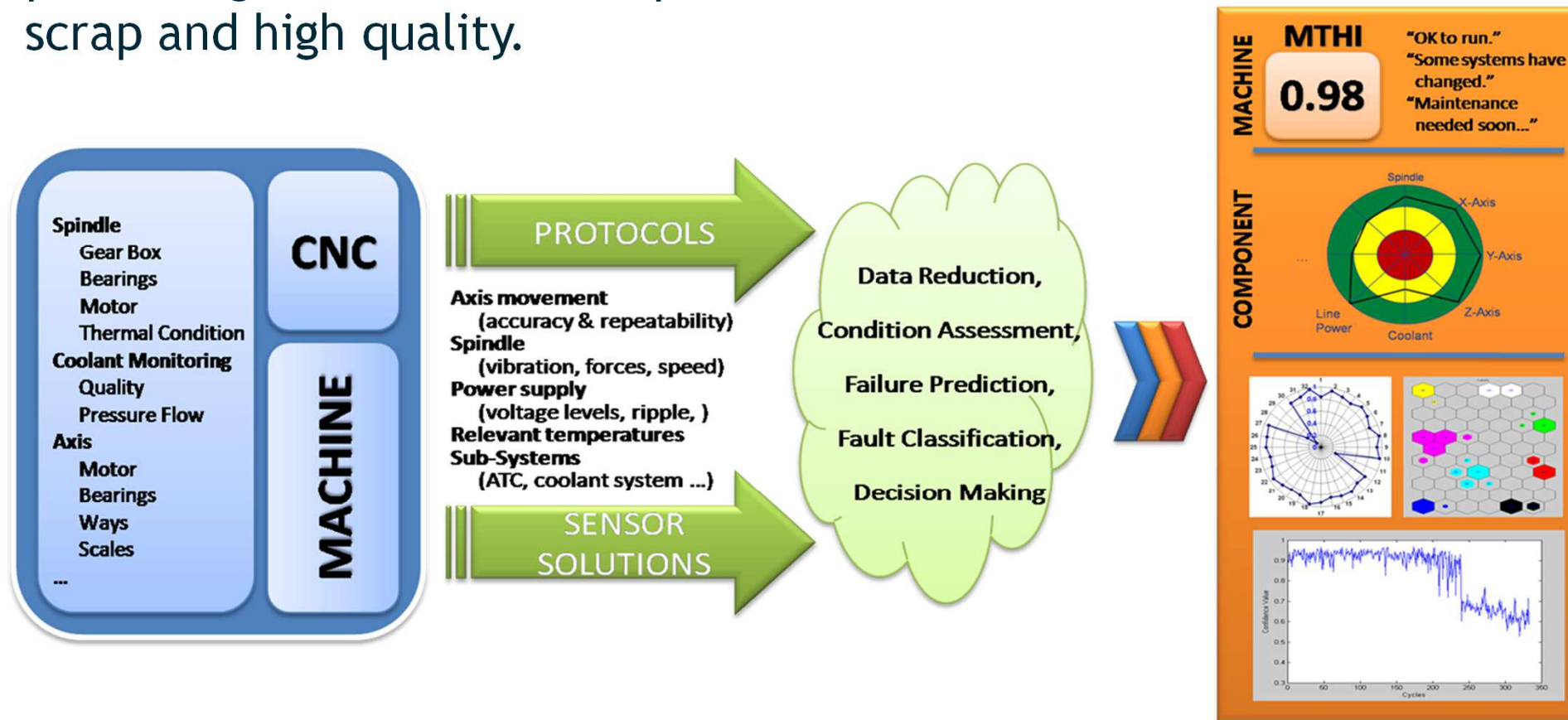
Smart Manufacturing Program at TechSolve



Monitoring, diagnostics, and prognostics for manufacturing equipment and operations relate closely to each technology area and feed and make use of the digital thread of the factory of the future.

PHM for Smart Manufacturing

Integrated health monitoring system capable of accurately monitoring and predicting the machine and process health for near-zero downtime, minimal scrap and high quality.



Collaborations

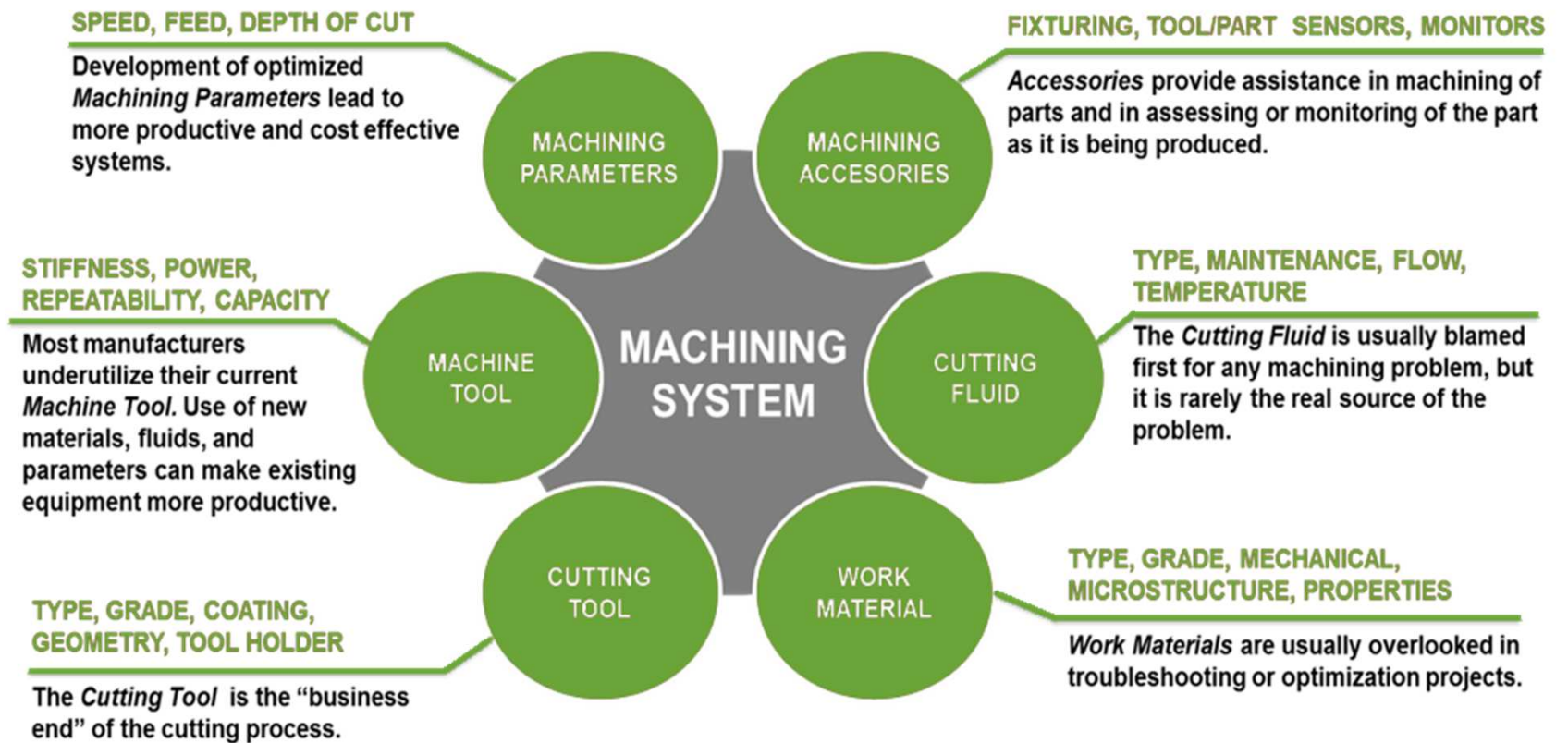
TechSolve teamed up with a number of academic and industrial organizations to evaluate, develop, and validate PHM technologies

- University of Cincinnati
 - **Intelligent Maintenance Systems (IMS)**
 - **Computer Science**
- Frontier Technology, Inc. (FTI)
- Siemens Corporation
- Palo Alto Research Center
- NIST - Intelligent Systems Division

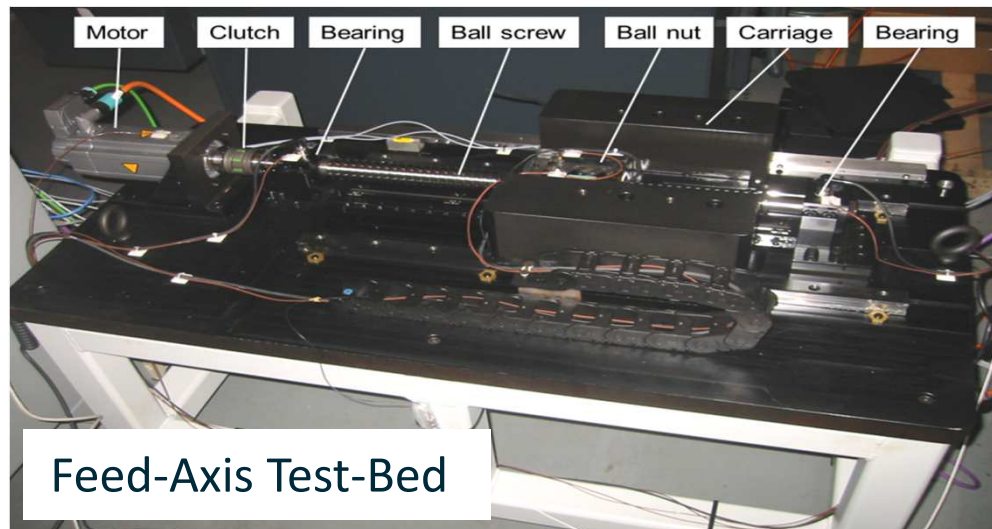
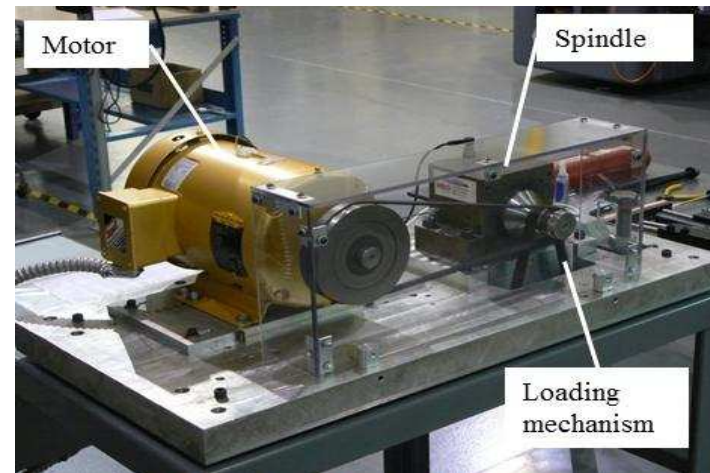


The Machining System- A System of Systems

- Spindle
- Feed-axis
- Chuck
- Hydraulics
- Tool changer
- Tool magazine
- Part handling system
- Pneumatic system
- Tailstock
- Turret
- Fluid system
- Bearings
- Way guides
- ...



Test-Beds

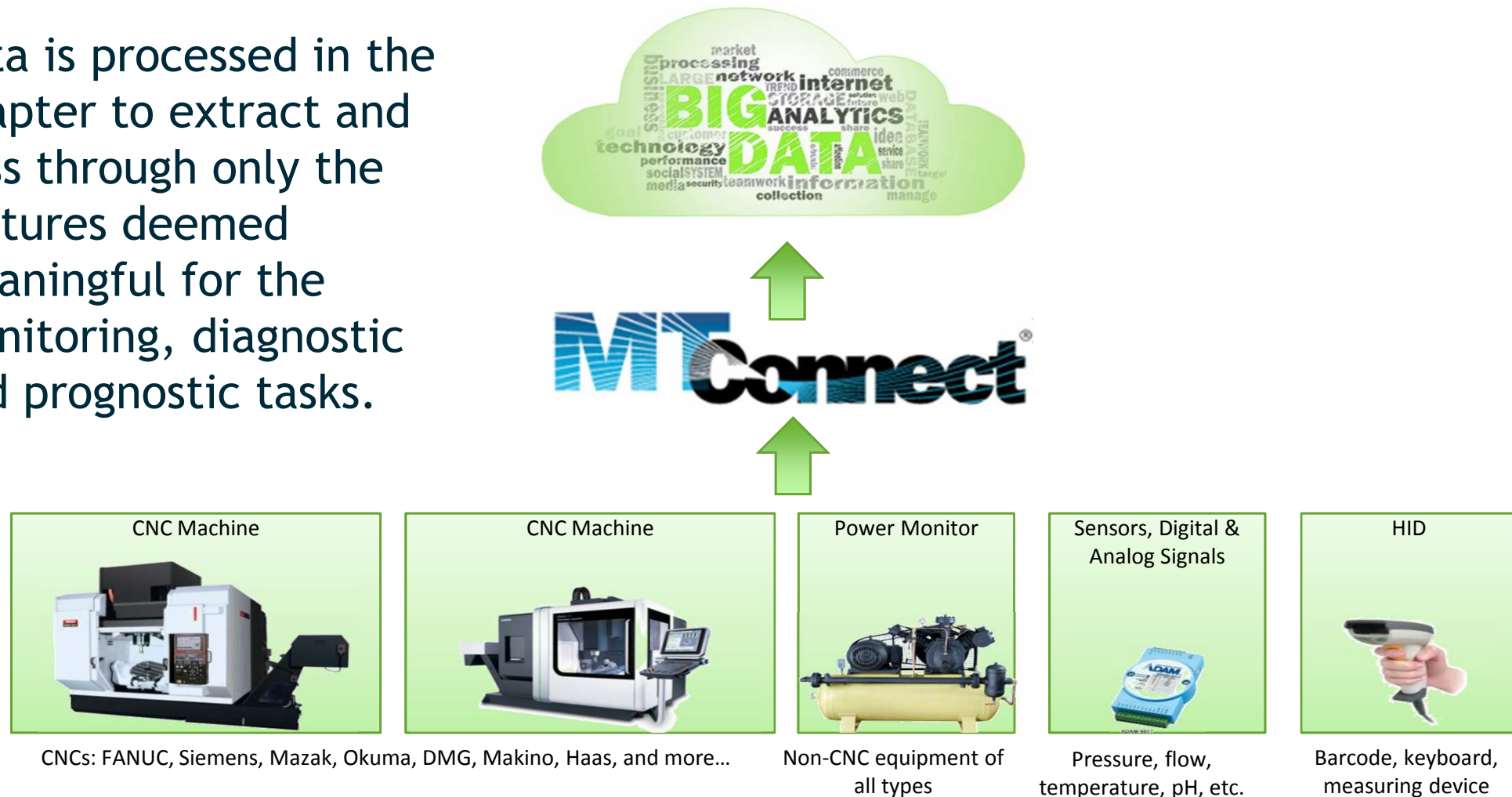


- All TechSolve's machine-tools are connected to IIoT
- Spindle and Feed axis test-beds are used for degradation tests



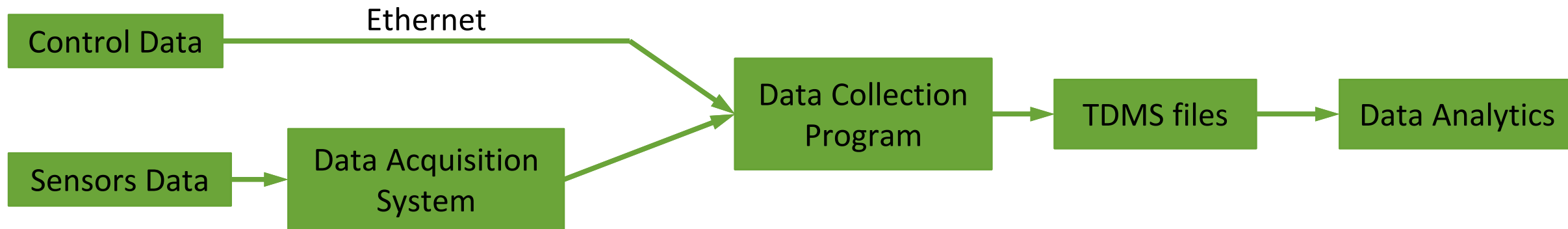
Edge Computing

Data is processed in the adapter to extract and pass through only the features deemed meaningful for the monitoring, diagnostic and prognostic tasks.

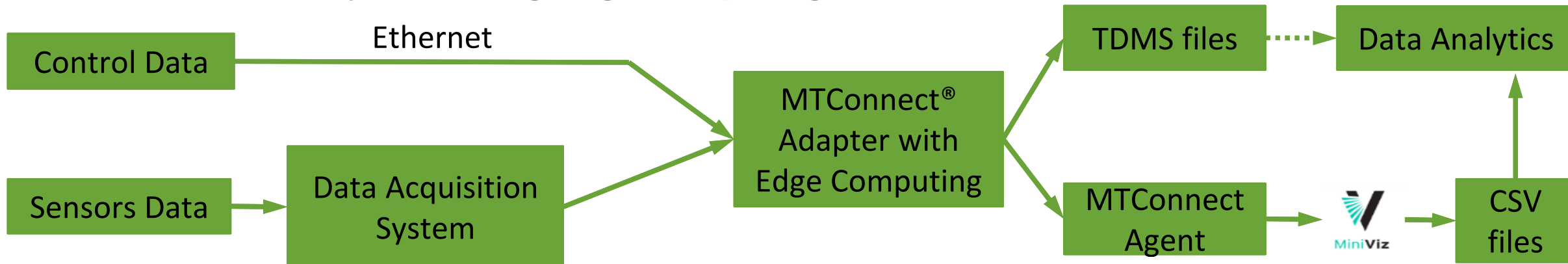


Machine-Tool Monitoring System Architecture

LabView-based system



MTConnect-based system using Edge Computing



Machine-Tool Data Sources

Measurement	Location
Vibration	Spindle (X,Y,Z axes), Feed-axis (X,Y,Z axes)
Temperature	X-axis bearing, motor of X-axis, bearing Z-axis, motor Z-axis, bearing Y-axis, motor Y-axis, spindle bearing, spindle motor, metalworking fluid, ambient
Power	Overall
Displacement	Machine Position (X,Y,Z)
Speed	Spindle
Feed rate	Feed-axis
Load	Spindle (X,Y,Z)
Percent Load	Overall
Time	Servo delay (X,Y,Z)

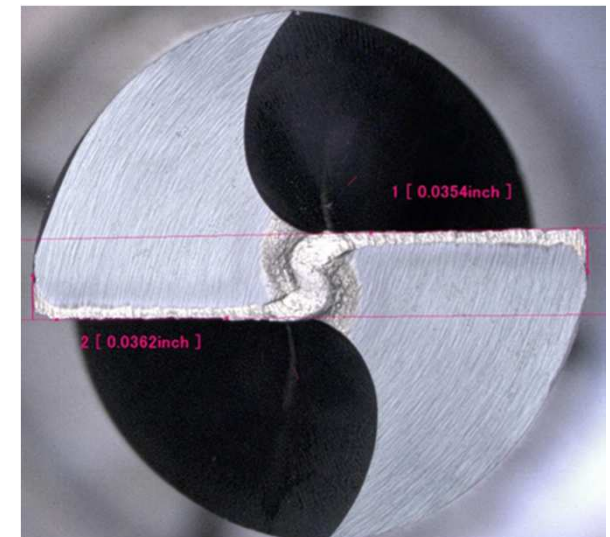
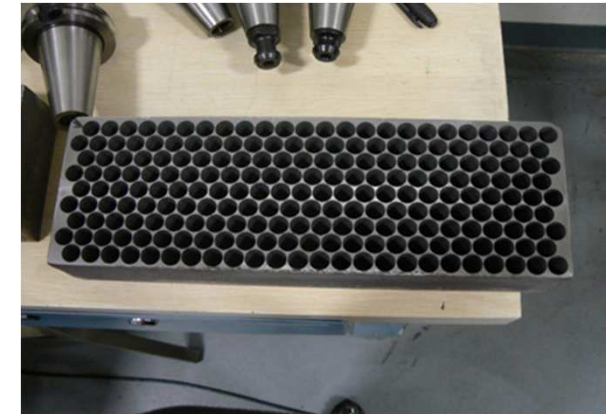
19 sensor channels sampled at 5000 Hz, and
38 controller outputs sampled at 10 Hz

Edge Computing - Features

- Simple statistics for signals other than vibration generated (e.g. mean, RMS, standard deviation, Kurtosis)
- Vibration signal is more information rich. To extract this information the RMS, peak to peak, kurtosis, energy in frequency bands, and amplitudes at bearing fault frequencies were calculated.
- Bearing Fault Frequencies include:
 - Ball Pass Frequency of Outer ring (BPFO)
 - Ball Pass Frequency of Inner ring (BPFI)
 - Fundamental Train Frequency (FTF)
 - Ball Spin Frequency (BSF)

Evaluation Tests

- A Milltronics HMC35 was programmed to drill 216 holes of 11.4mm diameter in a cast iron block.
- A total of eight blocks were drilled, with a drill replacement event after four blocks.
- A machine trigger was used to only collect data during the drilling feed cycle.
- The machine tool health was defined using several tool wear measurements.
- This case study was focused on tool degradation.
- The two outer wear measurements were averaged for an average outer corner wear target measurement.



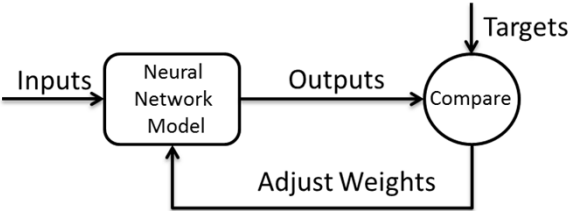
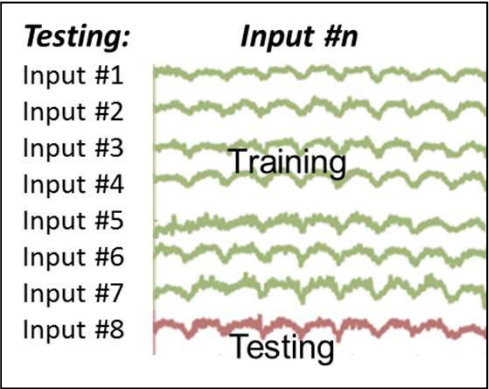
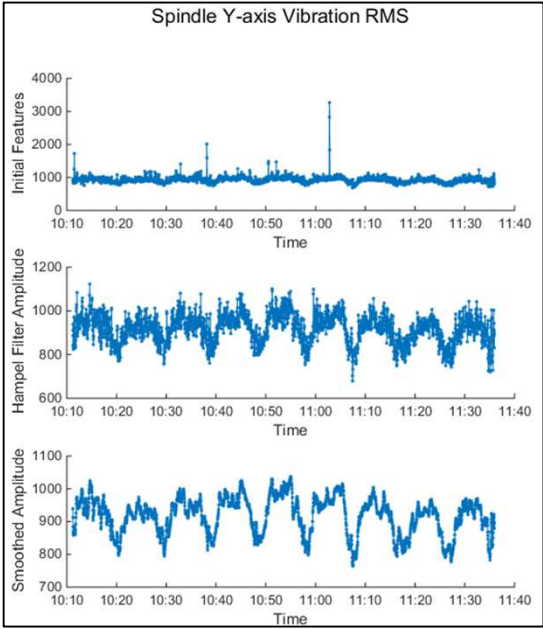
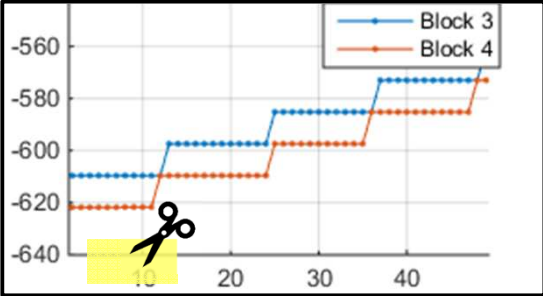
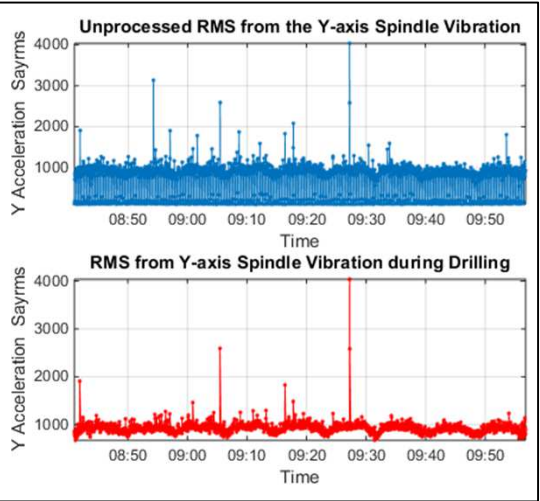
Data Analytics

Data Selection

Data
Synchronization

Feature Data
Filtering

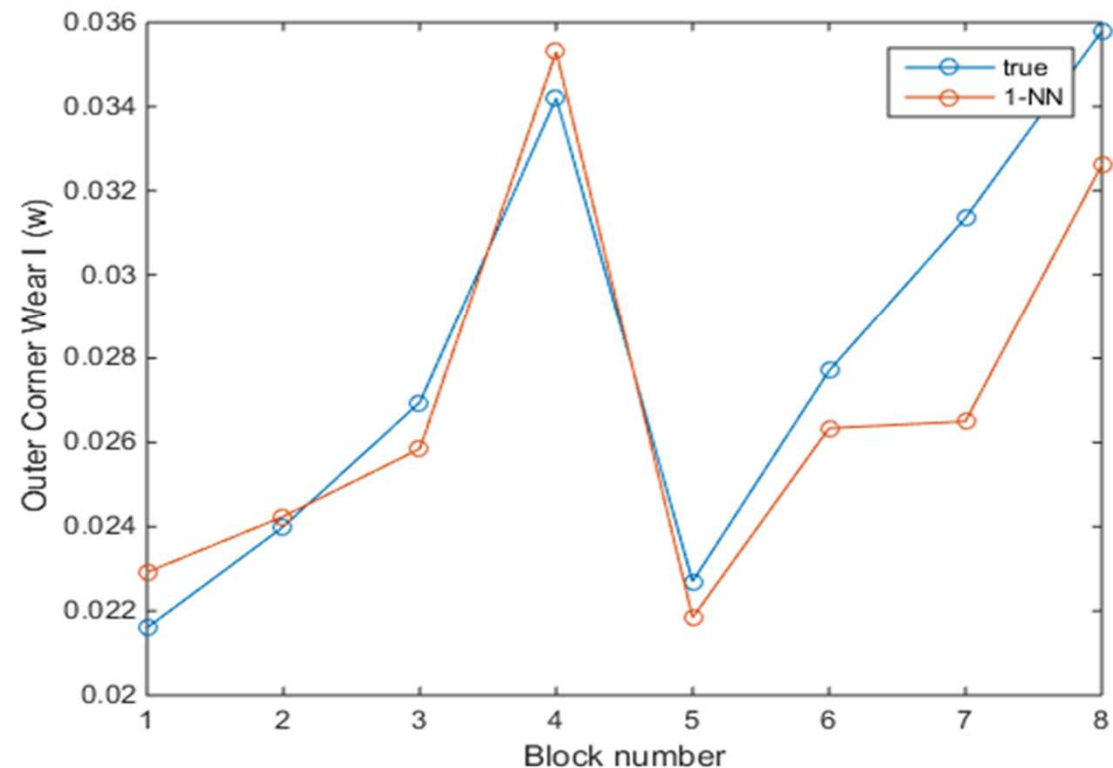
Modeling using
Neural Networks



Model Cross Validation Results

- Each feature is tested to find those that best predict the outer corner wear target.
- The best prediction performance based on a root mean squared error (RMSE) was the RMS of the Z-axis Acceleration, with an RMSE of 0.0727.
- The figure shows the actual and predicted average outer corner wear, where the predicted was based on the leave-one-out Neural Network.

Comparison of Outer Corner Wear Actual vs. Model Outputs Based on RMS from Z-axis Vibration



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Thank you!

Radu Pavel, Ph.D.

Vice President, Chief Technology Officer

TechSolve, Inc.
6705 Steger Drive,
Cincinnati, OH 45237
Phone: 513.948.2062
pavel@techsolve.org

