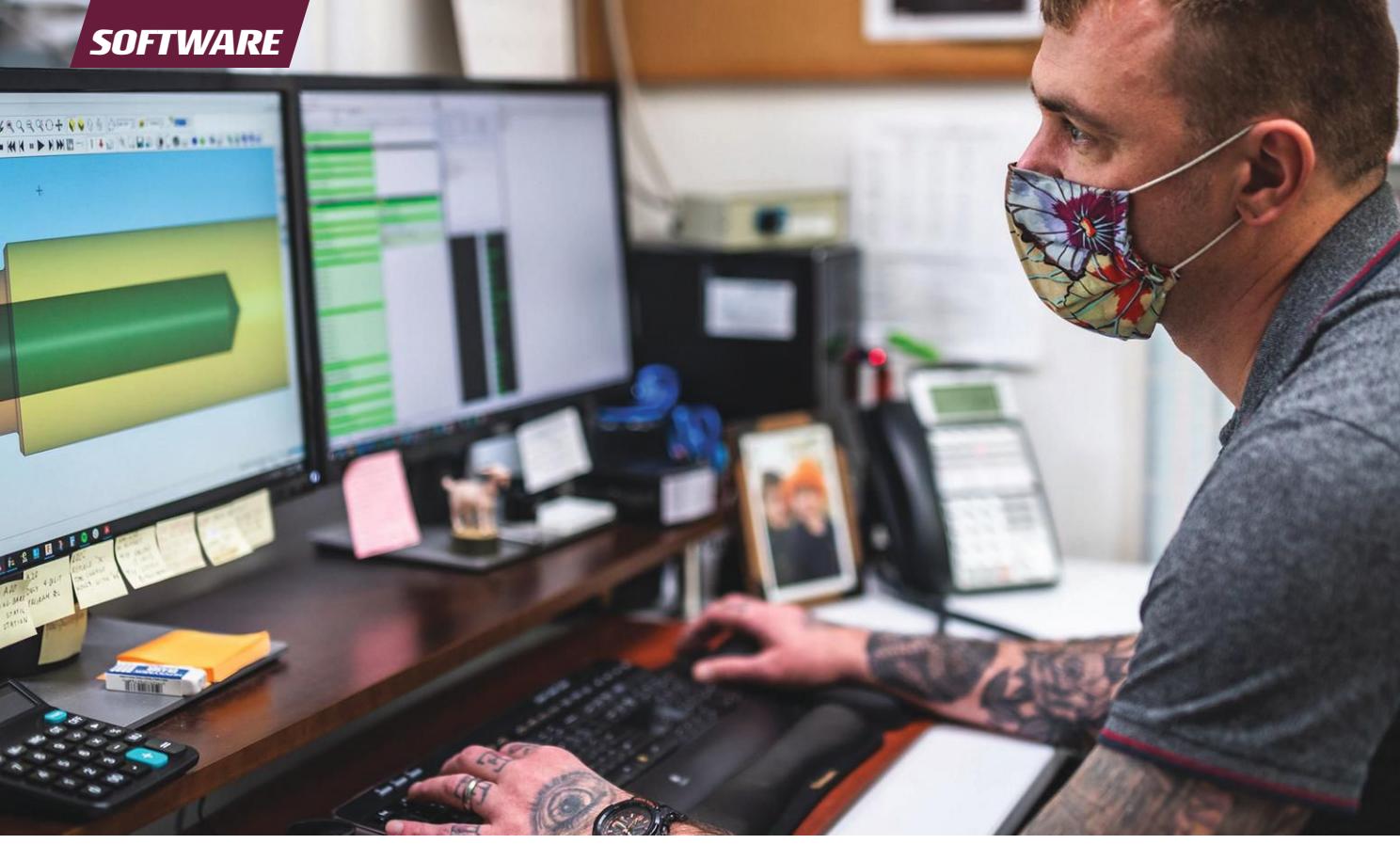


# Simulation Software Meets the Need for Speed

*The latest additions for CNC toolpath simulation adds speedier programs, better accuracy and digital twin capabilities*

**PATRICK WAURZYNIAK**
Contributing Editor

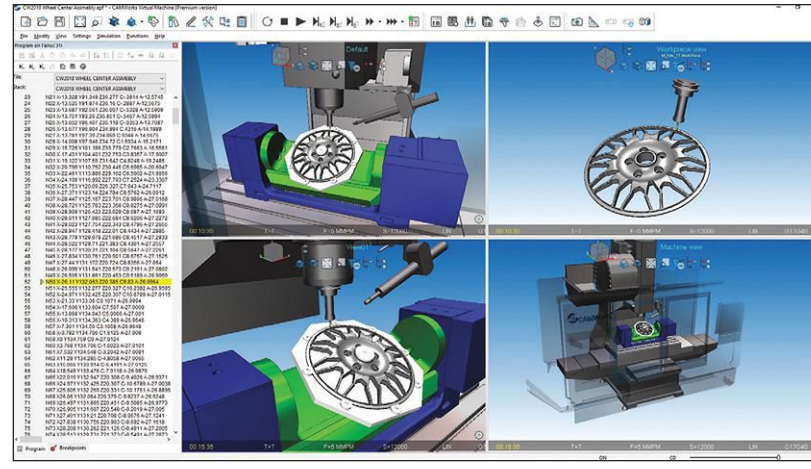
Toolpath simulation software gives manufacturers assurance that their machine tools will cut parts quickly and accurately, which is particularly useful when machining expensive materials like titanium or Inconel. Today's CAM software offers users a growing number of choices of how to prevent costly machine tool collisions and other metalcutting errors.

However, choices range from basic to sophisticated, and it pays to know when to use the right simulation for your individual needs.

To the point, most CAD/CAM systems feature some basic simulation capabilities using plug-in component modules that simply use cutter location (CL) data. CAM users needing higher resolution simulations can look toward third-party NC simulation programs,

***Manufacturers rely on digital twin toolpath simulation to reduce the machine setup time by an average of 65 percent, giving them the confidence to run the program and reduce the number of iterations during the test run. (Provided by DP Technology)***

such as CGTech's VERICUT or Hexagon's NCSIMUL. These third-party applications offer G-code simulation of all parameters used in the cutting process, including cutting tools, the machine tool and any accessories used in machining components, to help avoid costly mistakes.



***With the accuracy and performance improvements of simulation, programmers can get near instantaneous feedback and simulation can be used to interactively create each operation. (Provided by CAMWorks/HCL)***

## Fast and Accurate Metalcutting

Today's machine tool environments more often require that manufacturers employ digital twin simulation—visualizing the actual machining process for optimal accuracy. "A key trend in toolpath simulation is digital twin simulation, which provides a precise digital replica of the entire machining environment and leverages the full knowledge of your machine's capacities, such as axis limits, turning option, or kinematic chain, to maximize your productivity," said Chuck Mathews, executive vice president, DP Technology Corp., the Camarillo, Calif.-based developer of ESPRIT CAM software. "Digital twin simulation also drastically reduces machine setup time for manufacturers."

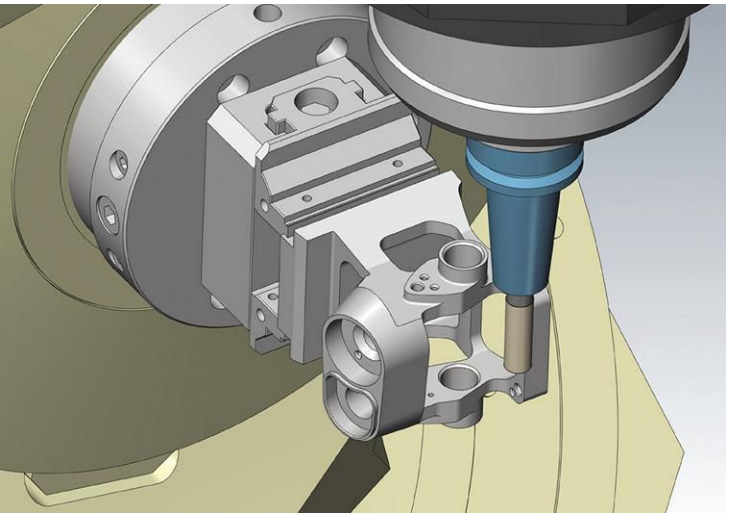
Another key trend is to incorporate digital twin toolpath simulation early, in the programming stage, rather than only in the verification stage, Mathews added. "With a complete machine awareness and the help of AI algorithms, modern CAM software can optimize the toolpath with the shortest cycle time (reduce air cutting, minimize tool changes, axis rotations), and produce clean, edit-free NC codes," he said. "This reduces the need to use separate software to verify and optimize the toolpath after programming."

Accurate G-code simulation avoids machine collisions and broken tools, according to Marc Bissell, senior applications specialist for HCL Technologies Ltd., the Noida, India-based developer of CAMWorks software. (HCL America Inc. is based in Scottsdale, Ariz.) "Many CAM systems still simulate based on internal CL, or cutter location data,

which can leave opportunities for errors in the final G-code program," Bissell said. "In addition, CNC machines operate differently based on their configuration and parameter settings. Using CAMWorks Virtual Machine, the machine simulation is based on the same G-code file that will run the physical machine and the virtual machine is configured to behave exactly as the real machine. This helps ensure WYSIWYG (what you see is what you get)."

## Simulation for Speedy Precision

Key trends in toolpath simulation are simple—delivering richer data that is immediately useful and increases the precision and productivity of the results. This is according to Ben Mund, senior market analyst for CNC Software Inc., the Tolland, Conn.-based developer of Mastercam software.



***Simulation in Mastercam shows a workpiece model being machined. (Provided by CNC Software)***

"Good toolpath simulation software will reliably track and note potential gouges, collisions, axis overtravels and more. Programmers can interrogate the tool motion itself to see exactly where a move is and other important pieces of information," Mund said. "Some simulation solutions also track material removal rates, warn of spikes, or track axis reversals. But in the end, all simulation software must let the programmer see the accuracy of the material remaining compared to the desired finished part.

"If a programmer can avoid running a setup piece or slowly stepping through the first run of a program at the machine, they save considerable time and money and boost their productivity. Having a reliable, accurate representation of the cut motion on the machine lets them know that a successful simulation guarantees a safe and successful cut," Mund added.

Other considerations are the ability to get specific information about the machine and cut to potentially refine a machining process and the general speed and ease with which a user can test multiple setups and strategies, he said.

Integrating component modules into CAM systems isn't always easy, Mund noted. "Incorporating specialized components into CAM systems is a powerful way of bringing together complementary software tools in a single package. It is a widely used technique across the CAM marketplace," Mund said. "While prevalent, it's not as straightforward as simply plugging in a component. Proper implementation requires changes, refinements, and new features to fully complement the tools and tool motion being simulated."

He also noted that, in addition to the integrated simulation delivered with a CAM system, there are also completely stand-alone simulation options unconnected to any CAM system. Both these options carry strengths and weaknesses, and it is good to evaluate both.

## G-Code Simulations

The third-party applications offering true G-code simulation and verification include VERICUT from CGTech, based in Irvine, Calif., and Hexagon Manufacturing Intelligence's NCSIMUL, acquired from a French software developer.

"Toolpath simulation and, more accurately, G-code verification, as performed by NCSIMUL, has historically helped manufacturers validate their programs, check the CNC machining process against any type of collision, and ensure that parts are produced right, the first time," said Silvere Proisy, NCSIMUL U.S. general manager. "Our user experience is articulated around those three steps, built into NCSIMUL verification since the beginning. Proving out CNC programs offline remains the predominant need for all users of toolpath simulation software and is even more crucial for multi-axis machining."

Developing greater ability to predict metalcutting issues is a significant emerging trend, he added. "While feed rate optimization when moving the spindle around parts or cutting material is the most obvious solution, simulating spindle torque limitations and cutting force applied to tools provides better technical data about the cutting process for programmers, even before parts head to real CNC machines," Proisy said. "Hexagon has addressed those optimization needs with

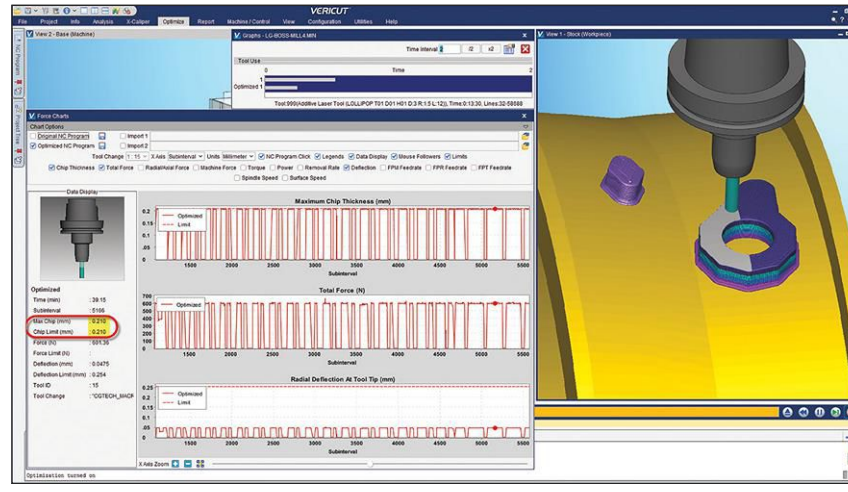
Optitool, and the physics of cutting with Optipower. We can even predict the areas of wear and tear on turning inserts."

Similarly, the G-code verification and optimization capabilities of VERICUT achieve higher accuracy with visualizations. "All roads lead to 'optimization,'" said Gene Granata, VERICUT product manager for CGTech. "Companies are searching for and learning which optimization products work best and deliver touted results. The shortest optimized run time isn't always best—it's more about 'real' constant chip thickness and consistency of machining conditions that provide the best overall results, increased tool life and extended CNC machine longevity."

Using specialized NC toolpath optimization software like VERICUT's Force optimization can address all of these issues in real time or batch processing, on new or existing NC programs, and destined for any NC machine—which is key for automating metalcutting productivity, Granata noted. He said key elements include gathering data to make data-driven decisions (instead of "guesses"); more accurate data helps companies provide more competitive quotes in a world of shrinking profit margins; connecting to CNC machines is becoming more popular, primarily for monitoring overall equipment efficiency (OEE); and access to "good" machining data (not just "Big Data") can enable programmers to make better decisions, improve machining methods, and achieve optimal machining results the first time out. "Doing so early in the manufacturing process, at the NC programming and simulation levels, is much more cost- and time-effective than on-machine prove-outs and testing," he added.

Additions to CGTech's VERICUT 9.2 software include:

- improved speed with faster collision checking, turning and mill-turn operations, and machining with complex cutting tools such as those often distributed by cloud-based tooling repositories;
- new cutting data graphs that provide the means to gather more key information about machining processes, highlight tool overloads/safety concerns, and show when cutters are underutilized or machining methods are inefficient; and
- enhanced "learn" modes for optimization, and more optimization strategies such as calculating feed rates and subdividing tool motions to achieve constant ideal chip thicknesses as much as possible, while simultaneously ensuring maximum allowable tool deflection, cutting forces, and spindle power demands are not exceeded.



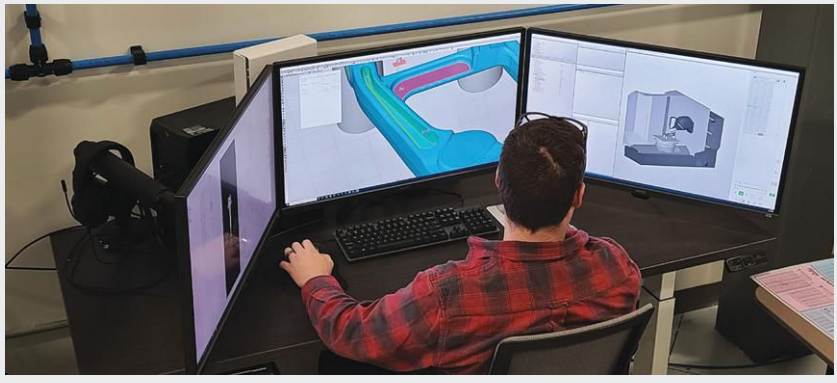

***Simulation with VERICUT Force Charts shows details of an optimized milling operation. Feed rates have been automatically adjusted to maintain constant ideal chip thickness as much as possible, resulting in machining times being reduced as much as 30 to 70 percent (as seen in horizontal bar graphs), while cutting forces are simultaneously kept at safe levels for the cutting tool and CNC machine. (Provided by CGTech)***

New features in NCSIMUL include faster processing as well as intermediate stock management that optimally restarts the simulation where the new G-code iteration generates a different result, Proisy said. "This is a smart way to save hours of simulation when setting up a new program with trial and errors.

"Beyond the traditional feed rate and force optimization capabilities, we are now addressing five-axis singularity point issues by predicting the lines of code where the user will have vibrations or surface quality issues," Proisy continued. "The simulation can rate the five-axis machinability from a cutting strategy and determine if the cutting feed rate is achievable; eventually the programmer will decide to reposition the part in the machine, if necessary. Before this new development, five-axis quality analysis could not be done prior to cutting the part, so bad surface quality could only be observed after the fact. Cutting time analysis for five-axis machining is becoming very important for better prediction; it's a key factor when deciding between the multiple five-axis strategies available."

# Simulations Optimize Nikola Motor's Machining Processes

**MACHINE TOOL SIMULATION** has been a standard part of manufacturing for over a decade. The challenge remains that while simulation can tell if a collision existed or not, it cannot do much to help overcome the challenges. Traditionally, simulation has been a pass/fail test. The programmer or manufacturing engineer must determine what toolpath adjustments are required to avoid the collision(s) and then repeat the test in simulation, often several times, until success is achieved.



***Nikola Motor Company used Open Mind's hyperMILL simulation software to optimize its manufacturing operations. (Provided by Nikola Motor Company)***

For Nikola Motor Company, using the *hyper*MILL Virtual Machine NC Optimizer from Open Mind Technologies, simulation not only uncovers collision problems, but also takes into account the bigger picture to help achieve the company's manufacturing goals, noted Riley Gillman, technical operations manager for the Phoenix-based manufacturer of electric semi-trucks. "The *hyper*MILL simulation software understands the kinematics and axis limitations of the machine tool, bringing a layer of software intelligence to automatically offer solutions to any problems we encounter. The software solves collision problems automatically, as well as optimizes the machine movement in ways that were not possible with our previous software."

The result is faster creation and execution of toolpaths and processes on the machine tool, resulting in much more efficient part production.

A recent example was a project where a fixture was too large for the machine tool. "I jogged the machine to see how far we could move the table in the Y axis without having the fixture collide with the machine and set soft limits," said Mike Jacobs, CNC prototype machinist for Nikola. "I was then able to set the same soft limits in the simulation environment, and the *hyper*MILL Virtual Machine NC Optimizer respected these limits when creating the NC program. Before using *hyper*MILL, the simulation I saw on my computer was not always what was happening at the machine, so collisions were common and I had to waste time running vectors—a time-consuming and complicated process."

Also, traditional postprocessing and simulation software does not recognize retraction to a safety point for reapproach—the tool leaves the clearance plane and "you are in the dark again," Jacobs added. "To solve this, the *hyper*MILL Virtual Machine NC Optimizer offers an incredibly productive job linking capability. For example, I have a part that has 200 separate jobs, so having the automatic, multi-axis job linking capability within *hyper*MILL Virtual Machine NC Optimizer is a huge benefit. The software keeps the tool close to the part from one frame to the next, without any extra instruction from me. Having reliable software to manage multi-axis movements from toolpath to toolpath with the smallest amount of space and distance possible—all while collision-checking the entire part and fixture within the machine travel limits—is a very big deal. And we are getting all this functionality with an excellent, user-friendly interface—just straightforward text and check boxes, which are easy to understand."

## What Users Look For

Machining is a complex process that must be simulated rapidly and accurately, noted DP Technology's Mathews. "With ESPRIT, we have integrated SimNC from Binary Spaces as the simulation engine for our digital twin simulations for programming, simulation, and optimization," he said. "The simulation engine is only one piece of the puzzle; what's more important is the amount of correct data for the various machine models on the market."

Binary Spaces, based in Teltow, Germany, has developed a new data format called GDML to support the definition of digital twins for machines, fixtures, and tooling, he noted. "Through extensive collaboration between ESPRIT and the machine tool OEM partners, the large GDML data library has been growing rapidly in the last few years to support the needs of our end users."

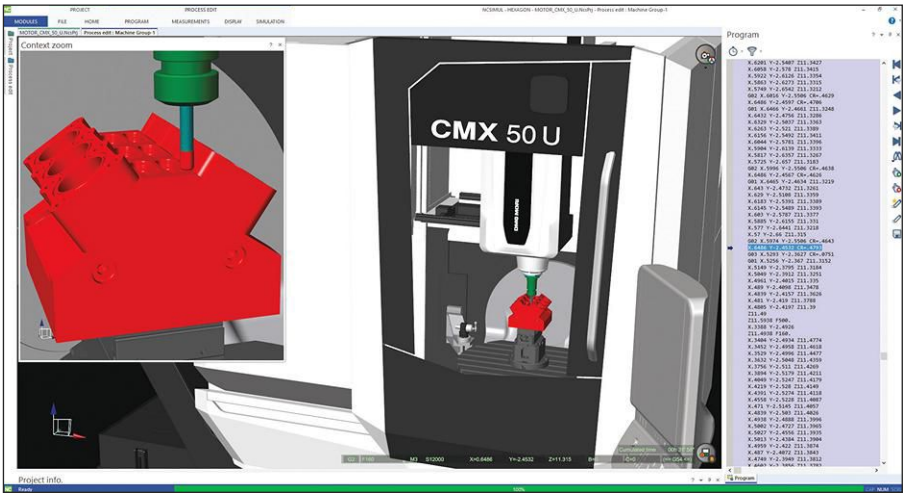
Toolpath simulation software is continually evolving to add higher assurance in order to consistently and reliably

anticipate a manufacturing process. "Using a 'digital twin' concept to model the actual machine components and controller performance, the computed toolpaths are simulated to identify collision potential and to enable high productivity on the machine tools," said Alan Levine, managing director, Open Mind Technologies USA Inc., Needham, Mass. "While third-party simulation software products check toolpaths independently of the CAM engine, current simulation systems from CAM manufacturers can improve the quality of the simulation by being able to connect detailed programming parameters in addition to the basic information of part, stock, cutter and toolpath. The availability of the complete manufacturing context avoids cumbersome and time-intensive efforts for individual verification of collision areas, and enables automation without losing safety."

In addition to traditional simulation tasks, the *hyper*MILL Virtual Machine NC Optimizer provides novel technology to manufacturers, Levine noted. "Not only are toolpaths checked against the part and machine models, but toolpaths can be optimized with respect to the machine tool kinematics and specific geometry elements, such as an asymmetric head or an offset head," he said. "While most CAM systems calculate with a view of the workpiece, tool and a fixture device, the *hyper*MILL NC Optimizer calculates best toolpath solutions while also considering the entire machining environment."

With integration between the CAM software and simulation, the *hyper*MILL NC Optimizer can also access program settings and use them to determine preferred toolpaths, Levine said. "For example, a programmer may want to change a hole depth without changing the CAD model, or drill a hole to be larger than the model. In these cases, there is a collision relative to the part model, but there is not a collision relative to the part model considered together with the programming allowances. Traditionally, the simulation is checking if toolpaths from the CAM system produce a collision or not, providing a go, no-go result," Levine added. "With the *hyper*MILL NC Optimizer, the simulation environment is doing this and also improving the toolpath."

Plug-in toolpath components are important to the simulation systems provided by CAM vendors, he said, noting that Open Mind uses MachineWorks' kernel for machine simulation. The UK-based MachineWorks plug-in kit provides material removal (or addition) and collision check. "The CAM provider decides how to use these tool kits and adds their own analysis capabilities, such as the *hyper*MILL NC Optimizer," Levine said. "The total simulation solution includes the standard material displays and collision notices as well as advanced functionality from the *hyper*MILL Virtual Machining environment, including smooth linking, analysis of constrained linear or rotary axis ranges, selection of five-axis machine variants and more."




***An engine block is simulated in Hexagon's NCSIMUL toolpath simulation software. The latest update includes speed and feature improvements to enhance the user experience and improve manufacturing quality. (Provided by Hexagon Manufacturing Intelligence.)***

## FYI

**CGTech**
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**DP Technology Corp.**
800-627-8479 / www.espritcam.com

**Hexagon Manufacturing Intelligence Division**
617-401-2197 / www.ncsimul.com

**CAMWorks/HCL Technologies Ltd.**
480-367-0132 / www.camworks.com

**Open Mind Technologies USA Inc.**
888-516-1232 / www.openmind-tech.com