Tech-Clarity

Addressing the Bottlenecks of FEA Simulation:

Enabling Innovation by Getting Even More Value from CAE

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Executive Overview

As companies seek to improve profitability and competitiveness, investments in the product development process can yield big returns. Empowering teams to make the best design decisions puts them in a great position to bring innovative, high quality, profitable products to market.

Simulation can be a powerful tool for supporting better decisions. However, several steps during the simulation process can slow things down and prevent companies from taking full advantage of potential benefits. Understanding simulation challenges can help companies put the right capabilities in place so they may realize even more value from simulation tools.

Simulation can be a powerful tool for supporting better decisions.

What challenges do companies experience as part of the simulation process? What slows the process down? How do successful companies get the most value from simulation? To answer these questions, Tech-Clarity surveyed over 160 manufacturers about their simulation processes. The results were analyzed to identify the top challenges associated with preprocessing, preparing for the solver, and postprocessing.

The research finds that:

- Preprocessing is the most time consuming part of the simulation process, taking up 38% of total simulation time
- Top challenges of preprocessing include finding problematic geometry, recreating CAD geometry, and defining assembly contacts
- Top challenges of postprocessing involve the time invested in filtering through vast amounts of data

The research also highlights the complexity of the environments in which analysts work. Companies report using 3.6 different CAD tools on average, with 84% using two or more CAD tools. Companies also work with 3.3 different solvers for analyses. This further aggravates the challenges associated with preparing models for analysis.

Preprocessing is the most time consuming part of the simulation process, taking up 38% of simulation time

Further analysis identified how Top Performing organizations address these challenges. Top Performers are those who are more successful than their competitors. Compared to competitors, they are more efficient, more innovative, produce higher quality products, and do a better job meeting cost targets. Some of the things they do to achieve this

success includes:

- Automating many time consuming, tedious tasks associated with preprocessing. They are twice as likely to automate assembly contact definition and 4-times as likely to automate geometry clean up.
- Maintaining flexibility and control so that models are not overly simplified and mesh size is appropriate. They are 52% more likely to have the ability to edit and control the mesh.
- Using visual filtering and sorting tools to more easily review, analyze, and share simulation results. They are 2.2 times more likely than peers to visually filter results, which allows them to interrogate the results and quickly focus on areas of interest.
- Ensuring their simulation solution works for their multi-CAD environment. They are 89% more likely than their peers to look for a simulation solution that has the ability to work with multi-CAD data.

Top Performers are twice as likely to automate assembly contact definition and 4-times as likely to automate geometry clean up.

In addition to examining the bottlenecks associated with simulation, this report provides guidance on best practices to address them. These practices will help product development teams get even more value from simulation so that they can make the right product decisions that will lead to more profitable products.

Support Business Goals with the Right Design Tools

The amount of competition in today's global economy makes it very difficult for a company to develop products that stand out. However, by empowering engineers to make the right design decisions, companies are more likely to release differentiated products with the qualities that win over new customers, while maintaining the loyalty of existing customers. Those who make smart investments in their product development processes will be better positioned to make the right design decisions to bring more competitive products to market. With this in mind, companies indicate there are a variety of goals driving their investments in the design process (Figure 1).

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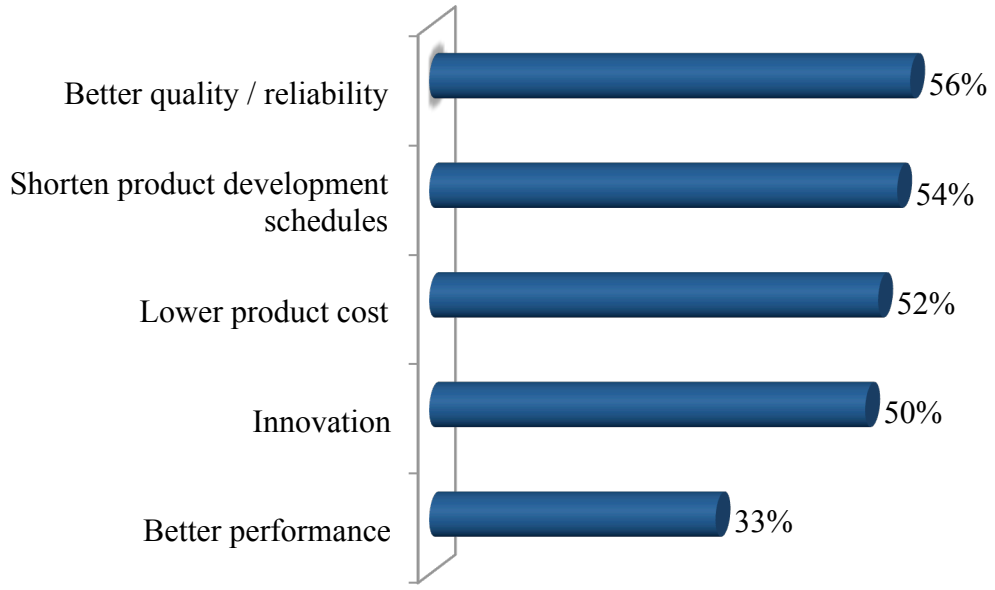

Figure 1 – Top 3 Goals Driving Design Investments

Product goals of higher quality and lower cost have a strong influence on design investments. At the same time, these goals often conflict, so balancing them is complicated. Product development teams need ways to conduct trade-off analyses to understand the impact of design decisions on both cost and quality. Investments into design tools can help provide this insight, empowering development teams to make better decisions.

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Time to market is also critical for competitiveness. Getting to market first enables companies to capture market share before competitors can respond. At the same time, product cycles have gotten so short, the window of opportunity for maximum revenue potential has shrunk. After releasing a product, companies have less time to recoup their development investment and collect revenue before the product is superseded by the next version or worse, replaced by a competitor's product. With this in mind, companies need to be as efficient as possible. Investments in design tools can help improve efficiencies, as well as help teams catch problems earlier and avoid release delays.

Innovation is also a critical influencer. Innovation often comes from iterating and evaluating different ideas. Investments in the design process can help companies evaluate more options in less time. While innovation can create revenue opportunities, it can also

introduce risk by the very nature of being new. With the right tools, companies can run through more virtual tests to become more innovative, while minimizing this risk.

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Examine the Value of Simulation

Simulation represents one product development investment that can support the goals listed in Figure 1. Simulation tools provide insight into product strength and quality as well as cost drivers such as the amount of material required. They can help identify problems early, when it is more cost effective to fix them. They also allow efficient evaluation of different design options to support innovation. In fact, Tech-Clarity's study, The Business Value of Simulation finds, "*Simulation allows companies to meet the demands for reduced cost and faster time to market, but without compromising product quality*." The study also finds simulation can offer further benefits. "*Beyond cost reduction, simulation helps companies raise the bar on their products. Simulation can help companies gain better insight and understanding of the physical behavior of their products than testing ever could. It also helps them innovate, allowing the freedom to test new concepts with confidence. Whether they are optimizing for weight, material reduction, and cost or testing new innovative concepts, early simulation helps manufacturers explore and learn from more design iterations*."

Understanding bottlenecks in the process and what to look for in a simulation tool can help ensure design investments achieve the desired goals.

However, the analysis process is involved and not all simulation tools are equal. Understanding bottlenecks in the process and what to look for in a simulation tool can help ensure design investments achieve the desired goals.

Identifying the Top Performers

To understand how the most successful companies approach simulation, Tech-Clarity identified Top Performing companies. Survey respondents were asked to rank their performance in relation to their competitors on four key design metrics. Respondents used a scale of one to five, with five being extremely effective. The top 20% were defined as the Top Performers. Table 1 shows the metrics used to define success and each group's respective performance.

	Top Performers	Average Performer
Develop products efficiently	4.2	3.3
Design high quality products	4.8	3.6
Meet product cost targets	4.0	3.1
Develop innovative products	4.7	3.5

Table 1 – Defining Top Performers

From Table 1, it is clear that Top Performers are more empowered to make the right design decisions. They have the insight to make trade off decisions to meet goals for quality, while still meeting cost targets. They can run through enough iterations to arrive at more innovative decisions. They accomplish all of this while still maintaining efficiency.

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Understand the Simulation Process

When looking to improve simulation, there are several distinct phases involved. Conducting a simulation involves:

- **Preprocessing**: The process of preparing a model for simulation and analysis. This includes defining the geometry, mesh, and boundary conditions. This step may involve simplifying the model. Models are often simplified by removing small features such as holes and tiny edges that do not impact product performance, but add to the calculation time of the analysis.
- **Solver**: After preprocessing, the model is ready for the analysis. The solver performs the numerical computation based on modeling input, and calculates displacements, forces and stresses within the model.
- **Postprocessing**: Once the solver finishes its calculations, it is ready for postprocessing. Postprocessing involves analyzing the results determined by the solver.

Figure 2 shows the proportion of overall simulation time each phase consumes. At 38%, preprocessing consumes the most simulation time, followed by postprocessing, and then waiting for the solver.

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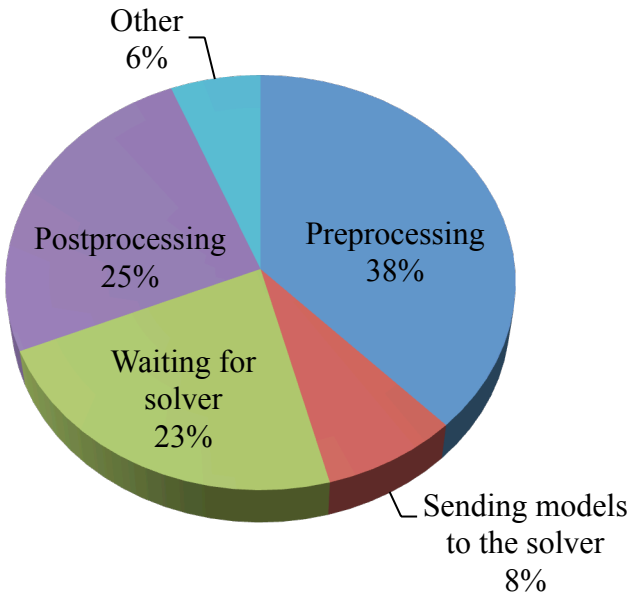

Figure 2 – Breakdown of Simulation Time

We will examine each phase to understand where to prioritize improvements and look at best practices for doing so.

Identify Improvement Opportunities during Preprocessing

Preprocessing involves several time consuming and tedious tasks. Preprocessing was also the top area respondents said needed improvement, reported by 32%.

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Figure 3 shows how much time each of these activities consume as a percentage of the total preprocessing process.

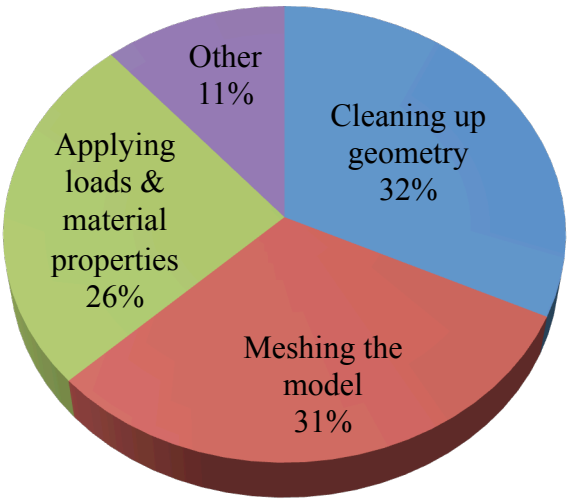

Figure 3 – Percent of Time Spent on Each Preprocessing Task

Given the amount of work involved, challenges with this stage were broken into two groups: cleaning up the geometry and preparing the model.

Cleaning up geometry is a very time consuming aspect of preprocessing, consuming 32% of preprocessing time.

Cleaning up geometry is a very time consuming aspect of preprocessing, consuming 32% of preprocessing time. The geometry used in the simulation model can come from a variety of sources. The most common sources of geometry are native CAD models (reported by 61%) or CAD models that have been translated into a neutral format such as STEP or IGES (reported by 62%). This geometry must then be brought into a CAE tool and prepared for analysis. Figure 4 shows the top challenges associated with this process (respondents were asked to select the top two).

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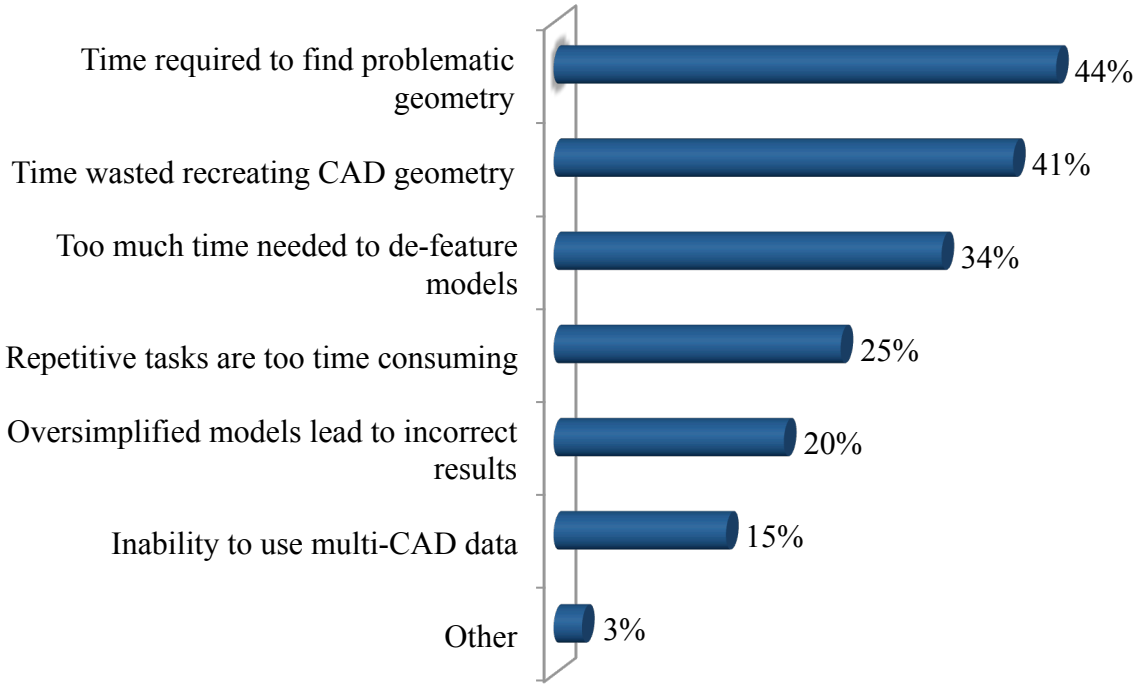

Figure 4 – Top Challenges of Geometry Clean Up

When importing the model into CAE, some geometry may not translate perfectly; this can cause problems with the analysis. Identifying these problem spots consumes a lot of time, and was rated by 44% as a top challenge. In some cases, the geometry cannot be fixed and must be recreated which duplicates efforts and wastes valuable time.

Identifying problem geometry is very time consuming, which is why 44% rated it as a top challenge.

To reduce the time the solver needs for analysis, models are typically simplified by removing features, such as small edges that will add to processing time, but have little impact on performance. However, de-featuring the model must be done very carefully so as not to remove features that will impact performance. For example, while small edges will usually not impact performance, in some cases, a small undercut could create a stress point that should be analyzed. With too much simplification, results will be wrong, diminishing the value of the analysis.

Once the geometry for the simulation model has been defined and cleaned up, features required for the analysis are added to the simulation model. This includes the mesh, boundary conditions, and loads. Figure 5 shows the challenges associated with this part of preprocessing. Respondents were again asked to pick the top two challenges.

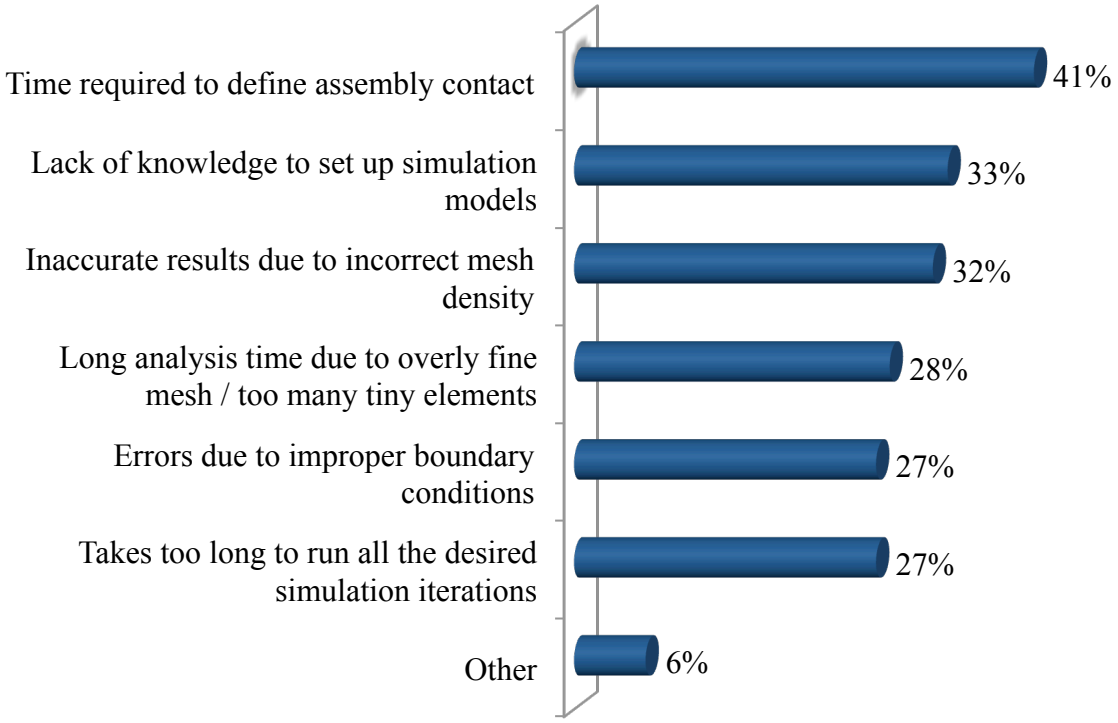

Figure 5 – Top Challenges of Simulation Model Definition

While it is important to understand the behavior of individual parts, understanding how those parts interact within the context of an assembly gives a more accurate picture of how the product will work as a whole. However, assembly joints and degrees of freedom impact performance. Are components glued, welded, or bolted together? Each contact must be defined, but this can be very time consuming.

Defining mesh density is another challenge of simulation model definition. The numerical methods used by CAE software typically require the model to be divided into small elements. The combination of these small elements is called a mesh. If the mesh is too big, results will be less accurate, but if it is too small, it will take the solver a long time to process. Mesh size is one of the many assumptions that must be made when defining analysis models. Other assumptions include boundary conditions and loads. The ability to make the right assumptions comes with knowledge and experience. If the wrong assumptions are made, the analysis results will be wrong or misleading.

Finally, to support goals around innovation and conduct trade-off analyses, it is important to evaluate multiple design iterations. However, the preprocessing involved for each iteration is time consuming.

Figure 6 shows some of the best practices Top Performers are more likely to adopt than their average performing peers.

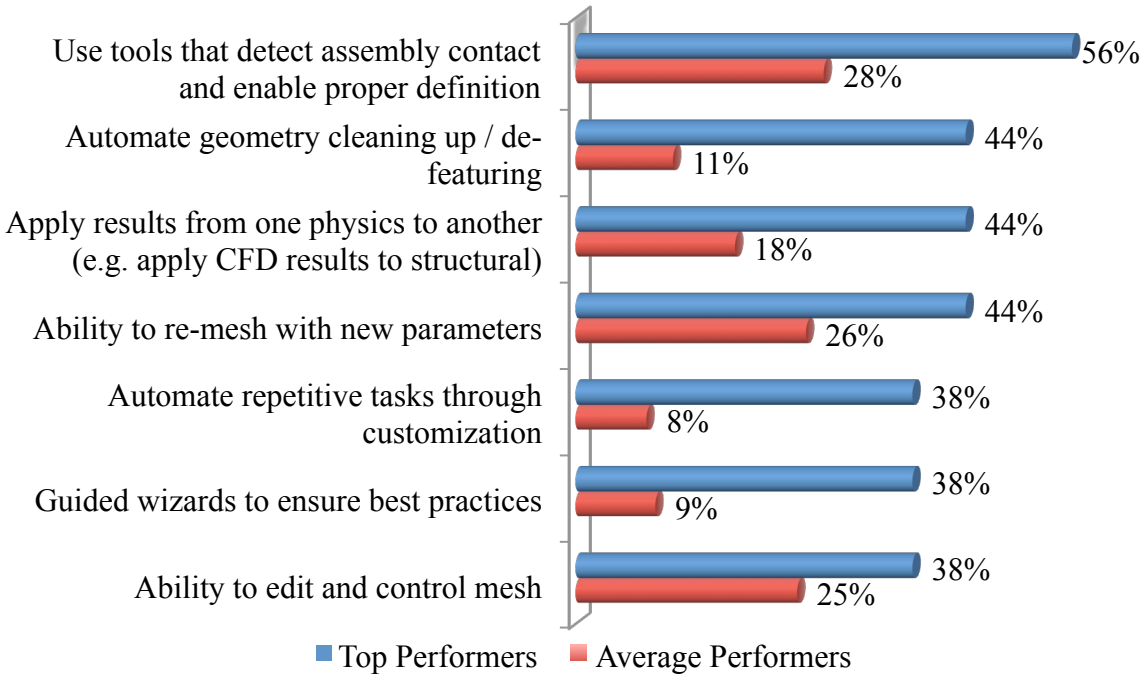

Figure 6 – Preprocessing Best Practices

Top Performers are more likely to take advantage of multiple automation capabilities to speed up the tedious and repetitive tasks of preprocessing. They are twice as likely to automate assembly contact definition and four-times more likely to automate geometry clean up. They are also 4.75 times as likely to take advantage of customization for further automation. All of this saves time and reduces the workload involved with preprocessing. Top Performers also take advantage of automated meshing, but more importantly, they still have the ability to control and edit it for cases when the mesh is not sized properly. Top Performers are 69% more likely than peers to have the ability re-mesh with new parameters. This reduces the time needed to evaluate multiple iterations, making it easier for Top Performers to innovate and optimize. Finally, Top Performers are 4.2 times more likely to use guided wizards to ensure best practices are followed. This guides the process of defining the model properly and helps avoid incorrect assumptions.

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Prepare for the Solver

Once the model is preprocessed, it must be prepared and sent to the solver for analysis. Figure 7 shows the top challenges associated with this process. Respondents were asked to pick the top three.

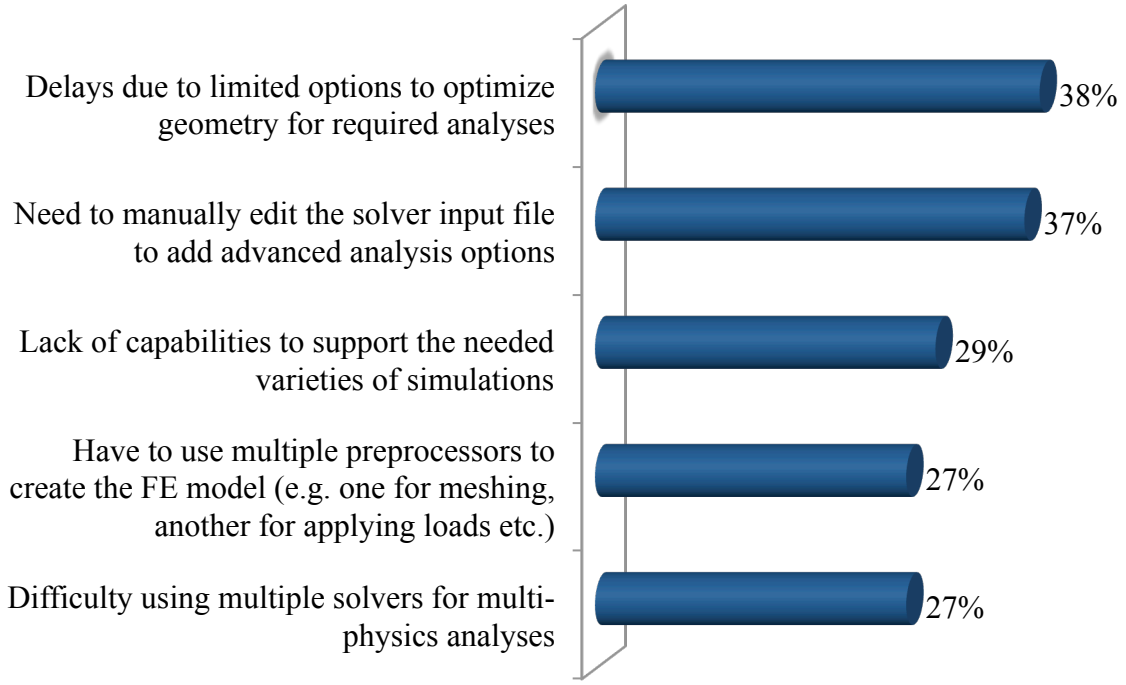

Figure 7 – Top Challenges Preparing for the Solver

Based on the type of analysis required, different solvers may be needed. For example, CFD (computational fluid dynamics) and structural analysis each have their own solver. On average, companies report using 3.3 different solvers. For each solver, the simulation model may need adjustments based on the type of analysis done. The model may also need to be simplified with a different approach or the mesh size or shape may need to be adjusted. If preprocessing tools lack the capabilities needed to optimize the model for the desired analysis, you have to either skip the analysis or use multiple tools, the latter of which adds time and complexity to the process.

On average, companies report using 3.3 different solvers.

Top Performers are 89% more likely than their peers to address these challenges with preprocessing tools that have the flexibility to optimize the model for the desired analysis (Figure 8).

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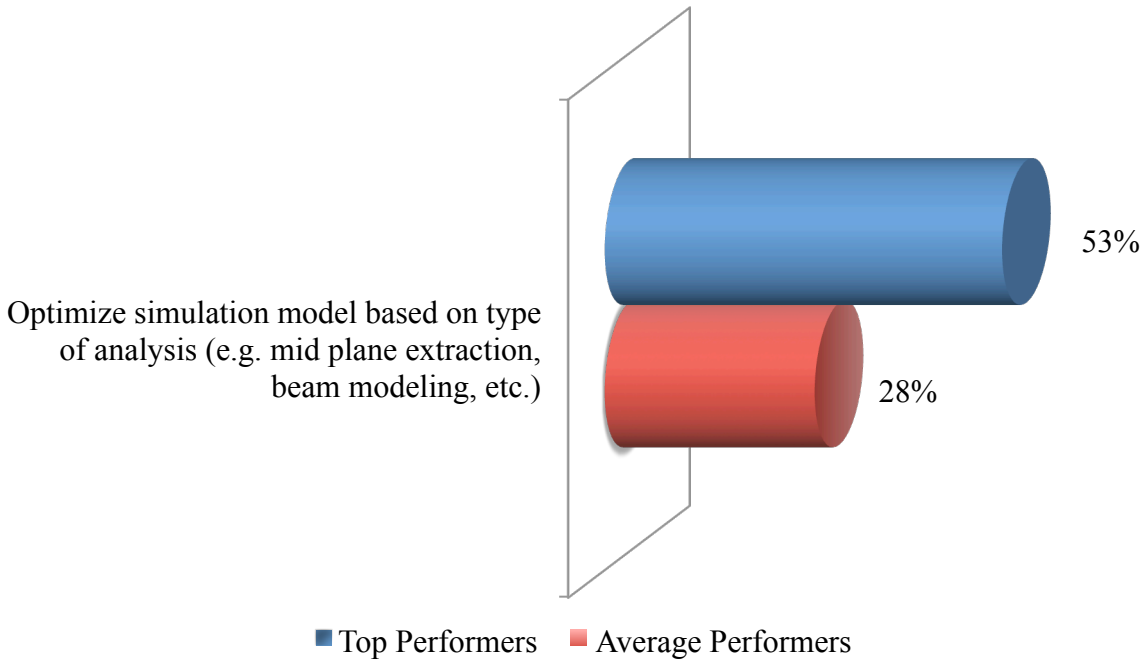

Figure 8– Best Practices Preparing for the Solver

Streamline Postprocessing

Once the solver completes the analysis, the results must be prepared for analysis. Figure 9 shows the breakdown of the tasks involved with postprocessing as well as the proportion of time involved. Fifty-four percent (54%) of postprocessing time goes toward working with the data, getting it ready for analysis.

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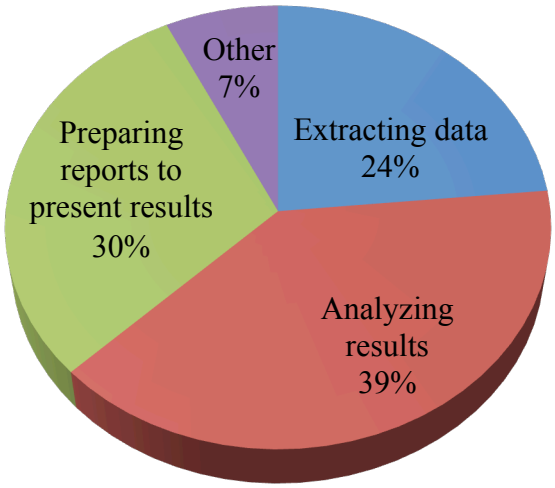

Figure 9– Percent of Postprocessing Time on Each Task

As Figure 9 shows, over half the time spent on postprocessing involves getting the data and results ready for analysis.

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The top challenges associated with postprocessing can be found in Figure 10. Respondents were asked to pick the top two.

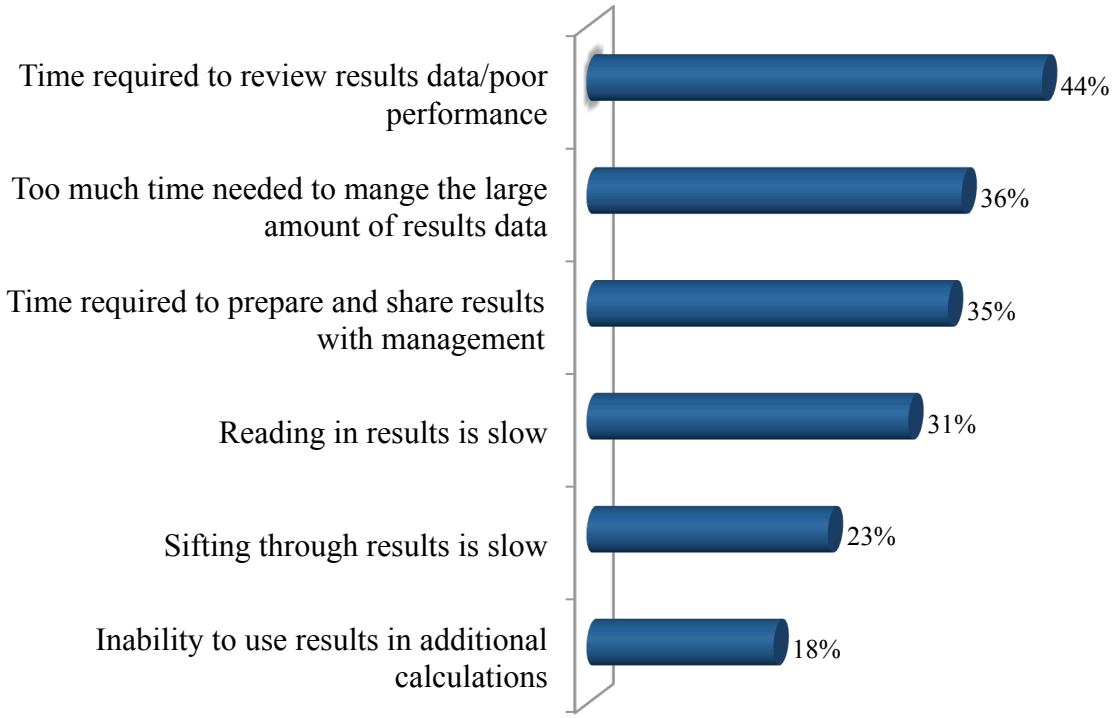

Figure 10 – Top Postprocessing Challenges

All of the postprocessing challenges are related to the overwhelming amount of data involved and the time required to review it. Companies need better ways to work with the results to more efficiently interpret them. Adding to the time required, the results are not in a format that is meaningful to management and more time must be invested to put the results in a format management can consume.

Figure 11 shows how Top Performers address these challenges.

Top Performers take advantage of tools that help them quickly sort and review the results so that they can get the view they need for analysis.

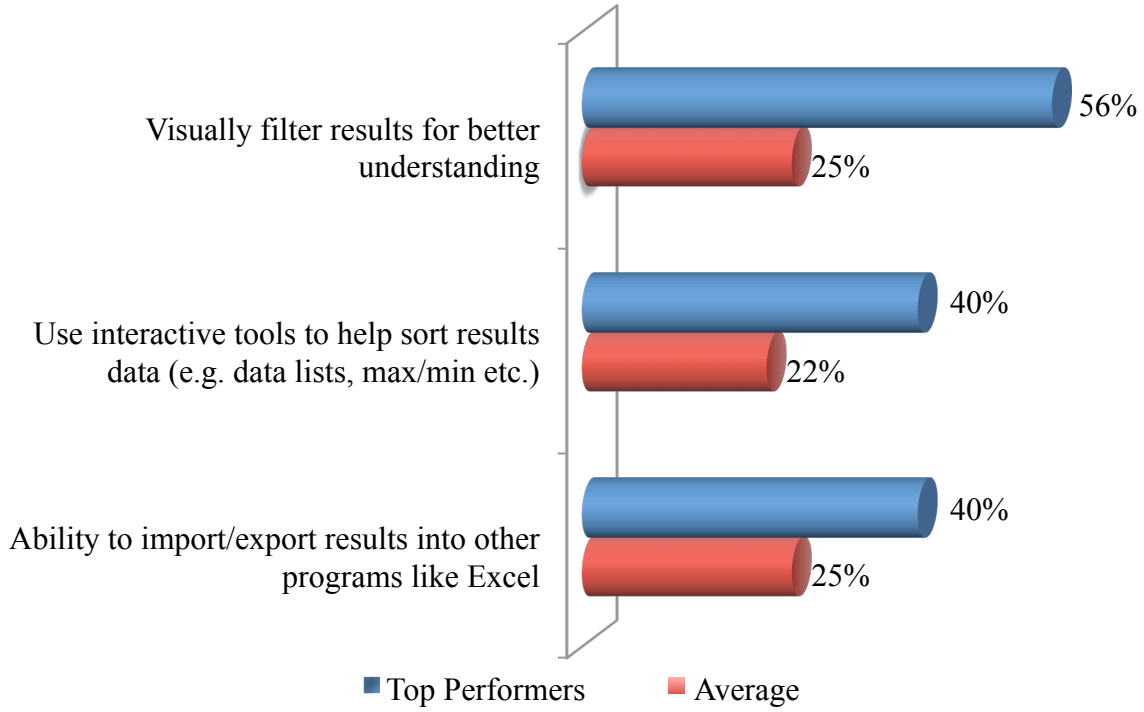

Figure 11 – Postprocessing Best Practices

Top Performers take advantage of tools that help them quickly sort and review the results so that they can get the view they need for analysis. They are 2.2 times more likely than peers to have the ability to visually filter results, which allows them to interrogate the results and quickly focus on areas of interest. They are also 82% more likely to have interactive tools to help sort results, which helps to manage the large amount of data. They can also export results to other programs such as Excel so that they can be used in additional calculations.

Top Performers are 2.2 times more likely than peers to have the ability to visually filter results, which provides a nice way to interrogate the results and quickly focus on areas of interest.

Look for the Right Qualities in a Simulation Solution

In order to support best practices, Top Performers value certain qualities in a simulation tool (Figure 12).

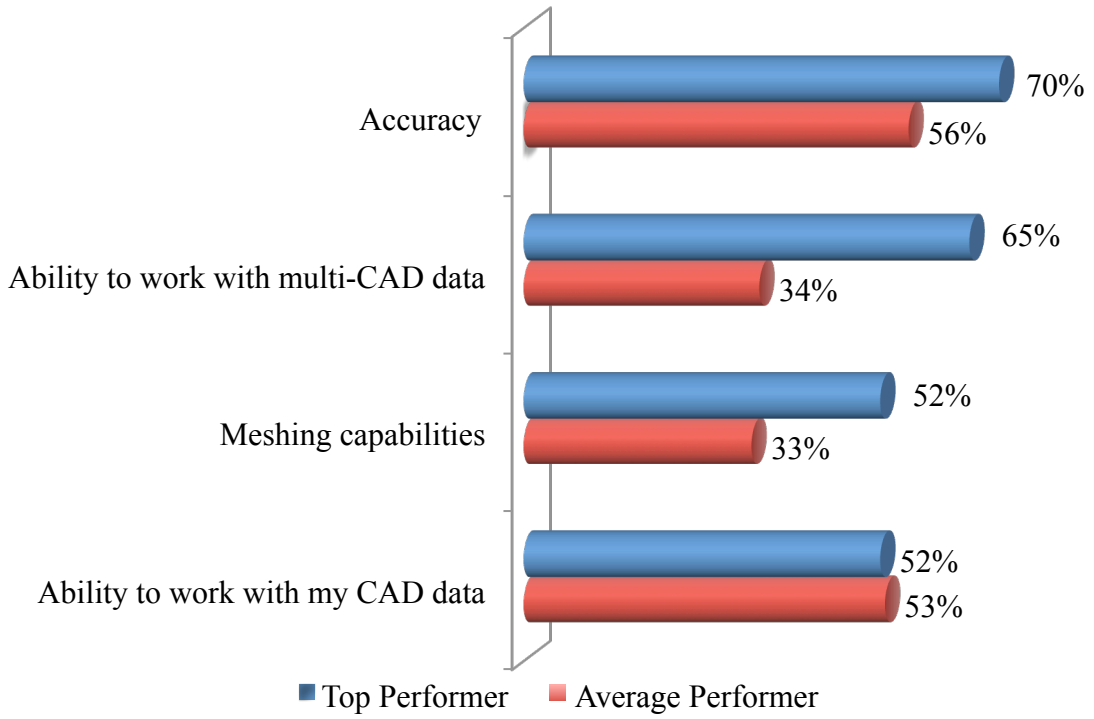

Figure 12 – Important Qualities in a Simulation Tool

Accuracy is most important, as the analysis is useless if the results cannot be trusted. Companies report using 3.6 different CAD tools on average, with 84% using two or more. Given how prominent multi-CAD environments are, Top Performers are 89% more likely than their peers to look for multi-CAD support. This enables them to work with all files in a single environment, as well as the flexibility to work with data from customers and suppliers if needed. For Top Performers, support for multi-CAD data is even more important than the ability to work with an individual CAD system.

Companies report using 3.6 different CAD tools on average, with 84% using two or more.

Top Performers are also 57% more likely to value meshing capabilities. Considering that preprocessing consumes the most time of the simulation process, yet has a direct impact on the accuracy of the results, it is an important area to evaluate when looking at a simulation tool.

Top Performers are 89% more likely than their competitors to look for the ability to work with multi-CAD data

When making investments in simulation tools, it also important to select a vendor who will meet your needs. Figure 13 lists the vendor qualities most valued.

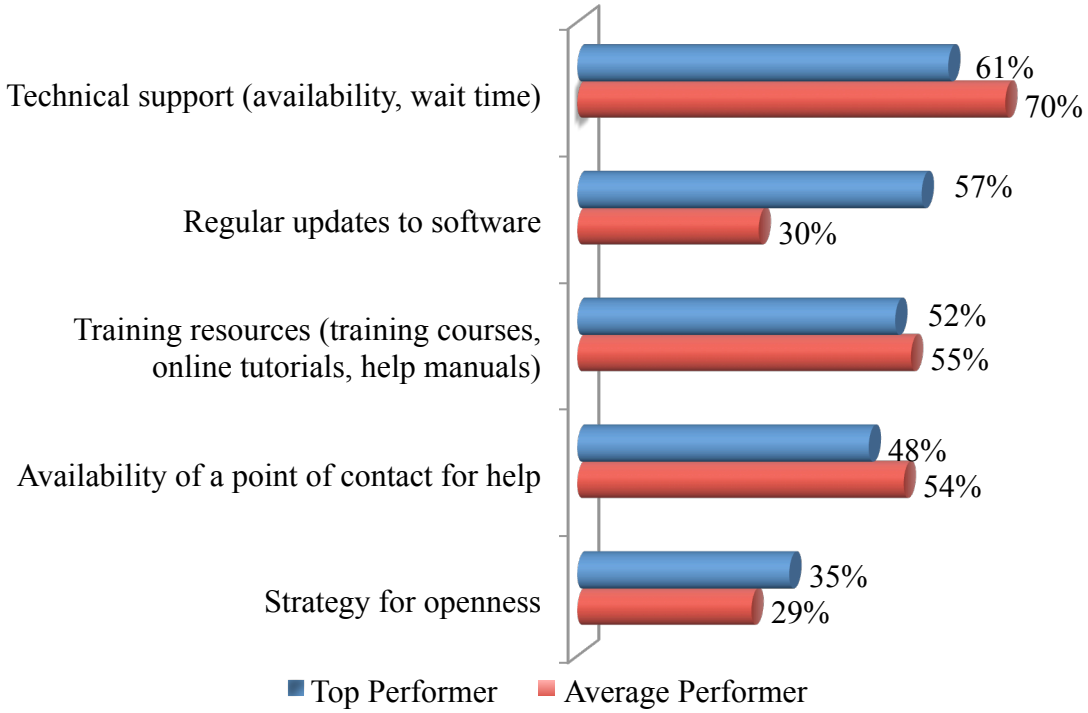

Figure 13 – Preferred Qualities in a Simulation Vendor

Top Performers and Average Performers largely value the same qualities in a vendor. It is important to work with a vendor who is a true partner and provides the needed support resources to ensure you are successful with their software. Respondents rate Technical Support, training resources, and a single point of contact among the most important qualities in a vendor.

Respondents rate Technical Support, training resources, and a single point of contact among the most important qualities in a vendor.

The area with the biggest difference is regular updates to the software. Top Performers are 90% more likely to value a vendor who is actively developing their product and providing regular updates to the software.

Companies also value a strategy for openness. Given how common multi-CAD environments are, companies appreciate a vendor who is open to supporting other formats.

Conclusion

To beat the competition, companies need to develop products that are innovative and high quality, yet cost effective. Accomplishing this requires good decisions during development, and supporting design decisions drives many companies to make investments in the design process.

Simulation tools enable companies to efficiently make better decisions about cost and quality. They also guide decision making around experimentation, which leads to greater innovation. However, there are several places that slow down the simulation process and impede overall product development. Looking at tools that improve the efficiency of these areas will enable better decisions.

Best practices used by Top Performers enable them to beat the competition with more innovative, high quality products that meet cost targets.

Top Performing companies have implemented best practices to address many of the top simulation challenges. This helps them get even more value from their investments in simulation tools. As a result, they beat the competition with more innovative, high quality products that meet cost targets. These practices include automating time consuming, tedious tasks associated with preprocessing. They also use visual filtering and sort tools to review and share simulation results. As a result they can make better decisions, more efficiently, which helps them stand out from their competitors. They also look for tools that support multi-CAD data. This gives them flexibility to work with the data in their environment, no matter where it came from including others in the company, legacy data, suppliers, or customers.

Recommendations

Based on industry experience and research for this report, Tech-Clarity offers the following recommendations:

- Invest in the development process to improve innovation, increase quality, and lower cost. This represents the biggest opportunity to differentiate your products from the competition.
- Leverage simulation tools to support goals to make products more competitive. Simulation provides insight into product behavior to not only identify problems early on, but to also understand the impact of trade-offs so that design decisions are better informed.
- Automate tedious and time-consuming preprocessor tasks. This includes defining assembly contact, identifying problem geometry, and common workflows.

Preprocessing is the biggest bottleneck of simulation. Automating these tasks will save time so that results are available sooner, more analyses can be done, and companies will realize even more value from their simulation tools.

- Use meshing tools that provide automation as well as flexibility so that mesh size is appropriate. Meshing models is one of the most time consuming tasks of simulation. Automating it will save a lot of time, but flexibility enables options to make adjustments to mesh size when needed. For example, in critical performance areas, a finer mesh may be needed so that more calculations are done in that area for even greater accuracy or areas of little consequence can be given a larger mesh that will take less time to process.
- Balance automated de-featuring with control so that models are not so simplified, analysis results are unreliable. De-featuring is also one of the biggest time sinks for simulation so automated de-featuring will save time, but having some control gives the analyst the flexibility to ensure features, such as tiny edges that create stress points, are not removed from the analysis.
- Reduce the time to evaluate multiple iterations with functions that automate re-meshing a model with new parameters. With some solutions, when the analysis is rerun with new parameters, the mesh must be recreated, which adds time. The option to automatically re-mesh with new parameters means more iterations can be evaluated, without wasting time recreating the mesh each time.
- Use postprocessing tools that make it easier to work with all the resulting data. The top postprocessing challenges are related to the overwhelming amount of data produced during analysis. Tools that make it easier to work with all of this data, such as visual filters and sorting tools, will make it easier to analyze the results.
- Select tools that can work with multi-CAD data as needed. Companies report using 3.6 CAD tools on average which means they need simulation tools that can work with a variety of multi-CAD data.
- Use a vendor who can provide needed support resources. Companies identify the availability of technical support as the most important quality of a simulation vendor. When help is available when it is needed, down time and frustration can be minimized as users can reach out and then move on with assistance from technical support.

About the Author

Michelle Boucher is the Vice President of Research for Engineering Software for research firm Tech-Clarity. Michelle has spent over 20 years in various roles in engineering, marketing, management, and as an analyst. She has broad experience with topics such as product design, simulation, systems engineering, mechatronics, embedded systems, PCB design, improving product performance, process improvement, and mass customization. She graduated magna cum laude with an MBA from Babson

College and earned a BS in Mechanical Engineering, with distinction, from Worcester Polytechnic Institute.

Michelle began her career holding various roles as a mechanical engineer at Pratt & Whitney and KONA (now Synventive Molding Solutions). She then spent over 10 years at PTC, a leading MCAD and PLM solution provider. While at PTC, she developed a deep understanding of end user needs through roles in technical support, management, and product marketing. She worked in technical marketing at Moldflow Corporation (acquired by Autodesk), the market leader in injection molding simulation. Here she was instrumental in developing product positioning and go-to-market messages. Michelle then joined Aberdeen Group and covered product innovation, product development, and engineering processes, eventually running the Product Innovation and Engineering practice.

Michelle is an experienced researcher and author. She has benchmarked over 7000 product development professionals and published over 90 reports on product development best practices. She focuses on helping companies manage the complexity of today's products, markets, design environments, and value chains to achieve higher profitability.

About the Research

Tech-Clarity gathered and analyzed 160 responses to a web-based survey on designing and simulating products. Survey responses were gathered by direct e-mail, social media, and online postings by Tech-Clarity and Desktop Engineering.

The respondents were comprised of 46% who were individual contributors. Another one-third (32%) were manager or director level, and the remaining 22% from VP or executive levels.

The respondents represented a mix of company sizes, including 32% from smaller companies (less than $100 million), 20% between $100 million and 25% greater than $1 billion. 23% chose not to disclose their company size or did not know it. All company sizes were reported in US dollar equivalent.

The responding companies were a good representation of the manufacturing industries, including Industrial Equipment and Machinery (30%), Aerospace and Defense (20%), Automotive (18%), High-tech and Electronics (15%), Life Sciences (14%), Consumer Products (9%), and others. Note that these numbers add up to greater than 100% because some companies indicated that they are active in more than one industry.

The respondents reported doing business globally, with most companies doing business in the North America (85%), about one-third doing business in Western Europe (32%),

Asia-Pacific regions (27%), Eastern Europe (10%), Latin America (13%), and Africa (5%).

Respondents not directly involved in designing and/or manufacturing products were excluded from the analysis.