THE VALUE OF VIRTUAL SIMULATION VERSUS TRADITIONAL METHODS

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Virtual Simulation users saw a 16% decrease in overall development time and a 13% decrease in overall product cost for new products.

Based on the experiences of over 550 respondents, this report will explore how companies today are approaching New Product Development and Introduction (NPDI) and product simulation. Specifically, how companies who have turned to virtual simulation have outperformed their peers who **still rely solely on manual calculations or physical prototyping**.

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The push to more innovative and complex products helps to differentiate products from competitors; it also results in designers being forced to make trade-off decisions between speed, cost, and quality.

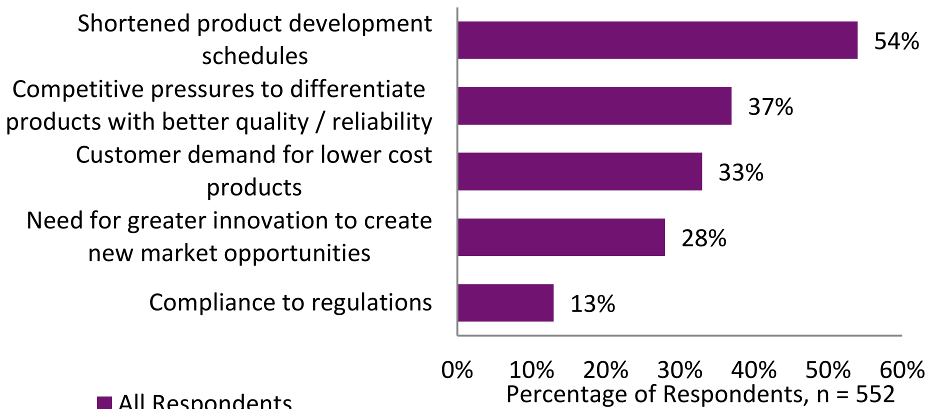
As companies struggle to competitively differentiate their products as well as beat their competitors to market, quick decisions within engineering have become increasingly critical to product success. These decisions can have a profound impact on three important factors for a product – speed of development, cost, and quality. Many have turned to simulation to help designers make effective decisions. However, increasing product complexity leaves companies struggling to accurately predict the behavior of their products prior to physical testing. Hand calculations can no longer keep up with the needs of designers today and prototyping is expensive and time consuming. As a result, Best-in-Class companies are turning to simulation software to arm their employees with the insight needed to develop and optimize today's products.

New Products are Critical for Success

New products are the backbone for most organizations these days, as over a third of a company's revenue can be earned from these products (37% of total revenue from recent Aberdeen research). Of course, competitive pressures are high to successfully deliver these new products (Figure 1). To beat their competitors, companies must get to market quickly with their products. Aberdeen's research has shown that the timely launch of a new product offers an organization's greatest opportunity for increased profitability, especially in industries like life sciences or high tech where the voice of the customer is becoming the number one priority. Designers also need efficient methods for making better decisions to improve quality, while keeping their products economical.

At the same time, companies need a better understanding of product behavior to enable the innovations that will create the market opportunities needed for new revenue streams. But as innovation is increased within a product, so too is the complexity of designing that product. This push to more innovative and complex products helps to differentiate products from competitors; it also results in designers being forced to make trade-off decisions between speed, cost, and quality.

Figure 1: Balancing a Multivariate NPDI* Equation



Souce: Aberdeen Group, July 2014

*NPDI - New Product Development and Introduction

Effectively balancing these factors is much easier said than done – trying to achieve this equilibrium has many challenges itself (see sidebar). Complexity is, by far, the overwhelming challenge felt by companies today when trying to develop new products – making it harder to evaluate the impact of different design alternatives. This complexity is across the board as well; no matter the industry, products are becoming increasingly elaborate in their use of mechanics, electronics, and embedded systems. The expansion in software and electrical/mechanical components and resulting interactions between these systems is the main driver behind this complexity (Table 1 below).

Top Challenges for Product Development

Respondents were asked to select the top two challenges they feel for determining product behavior:

- Products are becoming more complex - 42%
- Products operating in varying and complex environments - 37%
- Limited development resources - 34%
- Competitive differentiation is becoming more difficult - 29%
- Lack of tolerance in design flaws - 21%

Table 1: Products are Only Becoming More Complex

% Increase – Past Two Years	All Respondents	High Tech	Life Sciences	Industrial Equipment Manufacturer
Number of Mechanical Components	13.4%	12.4%	9.0%	13.7%
Lines of Software Code	34.4%	36.0%	32.9%	42.5%
Number of Electrical Components	19.6%	20.0%	17.7%	17.1%

Source: Aberdeen Group, June 2014

The Hidden Impact of Being Understaffed

In a recent Aberdeen study of over 500 companies, the issue of understaffing in engineering or high skill positions was explored. Companies that indicated they were understaffed in these positions saw the follow negative impacts on their product targets:

- **Product launch dates hit: 16% decrease**
- **Product cost targets met: 11% decrease**
- **Quality targets hit at design release: 10% decrease**
- **Product revenue targets met: 11% decrease**

Engineers play a critical role in the success of any company that designs and delivers products. Being understaffed or lacking talent in this area can be detrimental to success.

As products become more complex, the possibility of component interference increases, which, in turn, threatens the reliability of the system. In addition, the environments these intricate products operate in are complex. This further complicates the decision process, as insights into a variety of environments are required. Engineers need methods for assessing how multiple product designs behave in any environment that will not add substantial time to the constantly shrinking development schedules.

However, challenges come from more than just the actual product or its environment; there are internal issues that make product design a challenge, as well. For one thing, development is often hamstrung with limited resources (in fact, over 60% of surveyed companies feel understaffed in their technical positions). Engineers play a very important role in the success of any company that designs and delivers products. As a result, more effort is needed to address this complexity, with fewer people. Companies need to look into new methods to change the way they do business and make their limited design resources more efficient.

Defining Best-in-Class Product Developers

To identify best practices for product development, Aberdeen measured participants' ability to meet product launch dates, quality targets, cost targets, revenue targets, and change in development time. Aberdeen categorized participants as Best-in-Class (top 20% of performers), Industry Average (mid 50%), or Laggard (bottom 30%). We also refer to a fourth category, All Others (Industry Average and Laggards combined). Table 2 summarizes the aggregate performance of each category.

Clearly, the Best-in-Class have much tighter control over their products. Even in the face of all the challenges and roadblocks mentioned in the section earlier, these companies put out high quality products in the timeframe intended, and, at a low cost. Also, the 22% reduction in development cycles plays a huge role towards the continued success for the Best-in-Class, as shrinking development schedules is still the top pressure felt by all companies.

Table 2: Top Performers Earn Best-in-Class Status

Definition of Maturity Class	Mean Class Performance
Best-in-Class: Top 20% of aggregate performance scorers	89% of product launch dates met 22% decrease in length of development cycle over the last two years 88% of product cost targets 91% of product quality targets met at design release 88% of product revenue targets met
Industry Average: Middle 50% of aggregate performance scorers	69% of product launch dates met 13% decrease in length of development cycle over the last two years 68% of product cost targets 78% of product quality targets met at design release 71% of product revenue targets met
Laggard: Bottom 30% of aggregate performance scorers	38% of product launch dates met 8% decrease in length of development cycle over the last two years 38% of product cost targets 63% of product quality targets met at design release 41% of product revenue targets met

Source: Aberdeen Group, July 2014

This all points back to the same goal: determining product behavior as soon as possible. It is no surprise then to see that Best-in-Class companies are 122% more likely than competitors to have a strategy in place to improve this process. But that is easier said than done. How, exactly, do these successful companies execute this strategy?

The NPDI Lifecycle and Simulation

"Prior to incorporating software into the design cycle, the development process was driven primarily by a guess and check philosophy. Having the software has dramatically sped up development time and has allowed me to explore several alternative designs, helping to optimize the design much earlier than would otherwise be possible. Being new to the software, I've learned a great deal in a short time by consulting our in-house CFD expert which, in-turn, has given me increased confidence in both the setup and interpretation of my analysis."

~ Product Development / Engineering Manager, Small A&D Company

Bringing a product to market is a complex endeavor. There are many internal and external challenges throughout the NPDI lifecycle that can cause a product launch to fail. A major factor towards the success of a new product is an effective product design verification and validation (V&V) process. Companies that do not stress this phase of a product's lifecycle expose themselves to increased risks in product launch (poor quality, expensive recalls, costly product rework, or unexpected delays in product releases, an even increased liability). Simulation can be a powerful tool to optimize V&V for your products. Simulating product behavior has historically been integral to larger, complex industries like Automotive or Aerospace & Defense. However, with the many benefits of knowing how a product will perform prior to testing, simulation is being adopted by an increasing number of SMBs across a broad spectrum of industries.

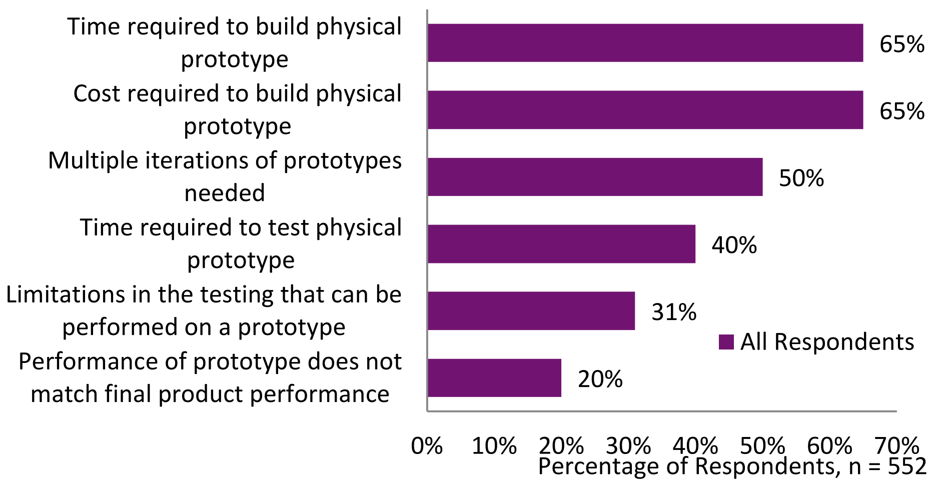
In general there are three methods that designers use for predicting product performance:

1. **Building a physical prototype**
2. **Performing physics calculations by hand**
3. **Utilizing virtual simulation through software (FEA, CFD, etc.)**

Physical Prototyping:

A prototype is an early model of a product built to test certain contraints or parameters. Prototypes are normally expensive to construct and time consuming as well, as indicated by 65% of respondents as the top two challenges of physical prototypes (Figure 2). Considering that multiple iterations of prototypes may be needed to get the results you are looking for, it is easy to see how the overall waste can add up. There is also the physical constraint; you need to have the actual prototype built to begin testing, adding more time to the development cycle.

Figure 2: Top Challenges of Physical Prototypes



In addition, there are numerous physical tests that can be conducted on a prototype – acoustics / vibration, fatigue, stress, fluid flow, etc. – all requiring different amounts of time to be completed. Fatigue testing, for example, can be highly time-consuming to perform depending on the material and the type of loading used. When companies are limited in their amount of design resources, the additional time spent building and testing prototypes can seriously delay product launch dates.

Prototypes are used to reduce the risk that a design may not perform as intended, however, in general, prototypes cannot eliminate all risk. Usually companies only build a single prototype, at the end of NPDI, testing a few physical cases. This is often only done on the most critical product and not all products, adding further risk to the business. Also, an often overlooked fact is that there are limitations in a prototype's ability to match the intended final performance of the product because of differences with the final product. The three areas where prototypes generally differ from the final product are in the materials and processes used, as well as the design fidelity. Also, most environments that products operate in are hard to factor into a physical test. This results in larger risk with prototyping as the experience and judgement of designers is relied upon in a qualitative way rather than being able to evaluate quantitatively. As a result, physical prototyping is often the phase of a product's lifecycle with the most inefficiencies.

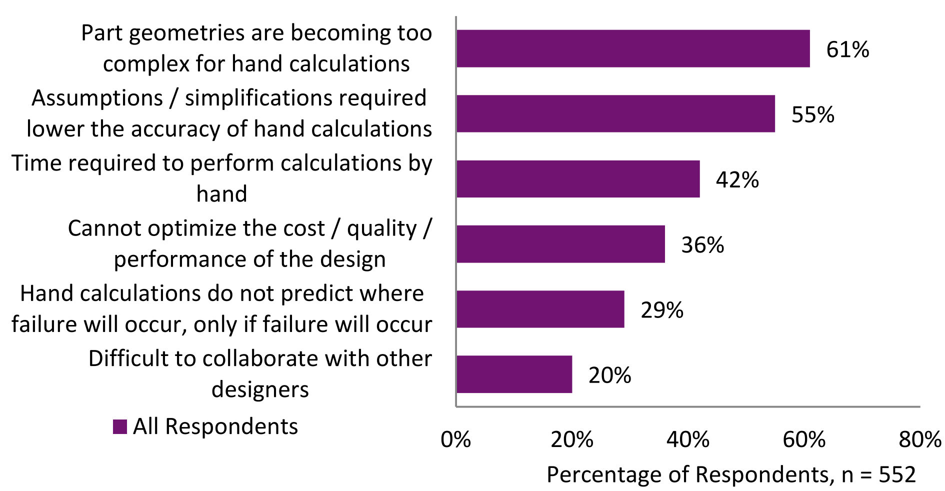
"A lot of power plants we work on are near the ocean, so over time the higher salt concentration in the air will accelerate corrosion. You need to be able to simulate operating conditions for 15 years or more down the line. Manual methods are too cumbersome to do this analysis, which is why virtual simulation is used."

~ Alex Vadney, Project Manager, BES&T

Hand Calculations

Performing calculations of stress manually has been practiced for centuries, and most engineers are accustomed with this approach – especially more senior engineers who had to rely on manual methods before simulation software was readily available. Those who continue to utilize hand calculations are comfortable with what they know and feel to be just as reliable and accurate as simulation tools; however, that is not the case (Figure 3).

Figure 3: Top Challenges of Hand Calculations



The reality is that hand calculations are simple, mechanical formulas that require broad assumptions and simplifications of multiple factors (geometry, tolerances, loading, etc.). Indeed, as the data shows, for everything but the simplest of part geometries, hand calculations are largely rough estimates of predetermined areas of concern. Often, they are only close approximations of the true maximum stress levels. However, sometimes they are only within range of the average stress levels, and fail to calculate the highest stresses entirely. Also, if calculations do predict failure, there is no insight provided on *where* the failure will occur, which is vital information to improve the design. In addition, the storage and management of manual simulation can be a problem as well, as most calculations are done through in-house excel spreadsheets. Collaborating and sharing these spreadsheets with other designers within the company can be challenging. This introduces further risk into the business if an employee leaves or a designer is working on an outdated version. Recheck processes can be long and designers do not have time to spare.

Spreadsheets or hand calculations can work on the most basic of products; those where there is little chance for unintended consequences. Also if there is a significant factor of safety, then hand calculations can be adequate. But as product safety and compliance mandates continue to increase, the amount of products that hand calculations can be used for are only going to diminish. In industries like High Tech, Industrial Equipment Manufacturers, or Life Sciences, the rising complexity in their products make it unrealistic for a manual approach to continue to be effective.

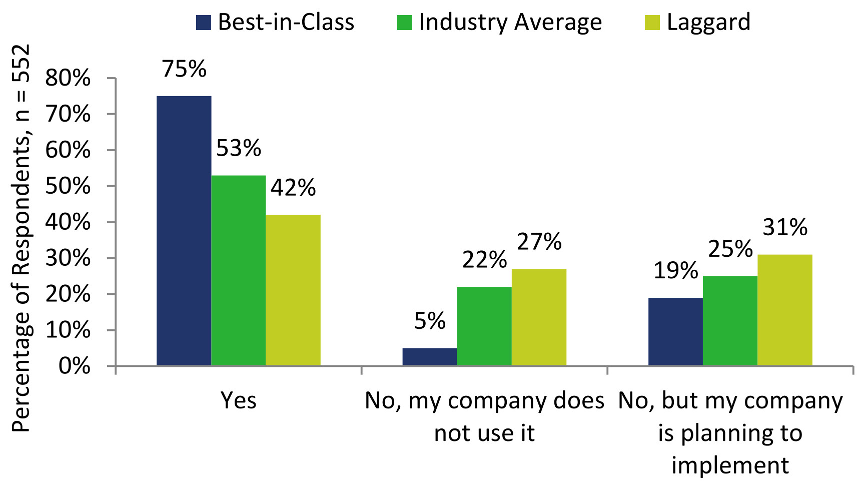
"Manual calculations used to be relied upon more heavily in our company. Typically these would have bigger factors of safety (FOS) applied due to the larger errors and less certain assumptions of these calculations. By switching to virtual simulation we are now able to optimize our products for cost, quality, and performance"

~ Product Developer, Small Industrial Equipment Manufacturer

Simulation Software

This leaves us with the third and final approach to predict the behavior of a product, simulation software, and this is the method that Best-in-Class companies rely on (Figure 4 below).

Figure 4: Turning to Virtual Simulation



Souce: Aberdeen Group, July 2014

"Turning to simulation software has vastly reduced development times by avoiding empirical prototyping. Fundamental development work rather than superficial is becoming possible and this is the main driver for recent HPC (High Performance Computing) acquisition."

~ James Slipszenko, Senior Project Engineer, SRA Developments Ltd.

Virtual simulation is the analysis or simulation of a product's behavior in a virtual environment, creating a virtual prototype of the product design. Best-in-Class companies are 53% more likely than their peers to conduct their simulations in this virtual environment. On top of that, only 5% of the Best-in-Class indicate they will not implement software tools eventually, a stark difference from the Industry Average and Laggards. This growing use is because there are more virtual simulation options today than ever before. At the beginning, only specialists in large companies, mainly in aerospace & automative industries, used simulation tools due to complexity and cost of tools. Next, designer engineers only had the option of conducting basic linear static stress analysis. But in recent years, simulation tools have drastically evolved in their ease of use, intuitiveness, and depth of capabilities - including conditions like nonlinear static stress, dynamic stress (vibration), fluid flow, heat transfer, and FEA-based stress and motion analysis. These capabilities can be combined to perform analyses that explore multiphysics scenarios as well.

Turning to software allows the Best-in-Class to develop virtual prototypes which are used to predict performance of the entire system prior to constructing their physical counterparts. Virtual simulation provides the unique ability to look at the system as a whole and identify issues that may not have been foreseen. The time required to bring the product to market is reduced substantially because virtual prototypes can be produced and tested much faster than their physical counterparts. Designers are also able to quickly explore the performance of numerous design alternatives without investing the time and money required to build physical prototypes or conduct numerous hand calculations. This ability to analyze multiple alternatives at a fast pace allows for an important practice: optimizing the design. Additionaly, the ability to explore a wide range of design alternatives allows the Best-in-Class to focus on advanced Design for Excellence (DFX) initiatives and optimize characteristics like manufacturability, serviceability, or configurability. To be successful, producing a product that performs as intended is not enough. You must always look for areas to continuously improve; product optimization is the perfect area to do so.The need to reduce time to market while optimizing products for higher levels of performance and reliability is a perfect fit for virtual simulation.

And what about those skeptical engineers who do not trust the reliability or accuracy from virtual simulation? There is always the option to use hand calculations to verify the results. However, those designers who have adopted simulation tools rarely find the need to question the results once they know how

Virtual Simulation and Physical Prototypes

Virtual Simulation users were asked to identify the impact simulation has had on the number of physical prototypes they use (% of virtual simulation respondents):

No Change – 14%

Reduced the number of physical prototypes – 48%

Enabled more partial prototypes and fewer complete prototypes – 29%

Eliminated physical prototypes completely – 9%

to use them. In fact, respondents using virtual simulation were asked by Aberdeen to select the top two biggest impacts they would feel if they were no longer allowed to use these tools (Table 3 below).

Table 3: The Impact of Virtual Simulation (or lack thereof)

Impact	All Respondents
More physical prototypes would be required	52%
Product may work, but would not be optimized for cost, quality, or performance	38%
Identifying root causes would be more difficult so troubleshooting would take longer	31%
Fewer scenarios would be tested because it is not possible to perform physical tests for all conditions	29%
Physical / experimental tests would take longer	24%
Product would be released faster because time would not be spent on analysis	2% *(9 respondents)*
There would be no impact	1% *(5 respondents)*

Source: Aberdeen Group, June 2014

"We have been able to generate more ideas and test concepts because of virtual simulation. More product development opportunities now exist. Innovative products will be able to be moved through the development process quicker."

~ Nicholas Findanis, Research and Applications Engineer, Pentair Environmental Systems

It is obvious that these design engineers realize how powerful a tool virtual simulation is in their efforts to improve NPDI. What is most telling, though, is the fact that **of the 299 respondents who are using virtual simulation, only a handful (9 respondents) do not believe it brings value**. Further, the 2% of respondents that were not satisfied with virtual simulation could be the cause of other factors entirely; there are best practices for virtual simulation itself which may not have been followed. Improper training, a poor company structure, or lacking centralized access to simulation results are all roadblocks that must be navigated when turning to virtual simulation. However, these challenges are not neccesarily a reflection on effetiveness of simulation tools as they are fixable.

Turning to virtual simulation is integral to a Best-in-Class company because of these benefits to NPDI, but how much of an impact does it have?

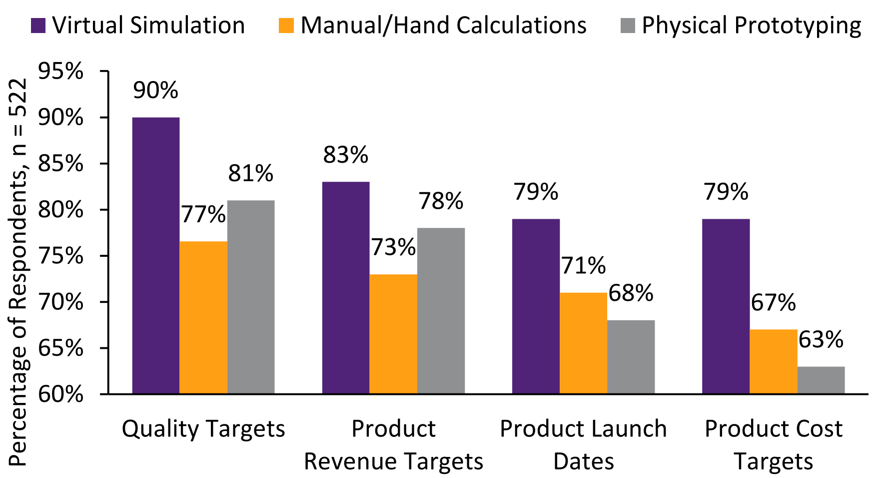
Breaking Down the Metrics and Performance

It is true that there is more to being Best-in-Class than just the technology tools that they use. Aberdeen research has consistently shown that it takes the right mix of talent, efficient processes, and technology. So even though Best-in-Class companies are more likely to turn to software for their simulations that may not necessarily be the catalyst for such superior performance. Luckily though, with such a large respondent pool, we can examine the three approaches to predicting product behavior and see how each performs from a metric standpoint. Figure 5 clearly shows that the use of virtual simulation results in more successful products.

"Using simulation software early, combining more physics, and encouraging collaboration has reduced our development costs. It has also improved the performance of our initial prototypes. As a result, our products have greater assurance of reliability and durability."

~ James Smith, Lead Mechanical Engineer, Sechan Electronics, Inc.

Figure 5: Are you Achieving your Product Targets?

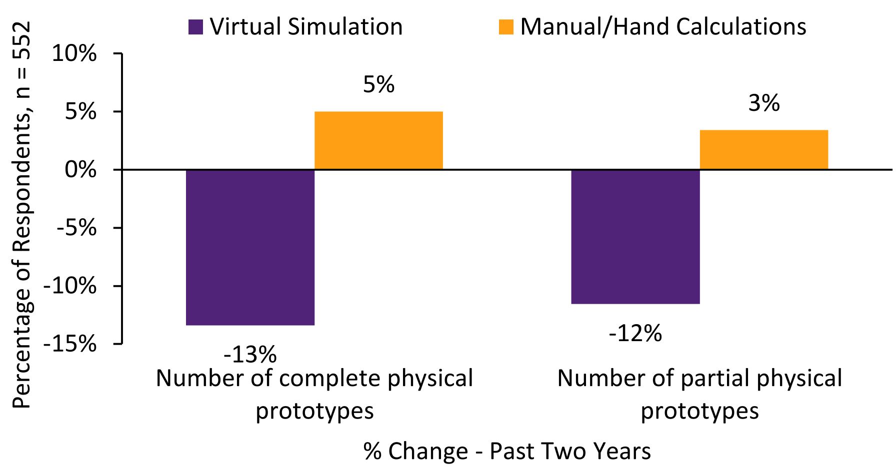


Source: Aberdeen Group, July 2014

For all of the product targets used to define the Best-in-Class earlier, virtual simulation easily performs the best. A major concern these days is the rising price of materials. However, there is a lot of over engineering due to factor of safety. Use of virtual simulation can minimize the amount of material used in a design by optimizing it to be as strong as it needs to be (maintaining quality), while eliminating any waste in the design (reducing costs). It is also possible to evaluate the performance of multiple materials at a rapid pace, keeping the development cycle minimized.

Manufacturing and testing prototypes can also take up a significant amount of overall time and make product launch dates difficult to hit. However, because software allows designs to be tested virtually, the dependence on physical prototypes can be reduced (Figure 6). Fewer prototypes means more time savings, which can help bring a product to market sooner. Besides saving development time, using simulation software to verify your designs will also mean that you will be able to greatly reduce the costs of manufacturing and testing these physical prototypes.

Figure 6: Simulation Software Reduces Prototyping



Source: Aberdeen Group, July 2014

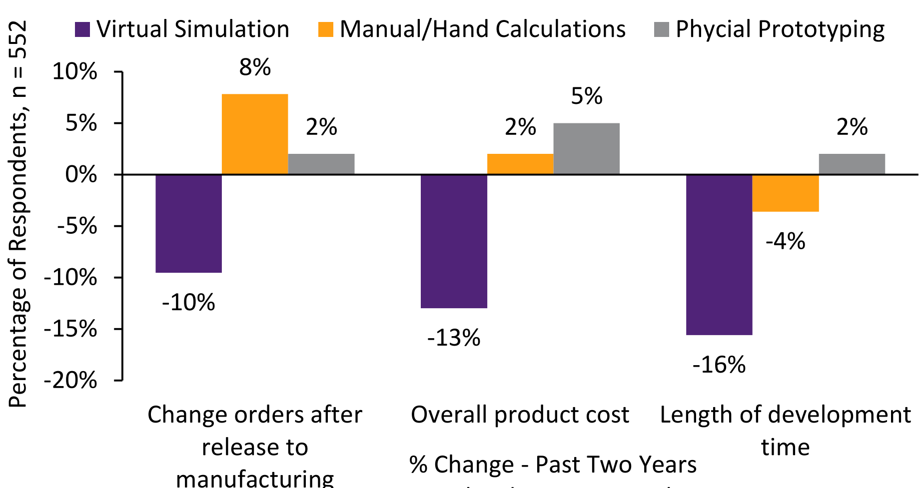
"The more detailed models we are using are giving us a better understanding of our virtual prototypes. We are able [to] estimate the sensitivity of our products and define production tolerances accordingly. This helps a lot not only during product development but also during [mass] production."

~ Peter Benko, Product Development Engineer, GRANTE Antenna Development and Production Corporation

In fact, in some cases, virtual prototyping can be superior to physical testing because high stress areas are often concealed for some time by low stress areas. A physical prototype may pass a single load test, but fail under repeated loading. Virtual prototyping is the most effective way to determine whether a product is safe for use. The increase in prototypes that manual users see is a direct result of the assumptions and simplifications of hand calculations. Real-world product geometry – such as a nozzle on a pressure vessel, or welded joints – is troublesome to calculate by hand. This results in inaccuracies in the simulation and increased prototyping to fix errors in the design.

Backing up the fact that virtual simulation is more reliable and accurate than hand calculations or prototyping is what occurs after the product leaves designers' hands. Virtual simulation users have seen a 10% decrease in engineering change orders (ECOs), while those relying on hand calculations have increased ECOs by 8%. What this means is that companies using simulation software are able to fix their designs before they get to production, unlike those utilizing manual methods, who fix their products afterwards (Figure 7).

Figure 7: Simulation Improves Overall NPDI



Source: Aberdeen Group, July 2014

These reductions in rework can work wonders on overall product cost. Combine this with a product design that is already optimized for cost/quality/performance and requires less testing, and the 13% decrease in cost reported by virtual simulation users makes perfect sense. Faster validation of the

Why are you NOT using simulation software?

Respondents not using simulation software were asked to select their top three reasons for not doing so:

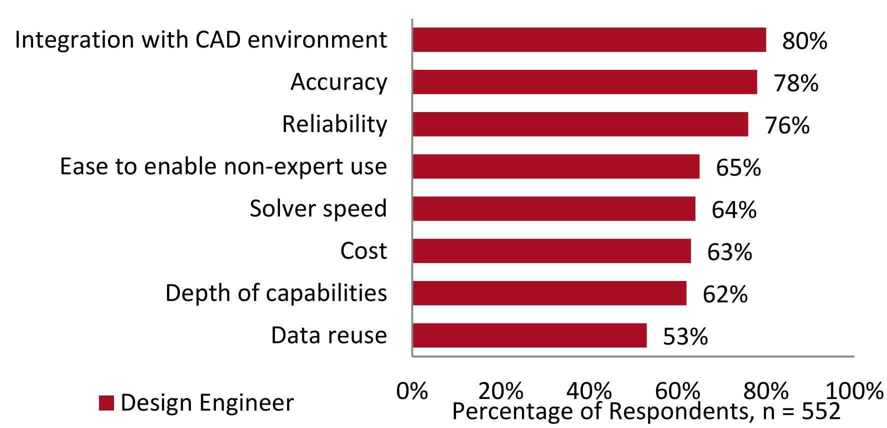
- Cost of simulation software solutions - 51%
- Lack of confidence in simulation accuracy- 46%
- Not sure how to correctly model behavior - 46%
- Lack of trained staff who can conduct simulations - 40%
- It takes too long to prepare models for analysis - 23%

product, less prototypes, and decreasing ECOs; all of these benefits are perfectly reflected in the sharp drop in overall development time for virtual simulation users. A 16% decrease in development time over the past two years is the perfect way to alleviate the top overall pressure designers feel today, thereby shrinking development windows. These differences in development time also allude to the fact that companies not utilizing virtual simulation run the risk of bottlenecks forming in NPDI. As recent Aberdeen research has highlighted, being first to market with a new product plays a huge role towards its overall success. The anecdotal thinking supporting the value of virtual software is backed up by the metrics; companies that have moved away from manual calculations and physical prototyping enjoy superior performance.

The Importance of Having the Right Tools

It is clear looking at the metrics that virtual simulation results in improved performance. But software can have its limitations if the user does not know how to effectively use it or if the software does not have the necessary features. It is important to realize what capabilities design engineers have found to be vital (Figure 8).

Figure 8: Features Important to Design Engineers



Source: Aberdeen Group, July 2014

When presented with a list of 14 qualities of simulation software, design engineers indicated integration with CAD, reliability, and accuracy are most important factors to look for. This comes as no surprise; if a designer does not trust the simulation results they will not continue to use the tool. Not far behind is the ability for the software to be used by non-experts. Allowing a non-expert to easily perform the analyses they require is crucial for any company exploring simulation software. Design engineers have been relying solely on hand calculations for years and one of the largest hurdles to overcome when moving towards a virtual product is the adoption rate of the tools. These features were all rated even more important than cost. This reinforces that the top focus for design engineers is easily to conduct realistic simulations that reliably predict product performance. The insight that comes from simulation software guides designers to make the right product decisions throughout the development cycle.

In addition, simulation can be conducted earlier and more often throughout the NPDI process (see sidebar). To maximize your efforts, simulation software should be used to analyze component and system-level behavior, as well as subsystem interactions before physical prototyping. Early simulation ensures that designs are validated from the beginning, saving time and money. With the right software, simulation can now become an integral part of the design process, not some separate function with its own tools and processes.

Key Takeaways and Recommendations

Every company is looking to improve how they do business. It makes sense that companies who target their NPDI process are put in better positions to succeed, as new products represent a company's largest potential for reward. However, NPDI also carries with it a considerable amount of risk; and improvement is

Simulate Early, Simulate Often

The Best-in-Class are not only leading the way when it comes to utilizing simulation software, they also are more likely to utilize simulation to validate each step of the product process.

Where is simulation used? (% of Best-in-Class)

Detailed component level design:
90% of respondents

Sub-system design:
81% of respondents

Defining system architecture:
73% of respondents

Verification and testing:
72% of respondents

Post manufacturing failure analysis:
69% of respondents

Trouble shooting at production ramp up:
51% of respondents

Manufacturing:
41% of respondents

not an easy task. A great deal of success hinges on a company's ability to balance innovation, cost, time, and quality during product development. With tightening schedules, increasing complexity, and insufficient engineering resources, this balancing act can be a daunting task. Effectively doing so requires organizations to improve their understanding of product behavior as quickly as possible. There is good news though; we can learn from those companies out there that are successful in this challenging environment. The reasons for turning to virtual simulation are simple:

- **Product complexity grows every day, manual methods cannot keep up with these new products.** As complexity increases so does the difficulty in predicting its behavior. The rough estimates from hand calculations should not be relied on when there are better alternatives available.

- **There is a real lack of resources among manufacturers, so provide designers tools to maximize their efforts.** Development resources are limited and overstretched in most companies—an issue that will only get worse as more baby boomers approach retirement. Best-in-Class companies realize that efforts must be made to make their designers more efficient.

- **The many benefits of virtual simulation cannot be overlooked; hand calculations have too many limitations and cannot optimize a design.** The metrics back the use of software resoundingly. Users of virtual simulation are more likely to hit their product targets, use less prototypes, and decrease overall cost and development time.

- **An accurate and reliable simulation platform that integrates with CAD is important, but you can't overlook the ability to allow for non-expert use.** A company that invests in a solution that only simulation experts can navigate is a company setting itself up for failure. In most companies there is a cultural friction to overcome; most engineers are apprehensive to give up their current tools and processes. Non-experts will quickly grow frustrated and go back to simulation methods they are comfortable with. This will drastically dampen the overall benefit virtual simulation brings to an organization.

Relying solely on hand calculations and physical prototypes is no longer a viable design approach. The benefits of virtual simulation far outweigh those of traditional design methods; software can no longer be overlooked as a tool to maximize product development efforts. Best-in-Class companies have come to rely on this enabler and as a result release high quality products on time and at low costs.

For more information on this or other research topics, please visit www.aberdeen.com.

Related Research

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High Tech NPDI: Ensuring Success By Managing Risk; April 2014

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