ADVANCED PRODUCT DESIGN FOR INDUSTRY 4.0

PART 2: DETAILED PRODUCT DESIGN

EARLIER SIMULATION, FASTER ITERATION, GREATER INNOVATION

Image courtesy of **Alberto Luque Marta**

INTRODUCTION

The world of product development, manufacturing and production is changing. With Industry 4.0 we're on the brink of a new dawn of automation and intelligence, with smart, connected products and the smart factories that produce them.

Autonomous drones capture progress as a new production cell layout is commissioned. Deep Learning-enabled devices with computer vision perform quality checks on the production line and provide data to continually improve processes. Intelligent, collaborative robots, "aware" of their environment, work alongside humans to assist with assembly tasks.

Advanced computing devices harvest huge amounts of data from products in the field, to feed design and simulation systems and help ensure that next-generation products learn from those that have gone before.

Virtual reality (VR) presents everyone in the development process with the information they need in a rich, immersive, and collaborative environment. Ultra-powerful workstations are used to design, simulate, and visualize products, production cells, and factories. Then, once manufactured, virtual products—or "digital twins"—can be connected through the Internet of Things (IoT) to their real-world manifestations.

At the heart of all of these processes, NVIDIA plays a strategic role in empowering the manufacturing industry to implement Industry 4.0. For the past 20 years, NVIDIA has sustained investments in research and development (R&D) to continually push the boundaries of graphics processing unit (GPU) technology. The use of GPUs has, for some time, extended far beyond simply powering computer graphics displays and design software.

Today, a wide range of NVIDIA software and hardware solutions enables manufacturers to develop artificial intelligence (AI) capabilities for industrial collaborative robots and autonomous vehicles in the smart factory. In addition, advances in GPU-accelerated workflows are powering productivity improvements and speeding time-to-market as manufacturing companies move forward with advanced product design for Industry 4.0.

The NVIDIA® Quadro® visual computing platform is helping product design teams radically transform the traditional product development process. The introduction of leading-edge technologies such as AI, virtual reality (VR), interactive physically based rendering, real-time engineering simulation, and 3D graphics virtualization, are driving the development of the next generation of smart, connected products.

Image courtesy of **SOLIDWORKS Visualize**

THE ROLE OF SIMULATION AND VISUALIZATION

The first part of this Advanced Product Design for Industry 4.0 series looked at how visual computing is used to streamline decision making, speed up concept generation, and capture, secure, and centralize design intent across dispersed design groups.

This second part now explores how advanced computation technologies are being applied to the world of detailed design, specifically looking at both simulation and visualization.

As concepts begin to mature and formalize, the engineering-to-production process starts to focus on details, which determine how the part will eventually appear, how it will be manufactured, and how it will perform in the real world under actual operating conditions. It's at this stage that two key workflows emerge and play a pivotal role in the future of the project at hand: design visualization and simulation.

VISUALIZATION

In the detailed design phase, photorealistic rendering helps drive better-informed decisions during the development process. Alongside pure function, a key part of any product is how it looks, feels, and interacts with the world around it.

At this stage, it's common for photorealistic rendering to be applied directly to the 3D CAD model. This can be done directly inside the viewport of the 3D design tool or in a complementary software application that links to the 3D design tool.

GPU-accelerated physically based rendering (PBR) is based on physics, so the rendering output shows how the product will truly appear in real life once manufactured, which leads to more confident decision making. PBR achieves its photorealistic results, without the manual setup or many of the trade-offs and shortcuts traditionally associated with producing computer-generated imagery.

GPU-accelerated PBR technology is widespread in many CAD-centric visualization systems. SOLIDWORKS Visualize, Siemens NX Ray Traced Studio, and Dassault Systèmes 3DEXPERIENCE CATIA Live Rendering, all take advantage of PBR, as well as Chaos Group V-Ray GPU, which has plug-ins for many leading 3D design applications.

Importantly, GPU performance can scale to make PBR fully interactive, so a designer or engineer can quickly gain a good understanding of how a product will look in real life while working on the design. No waiting for a preview render—simply tweak the model, materials, or lighting.

Immediate feedback encourages experimentation in a digital environment, without firms committing to costly physical prototypes and a lengthy materials selection process. More iterations in shorter timescales lead to greater confidence in making informed decisions through accurate visualization, and ultimately to better designed products.

Photorealistic rendering becomes particularly vital when the decision-making team contains a mix of both technical and non-technical members. For those unaccustomed to orthographic projection–style display methods, whether wireframed or shaded, having a 3D digital model presented with high-quality materials and realistic lighting gives a much better basis for discussion and decision making.

French automotive design firm PGO Automobiles uses SOLIDWORKS Visualize in the prototyping design stage to simulate and validate new designs. Unlike the global car manufacturers, it cannot afford to build clay models, so the company uses interactive physically based rendering to help make the right decisions on aspects ranging from simulation of different colors to fault detection in the car body design.

As Nicolas Urffer, studies manager of PGO Automobiles, explains, "All validation can be done interactively now. We can work on the model data, change and display it as needed... Whether we are in a design discussion, using the rendering for an internal presentation, or updating our shareholders on a new design, we have a solution at our fingertips that works perfectly for us."

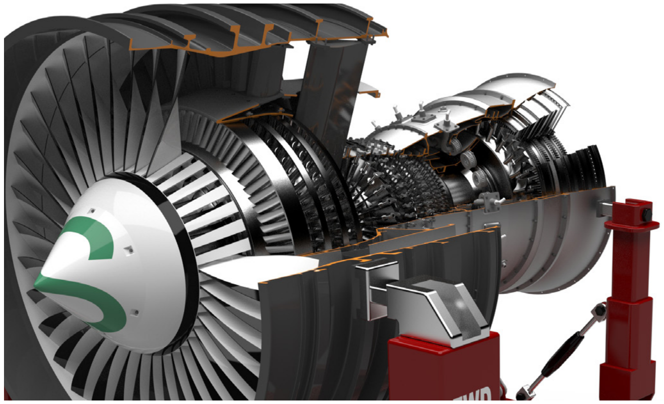

Image courtesy of **Siemens NX Ray Traced Studio**

SIMPLIFYING COMPLEXITY, ENABLING COLLABORATION

Faster rendering transforms workflows. Traditionally, design teams' only choice was CPU-based rendering. Depending on the complexity of the model and the image resolution, rendering on CPUs could take minutes, hours, or even overnight. And when the resulting image was not quite what was wanted, the time-consuming process began again. This meant that photoreal renders were often used sparingly and many design teams still follow this workflow today. However, with the integration of GPU-accelerated physically based rendering engines into a broad section of CAD software, access to fast rendering is within the reach of millions of designers and engineers. As a result, it's very advantageous to equip designers with the right workstation hardware, whether that's a desktop, mobile, or virtual workstation.

High-end NVIDIA Quadro GPUs or multiple Quadro GPUs in a single desktop or virtual workstation can deliver high-resolution renders in seconds. Then, when edits and tweaks are made to the model in 3D CAD, the rendering updates instantly, allowing informed decisions to be made right away. As complex scenes are created and rendered with higher-quality textures, more GPU memory is required to ensure fast performance. Ultra high-end Quadro GPUs not only offer incredible levels of compute performance but, with NVIDIA NVLink™, a dedicated high-bandwidth GPU interconnect, two GPUs can act as one, doubling the amount of available GPU memory and performance.

NVIDIA Quadro is not just about delivering new levels of performance. The latest NVIDIA Turing™ architecture, at the core of the NVIDIA RTX™ development platform, fuses real-time ray tracing, AI, simulation, and rasterization to fundamentally change computer graphics. New AI, ray tracing and simulation SDKs, take full advantage of Turing's capabilities to help designers deliver 3D designs, highly realistic simulations and cinema quality rendering faster than ever before. Dedicated Tensor cores and RT cores in Quadro RTX GPUs take advantage of game-changing artificial intelligence (AI) denoising technology to significantly cut the time it takes to produce render output. The ability to visualize cinema quality renders in real-time during the design workflow is hugely beneficial to designers. Not only can they instantly view how design modifications will appear in real life to make better informed decisions right away, but they can communicate their design intent more effectively to a wide range of stakeholders and decision makers with accurate visual simulations of their products.

Denoising is already finding its way into a number of visualization systems, including Chaos Group's V-Ray Next and its GPU renderer, V-Ray GPU. AI-enabled denoising works by rendering a "noisy" image with minimal light ray bounces and then using a neural network to predict what the final image would look like if it were rendered with thousands of bounces.The neural network is trained with tens of thousands of image pairs, where one image has been rendered with one path per pixel and the "reference image" has been rendered with 4,000 paths per pixel. The neural network learns how to map the different types of noise to the correct denoised pixels. The resulting image looks very similar to one that has been generated with thousands of light bounces, but it's delivered in a fraction of the time.

OPTIMIZED WORKFLOW

High-performance GPUs play an essential role in PBR, but workflow efficiency isn't just about having ready access to powerful, highly-scalable compute resources. The ability to quickly set up scenes and apply materials also plays a very important role.

High-dynamic range (HDR) image-based lighting is a fundamental part of PBR systems. Using real-world or idealized 360-degree environment images, a designer can quickly set up basic lighting for a project and then add more traditional computer-generated imagery (CGI) lighting assets where needed. This can reduce both time and effort, which is key to achieving fast, realistic rendered assets.

Realistic physically based materials, whether used digitally or captured from the real world, are becoming more commonplace. These save time and effort when defining materials for a project.

There are also efforts to make the sharing of materials more efficient, which is important as a 3D model moves through the development process using different design software tools. The Material Definition Language (MDL) format, developed by NVIDIA, allows for the exchange of common materials between leading systems, including Siemens NX, Chaos Group V-Ray, ESI Group IC.IDO, and others that use physically based rendering engines (e.g., Siemens NX Ray Traced Studio, CATIA Live Rendering, SOLIDWORKS Visualize, and McNeel Rhinoceros).

PBR isn't just about aesthetic evaluation. It can also be used to answer other, more technical questions. For example, are LED arrays bright enough to warn an operator that a machine is running, or are they obscured in daylight conditions?

GPUs and their highly parallel, scalable architecture are extremely well suited to rendering. Powerful, professional-grade GPUs can be found in mobile and desktop workstations. To cut render times even further, multiple GPUs can be used in desktop workstations, render farms, and the cloud.

Siemens NX Ray Traced Studio, SOLIDWORKS Visualize, CATIA Live Rendering, and other CAD tools all benefit from GPU-accelerated ray-trace rendering. Chaos Group recently released V-Ray Next GPU for Autodesk 3ds Max, with the design visualization software company saying GPU rendering is now as important to them as CPU rendering. V-Ray Next GPU will soon be available for McNeel Rhino as well.

Recently, using fully immersive virtual reality (VR) at the conceptualization stage has emerged as a trend. This enables designs to be experienced at human scale long before they're built, allowing new ideas to be generated and more informed decisions to be made at an earlier stage of development.

Immersive VR in design and manufacturing has historically been the sole preserve of the automotive and aerospace industries. However, low-cost, high-quality head-mounted displays (HMDs), which were made possible by major performance advances in GPUs, have now brought the benefits to a much wider audience.

The benefits of VR are well documented. An HMD like the HTC VIVE Pro can give the user an incredible sense of physical connection to a virtual product–an experience that can't be rivalled by viewing a 3D model on a 2D screen.

Using VR at the concept stage can give designers confidence to make the right decisions early on—before major changes become prohibitively expensive in terms of cost and time. VR can also be used to visualize and interact with models in context with photorealistic materials, lighting, and finish.

Getting data into VR can still be an involved process of data transfer and geometry optimization. However, a number of systems, including Rhino, Alias, and SOLIDWORKS, currently do, or will soon, support HMDs directly in the viewport. Designers can work on a concept model, throw on a headset, and see exactly how it will look at human scale.

Image courtesy of **Dassault Systèmes CATIA**

VR OF THE DESIGN WORKSTATION

Visualization on a 2D display plays an essential role in product development, but there's also an emerging trend to implement virtual reality (VR) technology at a very core level.

Driven by today's powerful GPUs, combined with dramatically lower-cost head-mounted displays (HMDs), full-scale, immersive VR is gaining serious momentum in the design and engineering world, particularly when compared to the more traditional, historically more expensive solutions. Firms that previously were priced out of using VR can now get on board for a relatively low cost, as Nicolas Urffer, studies manager at PGO Automobiles, explains: "While computer-aided virtual environments, or CAVE systems, have been used by large automakers for some time, these large, costly systems were not financially viable for smaller producers. Now, using the new generation of HMD technology, PGO can bring its models to life virtually and enhance design decision making even further. This technology supports us in delivering an outstanding online experience to our customers, creating the most beautiful vehicles and competing in a challenging marketplace."

What VR offers over traditional design visualization is a sense of scale and physical connection to a product that cannot be experienced through a 2D image. Getting data into VR can still be a challenge, as CAD models are complex, and the geometry typically needs to be simplified to deliver a comfortable experience with a VR headset like the HTC Vive. But this is getting easier all the time. Tools like ESI Group IC.IDO and Virtalis VR4CAD offer optimized routines, and VR is also starting to appear in design applications such as Autodesk Alias and soon, Rhino and SOLIDWORKS.

The future of immersive VR for design and engineering is being explored in NVIDIA Holodeck™, a next-generation collaborative platform. Faster GPUs and advanced technologies allow photorealism and physics-based haptic interaction in collaborative VR environments without the data decimation typically required today with 3D models.

Image courtesy of **SOLIDWORKS Visualize**

MAKING VISUALIZATION ACCESSIBLE

Visualization is becoming an essential tool for designers and engineers. Now Quadro-powered desktop and mobile workstations, as well as virtualized workstations, have made physically based rendering (PBR) accessible to many more engineers in the product development process, from concept to detailed design.

NVIDIA Quadro Virtual Data Center Workstation (Quadro vDWS) software delivers the power and performance of physical workstations to virtual machines from NVIDIA GPUs in the data center, even with the largest 3D models, while allowing firms to dynamically allocate computing resources as workflows dictate. Companies make better use of available resources while also giving more designers and engineers visualization tools so they can directly experiment with materials and colorways, without having always to rely on a central visualization expert.

Consider the large organization with a broad set of products tailored to local markets, both in terms of product variation and materials specification, as well as color and finish. With graphics virtualization and centralized data storage, it's possible for each local team to define, render, and approve their own culturally and geographically appropriate product variants using the same set of data and the same systems, while the corporate group retains control over the data, revisions, and intellectual property.

THE NEW SIMULATION WORKFLOW

Workhorse 3D design tools allow designers and engineers to define, experiment, and capture shape and geometric function. Simulation follows on from this to predict, accurately and robustly, how a product will perform, both structurally as an object and when interacting with the world around it.

The downside to engineering simulation is that the workflow has traditionally been very compute intensive, with it sometimes taking hours to generate results. This is true for both CAD-integrated simulation tools, aimed at the designer or engineer, and more traditional standalone analysis and simulation solvers, aimed at the analyst and specialist. In many respects, lengthy solve times have kept simulation from becoming a more integral part of the product development process.

ANSYS Discovery Live (ADL) takes a radical new approach to simulation. It uses new GPU-accelerated solve technology that runs on a workstation with a powerful GPU and gives near instantaneous results. This makes it particularly well suited for the early stages of design. Engineers simply load up a CAD model, apply boundary conditions, loads/forces, and inlets/outs where appropriate, and get results back in seconds. No time is spent waiting for a mesh to generate, and no hours waiting for finite element analysis (FEA) or computational fluid dynamics (CFD) solves to complete. Since ADL is compatible with many CAD tools, a wide range of engineers and designers can take advantage of it.

ADL has the potential to disrupt the traditional simulation workflow. Previously, a project's amount of simulation work may have been dictated by available time, due to lengthy computational cycles. ADL removes that restriction. It allows greater experimentation much earlier in the product development process—which means decision making becomes more informed and simulation can truly influence design, rather than simply verify it.

Consider a design team working on a new pump. The traditional workflow would require a CAD model to be built and then CFD tools used to simulate fluid flow through that pump—a process that could take hours to complete. Should a design change be required, the 3D model would need to be edited and the CFD model updated and recomputed. That's potentially many hours of work for each design iteration.

With a real-time simulation tool like ANSYS Discovery Live, the initial design model can instantly show the fluid flow. Simple design changes can then be made inside the software—and results inspected immediately. The process shifts from hours to seconds. Simulation results are gained as quickly as you can make your design change.

Real-time simulation makes for a very different engineering decision-making process. Whereas traditional simulation tools would typically be used to validate more complete and concrete engineering projects, real-time simulation has the potential to put simulation truly at the heart of design and engineering.

Seattle-based Wibotic, for example, is using ADL to accelerate the development of wireless charging stations for drones for robotic applications. As Chasen Smith, lead mechanical engineer at Wibotic, explained in a recent interview, "An iterative design process with a simulation tool takes hours every time you want to modify something traditionally, but with ANSYS Discovery Live, I've pretty much been able to design on the fly."

With the recent integration of ADL into PTC Creo, a growing number of design engineers will be bringing real-time simulation into the modeling environment.

GENERATIVE DESIGN: AN AI-DRIVEN ENGINEER WITH SUPERPOWERS

In recent years, generative design has come to the forefront in some design and engineering circles. The term has come to describe a more explorative design form that opens up new design possibilities by leveraging advanced parallel computation with techniques from topology optimization and machine learning.

Imagine the ability to take a basic set of engineering requirements for a part or set of parts. The engineer defines the known loads and constraints, the fixing and mounting points, and the areas where other parts need to operate, along with a list of possible materials and manufacturing methods. All of this is then given to an AI-powered design system, which explores an open simulation domain and a wide variety of production methods. A range of validated solutions (using built-in FEA) to a predefined design or engineering challenge is then presented. The user can then filter through those results to narrow down the selection to a handful of possible solutions for further exploration.

This is the promise of generative design, and it has the potential to revolutionize how both design and engineered forms are developed to make them stronger, lighter, and more efficient than ever before.

DIALING IN THE DETAILS

ANSYS Discovery Live is not a one-size-fits-all solution for engineering simulation. It's intended to be used as an upfront tool for informing the design and engineering process with highly efficient, simulation-based data. However, once the design starts to be formalized, there's still the need to dive into the details with more extensive simulation studies. Here the traditional standalone simulation solvers come into their own and, with them, more challenges in terms of computation.

Today's advanced simulation solvers are able to take advantage of the huge levels of computational power offered by double-precision GPUs powered by NVIDIA CUDA. Importantly, multiple GPUs can be added to workstations or servers for scalable performance. Because data size can be a challenge when it comes to simulation, connecting two GPUs in a workstation with NVIDIA NVLink effectively doubles the GPU memory, providing the ability to tackle massive models.

For fastest solve times, multiple GPU servers can also be linked together in a cluster or in the cloud. GPU-accelerated CUDA solvers are now available in a range of leading applications, including ANSYS Mechanical and Fluent, Dassault Systèmes SIMULIA Abaqus, and Siemens NX Nastran.

Because data generated from advanced simulation studies are often on the order of terabytes, coupled with a growing trend for multi-physics simulation where results need to be shared between systems and multiple solvers are interlinked, simulation workflows are particularly well suited for the data center. This is another example where the use of advanced, GPU-accelerated virtualized workstations generates real dividends for organizations pushing the boundaries of simulation.

In addition to benefiting from data center storage and security, a virtual desktop infrastructure (VDI) environment helps centralize the administration and delivery of these diverse systems. An organization is able to specify requirements for each solver and the software environment around it, ensuring that the virtual workstation delivered to its users is precisely matched to individual requirements and the system. GPU-accelerated virtualization also offers flexibility in how powerful simulation tools are accessed. The analyst or specialist engineer is no longer tied to their desk and the compute cluster at the central office; they can now work from anywhere.

Administrators can ensure that each user has the ideal virtual workstation needed to use their toolset most efficiently, whether that's a mix of CPU or GPU computation, as the software demands. This is something that Honda's R&D center explored when rolling out GPU-accelerated virtualized client machines in a number of configurations to its users at 26 R&D centers across the globe.

Masashi Okubo, assistant chief engineer at Honda R&D Co., Ltd, explains how NVIDIA vGPU technology has transformed the way it deploys workstations to its engineers: "No conventional system could flexibly allocate processing performance to each CAD/CAE engineer. Across all Honda group companies, more than 4,000 VDI systems are taking advantage of not only better application performance and user experience but also the additional value of faster access to data and enhanced security of IP."

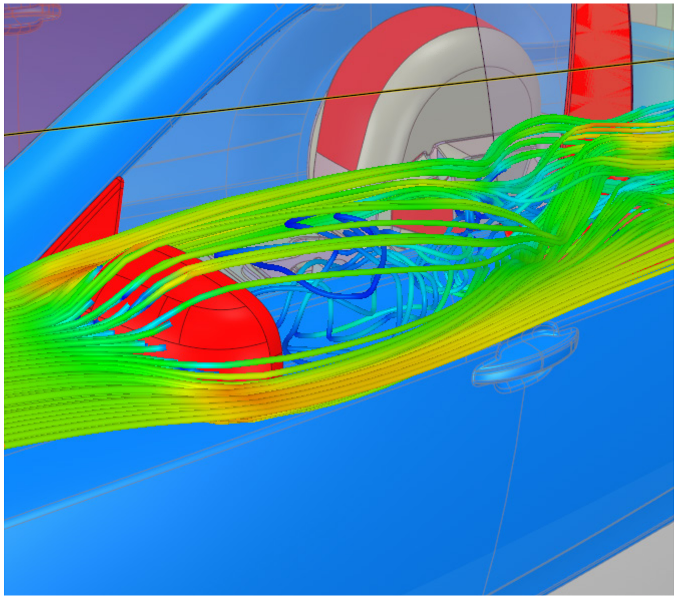

Image courtesy of **ANSYS**

Image courtesy of **Siemens NX Ray Traced Studio**

CONCLUSION

The detailed design process is complex and requires time, effort, and expertise to tackle efficiently. Visualization and simulation have become key to many organizations, but until now both required too much time to truly influence the early stages of design. For most design teams, simulation has remained a tool to assist with validation of already mature and well-developed ideas, rather than driving their creation. At the same time, photoreal visualization is often only used when the project is nearly complete or marketing images are required.

However, new GPU-accelerated technologies are bringing visualization and simulation closer to the early phases of the detailed design process. With the advent of real-time simulation combined with integrated 3D model editing tools and instant computation, enabled by more powerful GPUs, it's now possible to make simulation a true part of the product development process.

Furthermore, the use of AI-driven denoising, combined with true photorealism, standardized materials and lighting, is transforming the role of visualization in product development. By dramatically accelerating the process, designers can make better-informed, faster decisions and explore many more iterations than before.

Product development is also starting to benefit from exciting new advances in AI-driven generative design. This takes techniques from topology optimization and combines them with parallel computing, machine learning, broader simulation domains, and a variety of manufacturing processes to solve specific performance requirements.

Detailed design and engineering has always been about making informed decisions based on prior knowledge, prediction, experimentation, and robust data. This is true whether that's a decision on the correct profile for a structural component in a train chassis or which material surface will perform best under the glare of artificial lighting. Today, revolutionary technologies that simply didn't exist three years ago are empowering manufacturing companies by reinventing their workflows, processes, and project time scales to enable a new standard for advanced product development.

The holistic combination of AI, real-time simulation, VR, 3D graphics virtualization, and instantly computed, photorealistic visualization, are allowing teams to base their decisions on more immersive, more optimized, and more efficiently generated data. And this leads to higher-quality, more engaging products developed in much shorter timescales than have ever been possible before.

This is the second part of the e-guide series Advanced Product Design for Industry 4.0.

Part 3 will continue the discussion, focusing on design review, both for the individual and for the product development team. It will explore how advanced visualization techniques, combined with low-cost VR hardware, enable rich, immersive, and meaningful collaboration to take place and critical product decisions to be made.

Part 4 of the e-guide series will cover the use of visual computing technology in the production, installation, and servicing of products. It will also explore how visually compelling techniques are being used to great effect in the marketing and sales of manufactured products.