



# ADVANCED PRODUCT DESIGN FOR INDUSTRY 4.0

PART 1: PRODUCT DESIGN

MOBILITY, CREATIVITY, COLLABORATION, INNOVATION, AND SECURITY





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 in 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 feed back data to continually improve processes. Intelligent, collaborative robots that are "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 to their real-world manifestations.

At the heart of all of these processes is NVIDIA, playing a strategic role in empowering the manufacturing industry to implement Industry 4.0. Over the past 20 years, sustained investments in R&D have resulted in NVIDIA continually pushing the boundaries of graphics processing unit (GPU) technology. This innovation extends far beyond simply powering computer graphics displays and design software.

Now, a wide range of software and hardware solutions from NVIDIA are enabling manufacturers to develop artificial intelligence (AI) capabilities for industrial collaborative robots and autonomous vehicles in the smart factory. These solutions will provide secure access to data at any time from anywhere on any device, with fully interactive 3D graphics, and deliver the compute power required for big data analysis.

In the realm of advanced product design for Industry 4.0, the NVIDIA® Quadro® visual computing platform helps product design teams radically transform the traditional product development process. This includes the leading-edge technologies like AI, VR, interactive physically based rendering, real-time engineering simulation, and 3D graphics virtualization needed to develop the next generation of smart, connected products.

## IDEATION, MOBILITY, AND PRODUCTIVITY

The world of product development has changed dramatically in recent years. The development process has also become even more complex—whether working from a blank sheet of paper and customer requirements or developing the next-generation of an already successful product.

Products have increased in complexity, as has the ecosystem in which they're developed. One person at a desk working on an idea in isolation is now a rare occurrence. Today's products are developed by cross-disciplinary (and often cross-border) teams that collect data from a wide variety of sources. This is the lifeblood of modern product development.

Conceptual designers sketch out new ideas over wireframes of standard internals using digital ink. Design engineers then develop those ideas further in 3D computer-aided design (CAD), creating fully detailed models ready for both virtual and physical testing.

In the field, researchers observe product use and input information using pen-based computers, while service engineers acquire data from products already hard at work. All this valuable information is then fed into a single, connected repository.



Image courtesy of **Andre Matos**

With this ecosystem in play, the need for a more structured, secure way of managing the process has never been greater. Because multiple partners engage in many parts of the process—across concept and mechanical design, engineering, electronic, electrical, and software—data centralization and security are essential. So is the speedy provision of the services and software needed to get the job done.

Product development teams are no longer tied to their desks, often visiting customers, presenting to management, or working with suppliers to tweak first-off tooling or resolve assembly issues on the shop floor. Designers and engineers can now work from anywhere, using thin and light mobile devices with new levels of 3D graphics performance that rival most desktop workstations.

Advances in 3D graphics virtualization can also deliver real benefits whenever and wherever inspiration strikes. With NVIDIA Quadro Virtual Data Center Workstation (Quadro vDWS) software and NVIDIA Tesla® GPUs, CAD users get instant access to a powerful virtual workstation through any Internet-connected device, such as a home PC or laptop. No more driving to the office on the weekend to catch up on work or explore new ideas for design modifications.

3D graphics virtualization also delivers huge benefits when it comes to version control. With all data centralized, teams can ensure that everyone is working off the same, up-to-date model, eliminating the need to synchronize multiple datasets or rework modifications that may have been made on out-of-date versions. This is particularly important during the conceptual phase when designs can change at a frenetic pace and teams are working across different time zones.

## SIMPLIFYING COMPLEXITY, ENABLING COLLABORATION

This section describes the key processes and workflows typically used in the formative stages of product development. With each, a direct and meaningful impact can be made on the efficiency of development as well as the productivity of the team involved.

### THE SKETCH

For the quickest path from inspiration to documented idea, the sketch continues to rule. But, despite its simplicity, the use of advanced computing devices with pen-based input can truly assist the process.

Digital data can be easily captured and stored using tablets with pressure-sensitive digital pens that offer natural sketching capabilities with a variety of pen types. This can be done in applications like Autodesk SketchBook Pro and Adobe® Illustrator®.

Recently, handheld, pen-based devices have evolved to include professional 3D graphics capabilities through NVIDIA Quadro. Using dual-purpose devices like these for the formative stages of design means product designers can move seamlessly between sketch and early-stage 3D concept model without changing hardware. And these highly portable devices can be used wherever they're needed, in the office or on the road.

Examples include handheld tablets and convertible 2-in-1 mobile workstations that can be transformed from tablet mode to traditional laptop in seconds with the flex of a hinge.

In tablet mode, these devices aren't limited to sketching. Recently, some of the more traditional CAD tools such as SOLIDWORKS, Siemens Solid Edge, and Siemens NX have added support for pen-based input. This not only allows for more intuitive markup but also direct control over CAD operations and commands.





Image courtesy of BBB3VIZ

## THE CONCEPT MODEL

This model has become the lifeblood of many projects—from small-scale consumer products to airliner interiors and all points in between—often superseding the physical conceptual model.

A visually correct, digital 3D model provides an unambiguous focal point for product teams to engage with and evaluate against their own requirements—and those of their customers.

At this point in the workflow, it's about making informed decisions across a wide spectrum of specialism, so everyone can begin to work out the details in their part of the process. Industrial design can explore surfaces while engineering plans out the internal details of the product. Purchasing and supply chain management teams can start planning suppliers while color, material, and finish (CMF) specialists source materials and surface finish details.

Team coordination is key, and graphics virtualization can help ensure that everyone involved has access to the latest model revisions. Keeping concept models in the data center in a secure, centralized environment helps reduce version control issues, in contrast to manually uploading models to a shared drive for others to work on.

Design visualization can also aid early decision making, helping compress development cycles and bring innovative products to market faster. Aesthetic properties can be explored through models that are rendered to a photorealistic level of quality using physically based materials to see exactly how color, material, and finish might play out.

Render speed is key, as designers need to quickly and iteratively explore options for not only form, but also material, finish, and lighting. For example, a design team could use physically based rendering (PBR) to evaluate surface finishes and treatments on a new product under a range of expected lighting conditions. Does the high-gloss panel on a new coffee machine stand up well under the glare of kitchen lighting, or would a matte surface create a higher perceived quality?

## NVIDIA VIRTUAL GPU TECHNOLOGY

It used to be that, in order to run graphics-heavy applications like 3D CAD, a personal workstation with a powerful GPU was required. However, recent advances in graphics virtualization changed this. Thanks to NVIDIA virtual GPU technology, demanding 3D applications can now be run directly inside the data center and accessed remotely from anywhere, on any device.

Importantly, the user experience isn't impaired, as Wesley Struble, a CAD system administrator at global automotive supplier DENSO explains: "NVIDIA Quadro vDWS made it so that 98-99 percent of our users could use the virtual environment just like a physical workstation sitting in front of them. Users are actually reporting back that it performs exactly the same as a physical workstation."

Graphics virtualization benefits are wide-ranging. It allows globally distributed product development teams to work together much more effectively. Instead of transferring huge CAD models across local area networks (LANs) or wide area networks (WANs), which can take hours, the latest revisions can be worked on instantly, as only image data is streamed from the data center.

Version control is also improved and syncing issues reduced, smoothing the path for "follow the sun" design. Anyone can now have access to powerful workstations on demand, not just the full time CAD users.

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 Audi

## PHYSICALLY BASED RENDERING: WHAT IS IT AND WHAT CAN IT DO FOR YOUR WORKFLOW?

The term physically based rendering (PBR) has been around for some time and is often used in conjunction with "photorealism." However, it's important to understand the differences between the two visualization fields.

When 3D rendering took off in the late 1990s, compute power was scarce. Software systems were built to allow the user to make tradeoffs, so complex scenes could be rendered close to photorealistic quality without spending months computing the results. These older-generation systems were commonly known as biased renderers.

As compute power became more abundant, a new approach to rendering began to take off, based on the true physics of how light interacts with surfaces. PBR uses a number of techniques to achieve photorealistic imagery without many of the manual setups, tradeoffs, and shortcuts traditionally associated with producing computer-generated imagery.

High dynamic range image (HDRi) environment maps provide context for renders, as well as accurate lighting conditions, with a simple import of a graphics file. Measured materials allow the accurate representation of materials without hours building them manually. And the use of GPU computation delivers results in a fraction of the time traditionally needed. In fact, the latest NVIDIA Quadro RTX™ GPUs, based on NVIDIA Turing™ architecture, enable instant creation of cinematic-quality renders. This allows design teams to quickly iterate on concepts and instantly view design modifications, even when working with massive 3D models.

Today, PBR technology is widespread in many visualization systems, both standalone rendering tools (such as SOLIDWORKS Visualize) and those integrated into workhorse CAD systems (such as Siemens NX and Dassault Systèmes 3DEXPERIENCE CATIA).

## THE ENGINEERING MODEL

As a product moves from the conceptual stage into the engineering stage, additional data starts to stream into the process. In today's high-pressure environment, multi-disciplinary teams are often pulled together at this stage of a project.

These teams are often geographically dispersed and not part of the same corporate structure. This presents challenges, both in the centralization of data and the team's requirements for software provision, data access, and managerial control. Those building a team comprised of industrial designers, engineers, and electronics designers will need to ensure that their interactions are efficient and that data is shared and made available to those that need it.

When spinning up that team, virtualization, powered by NVIDIA virtual GPU (vGPU) technology, can provide real benefits. Data is centralized and secure in the data center. Virtual machines (VMs) or virtual CAD applications are predefined and ready to be deployed. And those managing the project have the control they need to ensure that, as needs change, so does data access and provision.

For example, Honda's Automobile R&D Center uses NVIDIA vGPU technology to serve different classes of users throughout the world. Virtual machines can be flexibly allocated and matched to the exact performance requirements of knowledge workers or power users running graphics-heavy engineering applications, such as Dassault Systèmes CATIA.



Image courtesy of **Lessmore Design**

At this stage in the product development process, models start to increase in complexity, which leads to an increased need for more powerful computing hardware. To fluently pan, zoom, and rotate 3D CAD models in the viewport, a desktop or mobile workstation with a mid-range professional GPU or a GPU-enabled virtual workstation is needed.

Visual quality can be enhanced with realistic, real-time effects such as ambient occlusion, which renders shadows more realistically, adding depth to models, or full-scene anti-aliasing (FSAA), which smooths jagged lines on computer displays. Real-time effects like this aid decision making but put greater demands on the GPU, so a more powerful graphics card may be required for a smooth design experience. This is especially true when viewing models on 4K displays, as more pixels need to be rendered.

For even higher-quality visualizations of precise engineering datasets, GPU-accelerated PBR tools can be used. PBR is based on physics, so renderings show how the model will truly appear in real life, helping lead to more confident decision making. (See side bar for more information.)

Designers and engineers can take advantage of more powerful GPUs to visualize a wealth of data and get results back quicker. To cut render times further, multiple GPUs can be used in tandem inside a single workstation. In the case of the high-end NVIDIA solutions, two GPUs can act as one through NVIDIA NVLink™ technology, which doubles the amount of GPU memory to process exceedingly large datasets.



Image courtesy of **Andre Matos**



Image courtesy of Tom Grammerstorf

## CONCLUSION

Today, next-generation visual computing technologies can help accelerate product development processes, starting with the earliest stages of design.

GPU-powered solutions can improve existing workflows and enable brand-new innovations—from advanced pen-based computing that enhance mobile creativity and collaboration, to high performance visualization using Quadro-powered workstations. Global teams can use the power of 3D virtualization accelerated by NVIDIA vGPU technology to ensure they have the capabilities they need, when they need them, in a secure, accessible manner.

Any organization looking to gain more productivity from its teams and their resources needs to address availability and mobility of data, authoring and collaboration systems, and computation resources. The combined use of these leading-edge visual computing technologies is driving advanced product design for Industry 4.0.

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

Part 2 will continue the discussion, focusing on the use of analysis, simulation, and virtual reality to evaluate a product's form, function, and fit, as well as its ergonomics.

Part 3 will cover 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.