



Effective 3D Design Collaboration

A best practice for improving collaboration between industrial design and mechanical engineering

The pressure on business to deliver an excellent customer experience while participating in today's complex global value chains places new demands on the relationship between industrial design and mechanical engineering.

This paper draws evidence directly from the hands-on experience of hundreds of innovation projects to make the case for a new best practice that fully leverages the capabilities of networked 3D CAD software to improve collaboration between industrial designers and mechanical engineers. This best practice is particularly adept at facilitating a more efficient division of labor and maximizing the skills of these professionals.

Executive summary

Industrial designers are brought into the product development process to complement mechanical engineers in situations where a more active consideration of human perception can enhance the commercial performance of a product. This practice fosters an unusual relationship between these two disciplines: they share responsibility for the design of many of the same components even though each discipline is accountable for different aspects of overall product performance.

Early solutions to traditional challenges

Traditionally, companies implemented a sequential methodology where industrial designers focused on the artistic visualization and creative intent of the product, usually in the form of an image or model. This model would then be passed to mechanical engineering, which then was tasked with interpreting this “vision” and developing a technical design for a manufacturable product with predictable performance and cost.

This method of “sequential image interpretation” has many well documented flaws, which include but not limited to the failure to adequately account for change across a highly iterative design process, the loss of critical design attributes as images/models are exchanged and the need for inefficient rework to reconcile the unaligned perspectives of the industrial design and mechanical engineering disciplines.

Similarly, over time, industrial designers and mechanical engineers have adopted IT tools that are focused on discipline-specific productivity at the expense of establishing better role definitions with the potential of facilitating a better overall product development process. Two additional business trends driven by cost reduction also pressed this traditional method to the breaking point: outsourcing and globalization.

With this in mind, forward thinking companies realized that they needed an improved innovation process that was able to facilitate a greater convergence between industrial design and mechanical engineering, especially in terms of enabling these disciplines to share and exchange knowledge more effectively early in a project.

In turn, this led to companies to adopt a variety of initiatives, including the switch from classic 2D drawings to 3D CAD technology and the parallel implementation of early industrial design/mechanical engineering collaboration techniques. However, as the limitations of these initial initiatives became evident, other technology improvements (such as more powerful hybrid parametric modeling tools with complex surfacing capabilities) were deployed.

A new division of labor

The business challenges of delivering better customer experiences through lower cost innovation value chains has created a demand for a new leadership role for industrial designers. In this scenario, industrial designers need to have more control over configuration and external detailing while also being held accountable for the implementation risks they influence.

While early attempts to introduce this approach were successful overall, they led to duplication of effort (especially with respect to the need to provide precise documentation of manufacturable form). Recently, this productivity handicap has been removed by the evolution of a new 3D CAD solids based methodology called “space allocation sharing.”

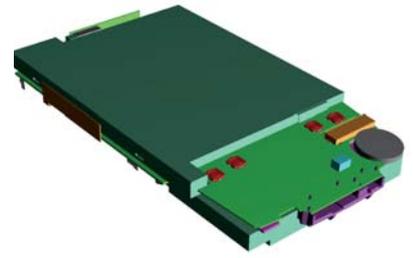
This approach not only eliminates the initial duplication, but also removes the traditional need for mechanical engineers to “reverse engineer” and re-document the industrial design. Practical experience has shown this new approach can reduce mechanical engineering effort by up to 60 percent, without increasing the scope of industrial design beyond traditional norms.

3D space allocation sharing has also demonstrated increased potential for low-risk, high-reward innovation by encouraging industrial designers to play a more proactive role in the overall product development cycle. The new space allocation method replaces the traditional “sequential re-creation” method of collaboration between industrial design and mechanical engineering by creating a new division of labor more adapted to today globalization and outsourcing initiatives.

As a result, industry design organizations take on the role of accountable leaders who perform “customer interaction design” with responsibility for the user experience, down to a fine level of detail. This role includes producing final, ready-for-manufacture documentation in 3D solids, including the main external shell forms and technical specifications of any property expected to be perceived by customers (e.g. weight, keypad feel). In addition, industrial designers are now responsible for proactively understanding and minimizing implementation risks using constraint anticipation techniques.

This approach frees mechanical engineering organizations from the ambiguous, unproductive tasks of interpreting design intent and re-documentation as well as from determining how to manufacture unresolved form. Mechanical engineers are now able to concentrate on achieving excellence in higher added value product elements and focusing their attention on the “design for optimal manufacturing” mission.

This paper concludes by detailing a variety of techniques for effectively implementing 3D space allocation as a best practice and maximizing a more efficient division of labor between industrial design and mechanical engineering.



HP Jornada PDA

From top to bottom:
3D Package, Frame ID data in brown-Mech E in blue, Final Product

Traditional challenges

While today's economy adds new challenges to relationship between the industrial design and mechanical engineering disciplines, historically the interactions between these two domains have been subjected to a variety of pressures. Traditionally, industrial designers were brought in to complement mechanical engineers in situations where it was supposed that a more active consideration of human perceptions could improve the commercial performance of a product.

Essentially, industrial design and mechanical engineering share responsibility for designing many of the same components even though each discipline is accountable for different aspects of the product's overall performance.

Sequential image interpretation as a basis for collaboration

The roots of the traditional collaboration process between these disciplines can be traced back to early industrial design pioneers, such as Raymond Loewy, a well known consultant, and GM's Harley Earl. These pioneers established a sequential methodology where industrial designers focused on the artistic visualization of the product's creative intent through an image or model. This model was then be passed on to the mechanical engineering group, which was tasked with interpreting this "vision" and developing a technical design for a manufacturable product with predictable performance metrics and cost targets.

This traditional method of "sequential image interpretation" has many well documented flaws, including the realization that:

- Industrial designs often need to be changed after marketing sign-off, sometimes quite radically, by engineers who may have little understanding of the original design intent; the more complex the product, the higher the probability this will occur.
- Industrial designs documented as images that need to be converted by engineers into dimensional databases often lose subtle, but important, characteristics in the process; the more complex the form, the greater this risk.
- In certain industries where the manufacturing complex forms is the norm (such as the automotive industry), expensive "reverse engineering" processes are required to assure faithful transition.

Despite these overall process flaws, sequential image interpretation has remained in the corporate mainstream for a variety of reasons. This inertia runs against established trends over the past 20 years, which have seen significant productivity gains throughout the rest of the product development process.

Industrial design innovations

However, it is important to note that this inertia has not been universal. Industrial design is a relatively new profession and after extensive case study analysis, a strong consensus on the role and value-add of industrial design has emerged from various management studies.

This new role is part of a larger trend towards recognition that all organizations, regardless of their underlying discipline, can improve their effectiveness by focusing more effort on planning and delivering unique and excellent customer/end user experiences. While none of today's innovation knowledge silos is fully equipped on its own to respond to this challenge, the human-centric and visionary aspects of industrial design are recognized as offering the best knowledge-based platform for progress.

Along these lines, forward thinking organizations (such as Apple and Philips) have evolved their industrial design operations to align with modern design management thinking to fulfill a broader, connective role. In this broader model, industrial design is linked with the other specialists and their knowledge silos. This new role expands the human interface responsibility of industrial designers beyond pre-sale persuasion (which focuses on the look of a static object) to a more holistic view of how products look, feel and behave. In turn, this holistic view is intended to produce more positive customer satisfaction throughout an entire experience-related lifecycle, which will enhance brand reputation.

This view challenges the classical relationship between industrial designers and mechanical engineers in several ways.

- The attention to detail needed to deliver better product experiences requires deeper consideration of build quality from the outset as an integral part of the design
- Late design compromises forced by downstream corrections are less and less acceptable for reasons of quality as much as efficiency
- The industrial designer's deep insight into the customer experience is expected to inform the basic product configuration as much as the shape of the outer skin.

In short, to deliver better quality experiences, innovation projects need to achieve greater convergence between industrial design and mechanical engineering knowledge earlier in the project. TheAlloy's award-winning Argus Thermal imaging camera is a practical demonstration of this imperative.

TheAlloy's real-world approach to industrial design innovation

The design for the Argus Thermal imaging camera was created by a "convergent" team at TheAlloy. This team consisted of industrial designers who were given extra mechanical engineering training and supervision. The



Suncorp

From top to bottom:
Inside product shell, Outside product shell - Alloy supplied 3D models in green, Engineer modified 3D models in orange.

camera uses internal electronic circuits similar to those found in competitive cameras. However, this camera's internal circuits were positioned within an enclosure in a novel configuration especially suited for its target market: professional firefighters.

This flat twin handle configuration facilitates fail safe transfer, in zero visibility, from one firefighter to another, making the camera less intrusive when not in direct use. These potential benefits were identified by TheAlloy's innovation team during hands on user research and the convergent role of the team empowered its members to attempt a totally new device configuration in parallel with the more classical layout initially favored by the client.

Market testing confirmed a clear user preference for the new ergonomic innovation. The convergent team proceeded to complete the full design for manufacturing the camera, as well as accepting responsibility for meeting its challenging environmental performance standards. Traditional industrial design/mechanical engineering collaboration methods would have inevitably resulted in a re-skin of the old configuration, missing as golden commercial opportunity.

Adding globalization and outsourcing to the innovation mix

At the same time that managerial innovators were making the case for a deeper convergence between industrial design and mechanical engineering, parallel outsourcing and globalization initiatives arose with a focus on cost savings. Unintentionally, these initiatives made convergence and cross-discipline collaboration even harder to achieve.

Effective collaboration depends on the willingness and ability of mechanical engineers to interpret the creative intent of industrial design visualizations. In turn, the ability to properly interpret these visualizations is inversely proportional to the level of separation between the two disciplines and their ability to share/exchange knowledge. While the differences between the professional knowledge sets of this two disciplines has been a traditional impediment to effective collaboration, outsourcing and globalization have add three additional degrees of separation to the industrial design/mechanical engineering relationship: commercial, physical and cultural.

Some of the more complex effects of outsourcing began to manifest themselves in the early 1990s when companies, such as British Telecommunications, started outsourcing the engineering realization and manufacture of its industrial designs. In these instances, outsourcing compounded the physical separation of extreme distance and time difference, as well as the cultural separation caused by the participation of teams with little English and totally different instincts (especially with respect to form, engineering practice and quality).

Companies began to realize that any form which could not be fully defined on a 2D engineering drawing could no longer be clarified using a note or



Argus3

From top to bottom:
Package, Exploded product shell, 3D assembly, Final product.

sketch in a meeting. Classical 2D drawings, even to engineering standard, were no longer sufficient to assure that a complex form, like a telephone handset, could be tooled correctly. The shape definition needed to be a physical model with the completeness and precision necessary to fully define the mold tool cavity. Practical limitations also made it extremely risky to hand over designs that left any outstanding issues that might require complex iterative changes.

Rapid realization of the need for new initiatives

In a relatively short time, faced with innovation value chains that needed to handle all 4 possible degrees of separation, the minimum acceptable format for industrial design documentation went from an image, to a 2D engineering drawing, to a physical tooling master-model.

Although the exact tactics used to overcome the challenge of 4 degree separation have changed considerably since the early 1990s, today's underlying collaboration principles have not. Globalized product developers need total completeness in documenting the industrial design to represent properties that affect the user experience. They also need to pull forward active consideration of as many realization risks as possible into industrial design, including responsibility for allocating sufficient space with appropriate enclosures that house a product's functional components.

Since then, the tactics themselves have been revolutionized by the rapid development of 3D CAD technology, which has functioned as an enabling tool to help improve the process of delivering excellent customer experiences through a global innovation value chains. However, it is important to keep in mind while 3D CAD has been highly valuable in this regard, other issues involving a more effective division of labor between industrial design and mechanical engineering still required additional improvement.

Evolution of 3D collaboration

Early implementations of the new industrial design/mechanical engineering collaboration methods achieved their core objective of better outcomes from globalized value chains but added extra documentation time and model costs to the design process. The parallel arrival of 3D CAD technology showed great potential to improve the productivity of the new more complex collaboration methods.

Early 3D collaboration

Early 3D design offered the theoretical prospect of productivity gains but neither early surface modeling technology nor early solid modeling offered a complete solution. The first uses of 3D collaboration were limited to improving the speed and accuracy of the master models used to document complex forms.

However, a series of projects in the early 90's using a non parametric solid modeling application successfully demonstrated that industrial designers could easily master 3D modeling (especially on complex 3D surfaces) and make good use of the enhanced visualization to manage manufacturing issues such as mold taper and risk issues while facilitating the allowance of sufficient internal space for components.

The use non parametric tools also encouraged a very practical and intuitive approach to sharing data sets created by different individuals: the use of Boolean operations to merge separately created elements. This process was used initially to allow two industrial designers to work concurrently on the same model (for example to allow one designer to progress the overall case forms while the other detailed the controls).

The lack of complex surfacing capability in early modelers resulted in their replacement by more powerful hybrid parametric modeling tools by the mid-90s. Experience comparing both parametric and non parametric approaches led to the conclusion that while parametric modeling provided users with essential control over their own design process, sharing open parametric data was not a practical basis for cross-discipline collaboration. The receiving party would need to understand the inherited code and sharing native parametric files required exact coordination release levels while the files themselves were considerably larger than non parametric sets. These three factors imposed severe constraints on global multi-party innovation.

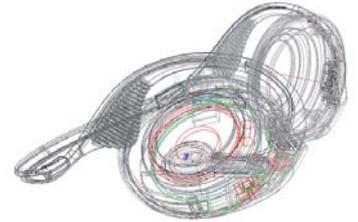
Spatial collaboration

In 2000, a definitive test of what came to be called the new "spatial collaboration" model materialized when TheAlloy was commissioned by Hewlett Packard to design the Jornada 545 PDA. The resulting design was very successful commercially and won a number of design awards. In addition the project was notable because it successfully met every challenge

the new spatial collaboration model could ever reasonably be expected to face as a solution for cross-discipline collaboration.

TheAlloy's final collaboration solution delivered high value ergonomic innovation by changing internal layout in complex ways which were only possible because the industrial design team was able to view the package in 3D. The industrial design database included shells of all visible components, as well as a hidden central chassis. Part files were continuously e-mailed to between participating team members, using the 8 hour time lag to obtain overnight replies to queries. The industrial data was created in TheAlloy's in house NX™ software then converted via STEP into the client's software format for release. The final industrial design revision was added to the database 24 hours before tooling release.

Since then, 3D CAD innovations, like assembly level parametrics, have facilitated many improved collaboration processes while their tactics have been altered occasionally to suit specific applications or external mechanical engineering preferences, but the basics of space allocation sharing have remained unchanged.



Qstik

*From top to bottom:
Concept sketch, Wireframe
model, Package within 3D
model, Final product.*

Emergence of a new breakdown of labor

The business challenges of delivering better customer experiences via globalized value chains has created a demand for a new leadership role for industrial designers where they exercise more control over configuration and external detailing while being held more strictly accountable for the implementation risks they influence.

Impact of space allocation sharing

Early solutions for driving this initiative were successful to a degree but led to duplicated effort as precise documentation was required for manufacturable form. This productivity handicap has been removed by the practical evolution of a new 3D CAD solids-based method called “space allocation sharing.”

This methodology not only eliminated the initial duplication, but removed the traditional need for mechanical engineers to “reverse engineer” and re-document the industrial design. Practical experience has shown this approach can reduce mechanical engineering effort by up to 60 percent, without increasing the scope of industrial design effort beyond traditional norms.

3D space allocation sharing also demonstrated increased potential for low-risk, high-reward innovation by encouraging industrial designers to play a more proactive role in anticipating and documenting assumptions about which geometric factors in overall product configuration will influence the product’s user experience.

The new space allocation method replaces the traditional “sequential re-creation” method of industrial design/mechanical engineering collaboration by facilitating a new division of labor that is more suitable for today’s globally oriented product development processes.

A new division of labor between industrial design and mechanical engineering

The role of industrial designers has evolved from creating subjective imagery, without accountability for realization, to accountable leadership for “customer interaction design.” In this new role, industrial designers are responsible for the user experience down to a fine level of detail.

This role requires industrial designers to produce final, ready-for-manufacture documentation (in 3D solids) of the main external shell forms, as well as technical specifications for any other property that is expected to be perceived by customers (such as weight, keypad feel),. In addition, industrial designers are expected to understand and proactively minimize implementation risks using constraint anticipation techniques. Similarly, industrial design deliverables have evolved producing “image suggestions” to establishing technical specifications that need to be either met or

amended in response to concession requests.

In this scenario, mechanical engineers are freed from the ambiguous, unproductive task of interpreting design intent and re-documenting it, as well as from the equally unsatisfying responsibility of determining how to manufacture unresolved forms, often to the detriment of product quality.

Mechanical engineers can now concentrate on adding higher value elements to the finished product and more clearly focusing on the design-for-optimal-manufacturing mission. As a result, they are able to spend more time creating and optimizing hidden technical detail, detailing material selection, tolerancing and selecting component vendors who are able to achieve the highest possible build quality. In addition, they can also perform other critical tasks such as determining performance and reliability and evaluating key resources including standard factory components, best designs for manufacturing and assembly/disassembly techniques.

Today, industrial design/mechanical engineering collaboration is facilitated through the use of shared 3D data elements within a common 3D model. The format for this collaboration can either be separate part files for industrial design and mechanical engineering contributions to each physical component or shared access to a common master model assembly that provides each discipline with permission to amend the parametric history created by the other.

Experience has also shown that this new form of collaboration also can play a key role in the unlocking of the theoretical benefits of product lifecycle management (PLM) by enabling industrial designers to create product configurations that make better use of data assets shared across projects, ranging from common parts to re-usable signature elements.

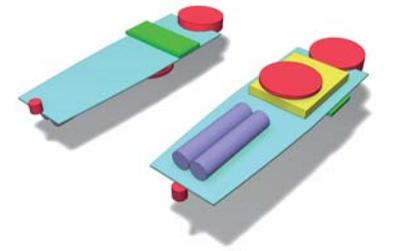
Continuing barriers to full collaboration

The new division of labor establishes two main challenges to managing industrial design:

- Getting industrial designers to take more responsibility for the manufacturability of their designs
- Equipping industrial designers with tools for creating and managing complex 3D surfacing in a parametric/solids 3D CAD environment

Both of these imperatives need to be addressed by reasonable amounts of internal training. Training in 3D software operation and complex 3D surfacing skill is arguably necessary for any industrial design professional creating complex form using 3D CAD. However, the training's specific content and emphasis will often differ from the standard software courses aimed at mechanical engineers. Today, lower-cost, easier to use solid modeling packages are available and the near universal consensus that "product development is done in solids" has eliminated this issue.

For external mechanical engineering teams, the main barriers to full collaboration has been a natural reluctance to inherit responsibility for data



Alloy Process

From top to bottom:
Package assumption, ID Shell around package, Complete ID shell, MechE additions (in green).

created by other disciplines.. This has been compounded by open mistrust of industrial designers' ability to deliver manufacturable form.

In practice, this trust barrier can usually be overcome by real world experience as industrial design teams prove their ability to deliver manufacturable data in actual projects. The recommended approach is to focus initially on demonstrating the ease of 3D sharing between both disciplines, with re-use presented as a purely optional benefit to be voluntarily adopted by mechanical engineers at their discretion.

Another important issue is the need for clear processes that allow mechanical engineers to make small fit adjustments to parts of the ID data, without them needing to understand the full parametric history.

In practice, the main practical barrier, and probably the only reason these techniques are not yet universal, is the lack of holistic innovation process management within companies and across complex multiparty value chains.

Best-practice collaboration

Space allocation sharing is a new method that represents a best practice for collaboration between industrial designers and mechanical engineers because of its well proven ability to deliver the best quality outcomes with the most efficient use of resources, even in the most complex global innovation value chain. Techniques for implementing this best practice include:

- Professional industrial designers and mechanical engineers should both be working in 3D solids. Co-working with the same software product is desirable but not essential (in this instance, release levels need to be coordinated).
- Collaboration through a common data standard (such as Siemens PLM Software's Parasolid® 3D geometric modeler) offers the optimum mix of flexibility and two-way data transfer reliability. STEP translation is reliable but small translation problems can delay individual releases.
- In addition to routine 3D CAD training, industrial designers will require specific training in data management and assemblies. Industrial designers will also require training and a documented standard practice that describes the design rules they should follow to assure manufacturability of the data they create. The more embedded these rules are within their 3D CAD environment, the easier and more reliable their adoption.
- At the very outset of any project briefing, the industrial design team should engage with the mechanical engineering team (and any other relevant project stakeholders) to agree on a database of schematic 3D geometries (as well as any associated variation rules for these geometries) that anticipate likely spatial constraints on the product design. The industrial design team should have full freedom to explore alternative internal layout architectures within the agreed variation rules, as these can unlock important sources of high value, low risk innovation.
- In the early stages of 3D industrial design, especially when multiple concepts are being investigated in parallel, a rough "sketch modeling standard" with complex, disorganized parametric histories reflecting iterative explorations is acceptable. However, the final refinement and documentation phase of the industrial design should include a full parametric rebuild to create a clean, well structured parametric history that will react reliably to late change requests and is suitable for integration in a full manufacturing database.
- Standard innovation procedures should state that the industrial design specification (including the 3D database) is an exact technical briefing requirement for the mechanical engineering process. This process should either be fully implemented or revised by common consent; it never should be ignored at the discretion of mechanical engineers working downstream.



BT Hub

From top to bottom:
Alloy designed 3D part,
Engineering designed
modifications in red,
Final product

- Within standard innovation procedures, the industrial design team should be held accountable for the design, 3D documentation and manufacturability of the customer interface surfaces as hollow shell-forms, solid modeled to a uniform wall thickness; this accountability extends from initial creation through to final production release.
- Project resourcing needs to ensure that the industrial design team is available throughout product development to receive and react promptly to engineering change requests as required, and to verify that the mechanical engineering data set fully and accurately reflects the industrial design data.
- For clarity of responsibility and to ensure reliable responses to late changes, industrial design data and mechanical engineering data should be kept separate in the master assembly database; ideally, this data should only be merged at the last practical point for specific releases, such as prototyping or tooling construction.

About the Author

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Gus has been managing & delivering award-winning, commercially successful, innovation, continuously, for the last 26 years for some of the world's top brands. His extensive and varied portfolio includes more than 800 projects, from cars, through phones, computers, TV's and radios, to elevators. He brings to the task a rare multi-disciplinary approach: he is an RCA trained industrial designer, but also with degrees in mechanical and systems engineering. After starting his career in car design with SAAB, Gus worked in-house at Sinclair Research before moving across into consultancy as Design Director of BIB, and then Managing & Creative director of Random Product Design before founding TheAlloy: experience led design in 1999.

Gus is a frequent writer and speaker on various topics around the common theme of innovation excellence and is frequently quoted in the media. Gus has been using 3D CAD since 1989 and has a long-held keen interest in the impact of 3D technology on the delivery and management of industrial design. He has spent the last 20 years, continuously testing and evolving new working practices looking to make the best possible connection between the new design technologies and the people who use them.

