2-19-2014

The Segmentation of Innovation: How Digital Design, Rapid Prototyping, and a Sharing Culture are changing the NPD Landscape

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This version:

February 19, 2014

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ABSTRACT

A 'perfect storm' of digital design, rapid prototyping, and social networking is fundamentally reshaping the new product development (NPD) landscape. Beyond design iteration speed and efficiency, this paradigm shift is affecting the locus of expertise and the form of ownership, which in turn enables achieving new levels of product performance and low cost as well as new forms of collaboration and transactions.

We identify four separate regions in this new NPD landscape, and label them traditional, entrepreneurial, community, and guild. Each NPD region is characterized by its own set of stakeholders and interaction dynamics. To help practicing R&D managers navigate this landscape, we discuss opportunities and challenges that each region presents for both firms and individuals.

Keywords: new product development, digital design, open innovation

1 INTRODUCTION

Throughout human history, we have observed two distinct eras of new product development, and we argue that a third era is currently emerging. These eras can be distinguished by the role that various actors play in designing, manufacturing, and ultimately using a product. The eras differ by who contributes to the work, where the locus of expertise resides, and the resulting product variety and quality.

The first of these product development eras (era I) developed with the dawn of humankind and lasted until the industrial revolution. In pre-renaissance times – with the exceptions of the ruling class – chances were that what anybody owned, he probably had designed and made it himself; i.e., clothing, furniture, or housewares. In other words, this person combined the roles of designer, manufacturer and user in one individual. Collaboration was minimal, and the resulting products, although few in quantity and crude in quality, tended to be tailored to the user's needs.

During the industrial revolution, a second era (era II) emerged. This era was defined by mass design and production by large firms, with the expertise centralized in those producing firms. Product users became consumers, with little or no involvement in the design and manufacture of these goods and services. Collaboration occurred between different experts, but rarely between experts and users. Product quality continuously improved and product cost fell with mass production, but variety was typically limited.

Currently, we argue that we are experiencing a shift to a third era (era III), one that enables new forms of collaboration, new levels of product performance, and – in some sectors – almost unlimited product variety via customization. But the *new* new product development landscape of era III is much less uniform than the NPD landscapes of previous eras. Instead, a set of powerful and reinforcing forces has segmented the new NPD landscape into several regions. Each of these regions exhibits unique characteristics that carry significant consequences for the actors involved, companies and individuals. Regardless of firm age or size, it is important for R&D managers to understand this landscape and leverage its inherent opportunities. In this research, we review the forces that have created this new landscape, use detailed case studies to illustrate the new segmented NPD process types, and recommend areas of opportunity for R&D personnel.

2 THE FORCES THAT CREATE THE NEW NPD LANDSCAPE

Just as the shift from era I to era II was caused by a combination of technological and social forces, so is the shift from era II to the new era III. The difference lies in the nature of these forces.

2.1 Era I > Era II: Industrial Revolution

The forces that drove the shift from era I, characterized by individualized products that were few in numbers and low in quality, to era II, which saw dramatically falling cost, increasing volumes, then gradually increasing quality, fall into three categories: energy, technology, and organization.

New sources of fossil fuels, combined with new technologies to harness energy (e.g., steam engines), led to an extraordinary multiplication of available power. In addition, the technology developments that allowed harnessing energy and its conversion into electricity enabled distributing power to almost any location.

Several key technologies also contributed to a dramatic increase in productivity. Automatic looms, electric arc furnaces, and moving assembly lines are examples of these technologies. In addition, quality improvements in manufacturing helped increase the repeatability and reliability of manufacturing processes to a point where interchangeable parts became possible, facilitating true mass production (Hounshell 1984).

Finally, growing and increasingly specialized organizations benefited from new management techniques and ownership structures. Factory work began to be measured and designed to be executed in an optimized way according to the principles of scientific management (Taylor 1911). In addition, the ability to pool capital through joint forms of ownership made investment projects possible in sizes which were hitherto only accessible to governments and very wealthy individuals.

2.2 Era II > Era III: Digital Revolution

In contrast to the shift between era I and era II several hundred years ago, which has been dissected by many historians, sociologists, economists, and political philosophers, the shift from era II to era III is still unfolding. We argue that three forces drive the shift from era II to era III: two are technical and one is social.

The first technical force that contributes to the emergence of the new NPD landscape, digital design, is itself a combination of two factors: the rapid performance improvements of computers over the past 60 years, and the increasing sophistication of digital design tools, such as Computer-Aided-Design (CAD), over the past 30 years. For example, since WWII, the progress in technical development of computers has resulted in an average rate of improvement of 45% per year and associated reduction in cost per calculation (Nordhaus 2007). Similarly, the cost of CAD systems continuously fell over the past 30 years (to the point that in 2014 some versions are free), and their performance and user-friendliness has drastically increased (Fixson and Marion 2012). Today, many

CAD programs provide substantial tutorials that allow steep learning curves, even for novices and children. In other words, the locus of expertise has moved to a large degree into the tool itself. As a result, the barrier for almost anyone to design products has become remarkably low.

The appearance of the second technical force is more recent – at least as it is broadly recognized (Anderson 2012). Over the past 30 years, various rapid prototyping technologies have progressed to a point that today they offer in the form of the various 3D-printing incarnations a mechanism that allows the fabrication of parts in almost any geometry in a batch size of one (Lipson and Kurman 2013; Petrick and Simpson 2013). Similar to CAD, the capabilities of these technologies have substantially increased and their costs have been dramatically reduced in recent years. While currently still more expensive on a unit cost basis than many mass production technologies for large production volumes, they open up small batch production that was hitherto economically impossible, and often technologically infeasible (Cohen, Sargeant, and Somers 2014). This in turn, makes it possible for almost anyone to manufacture a product, or to have it manufactured through low-cost Internet-based services. The independence from fixed tooling also means that much of the expertise for making parts and systems is moving into the tool, i.e., the printer, itself.

Finally, the third force is social. Children born in the 1980s and 1990s, sometimes called Generation Y or Millennials (Howe and Strauss 2007), grew up as 'Digital Natives' not only with the Internet and the vast array of digital tools, but are also accustomed to a culture of collaboration and sharing that differs from the one of previous generations. This culture is visible in communication behavior, in the way and the degree to which communities (both on-ground and online) are formed, and the formation of new forms of businesses that combine hierarchical and community aspects (e.g. AirBnb.com).

But not only are these three forces powerful in their own right, their joint occurrence generates a *perfect storm*, i.e., the individual forces combine and reinforce each other such that the whole has a greater impact than the sum of its parts would have (Figure 1).

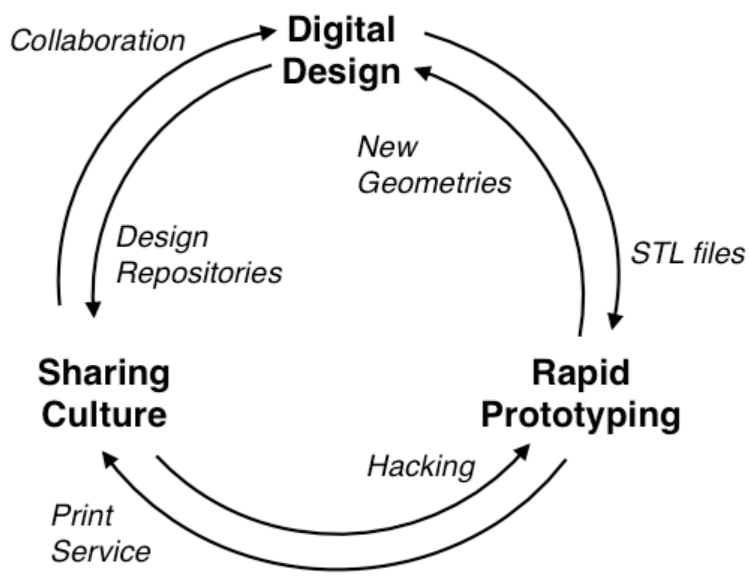


Figure 1: The era III 'perfect storm.'

For example, digital design tools such as CAD enable the use of rapid prototyping and make its use easier. Modern CAD programs not only create digital files describing the geometry of a component, its original purpose, but also allow easy conversion into file formats that rapid prototyping machines can read (e.g., STL file format). The latest SolidWorks® CAD software has a function that simply reads '3D print', just as word processing programs have a function 'print.' Likewise, the fact that 3D printing processes do not create the same manufacturing process-induced limitations and constraints as many traditional fabrication processes allows the generation of entirely new geometries in the CAD programs. Because CAD models are simply digital files, they can be easily transmitted and shared in digital repositories (e.g. GradCAD.com[1]). In turn, the sharing culture motivates users to collaborate on design projects, perhaps by modifying the same CAD model stored remotely in file sharing services (e.g., Dropbox.com). Finally, the independence of rapid prototyping technologies from its application area promotes its use in service form, i.e., a user can use prototyping capacity on demand (e.g., Quickparts.com), and on the low-end communities build their own 3D-printers by hacking, i.e., improving the printers of others.

2.3 How these forces create the new NPD landscape

The perfect storm of the three forces digital design, rapid prototyping, and sharing culture is segmenting the new product development landscape into four separate regions. As this new NPD landscape emerges, it is instructive to understand *how* these forces shape the new landscape (Figure 2). The advancement of digital design and fabrication tools shifts the locus of expertise required for product development work increasingly from a human expert into the tool. While powerful for both ends of the complexity spectrum, this shift has different effects for low complexity projects relative to those for high complexity projects. On the high complexity end (e.g., automobiles), the digital design tools open up new entirely new performance dimensions for product design, functionality, performance customization, analysis, evaluation, and life cycle monitoring. In contrast, on the low-end of the complexity spectrum (e.g., simple consumer products)

[1] www.GrabCAD.com is an online community that shares CAD files among users. Accessed February 18, 2014.

the main impact of this shift lies in dramatically lowering the entry barriers, in other words they permit almost everyone to engage in the product development process as a designer. This difference emerges because complexity and technological newness are contextual, and lead to different processes and procedures during product design and development (Balachandra and Friar 1997; Marion, Fixson, and Meyer 2012; Tatikonda and Rosenthal 2000). Individuals and firms pursuing less complex projects will have different technical and organizational needs than those pursing complex innovations. For example, resource requirements, both human and financial, can be vastly different between a several part consumer product and a complex motor vehicle.

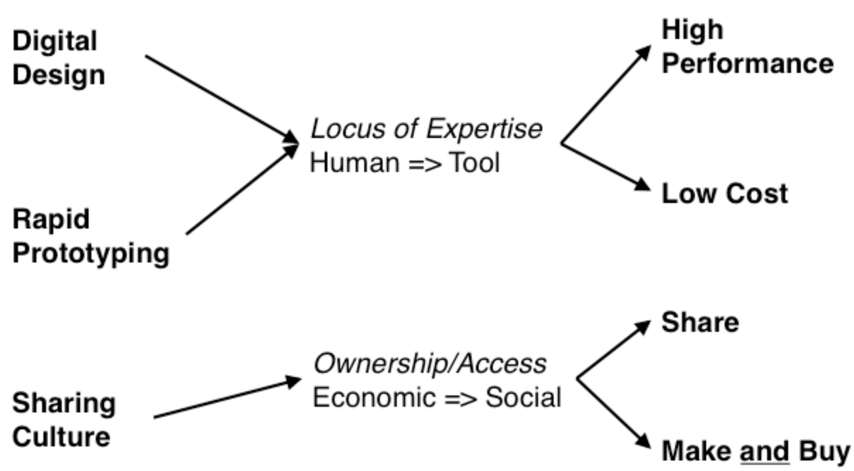


Figure 2: Effect paths of perfect storm forces.

The sharing culture, in part fueled by the growth of the Internet and mobile applications that make sharing almost effortless, is already creating new forms of organizing, adding community-structured forms to traditional organizations such as firms. Distributed innovation needs to leverage digital technology to its fullest, which has contributed to how physically distributed new product development is approached and executed (Eppinger and Chitkara 2006). This partial moving of economic activity into the social sphere will affect the traditional economic entities, both intra- and inter-organizationally, as well as enabling new forms of collaboration whose existence is depended on sharing behaviors.

3 THE NEW SEGMENTED PRODUCT DEVELOPMENT LANDSCAPE

These two dimensions, product complexity and nature of the inter-subject transaction, form a matrix that allows the identification of four regions in the segmented landscape of new product development (Figure 3). Below we describe the specific characteristic of each region in detail, and discuss opportunities and challenges that each region affords.

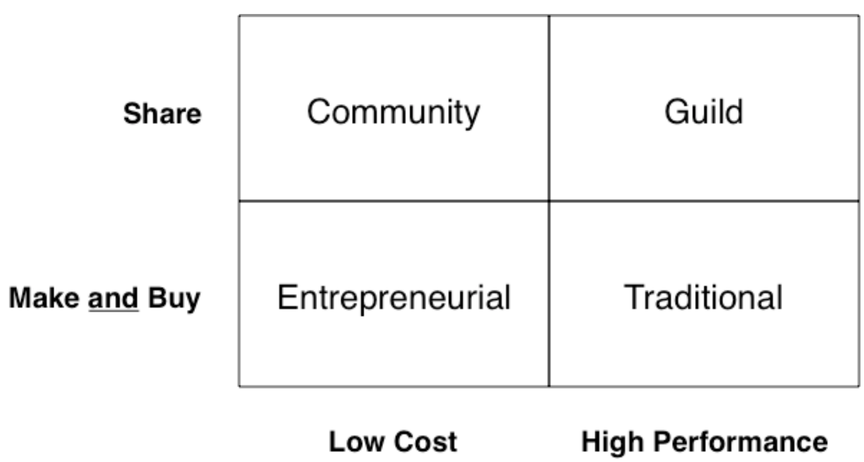
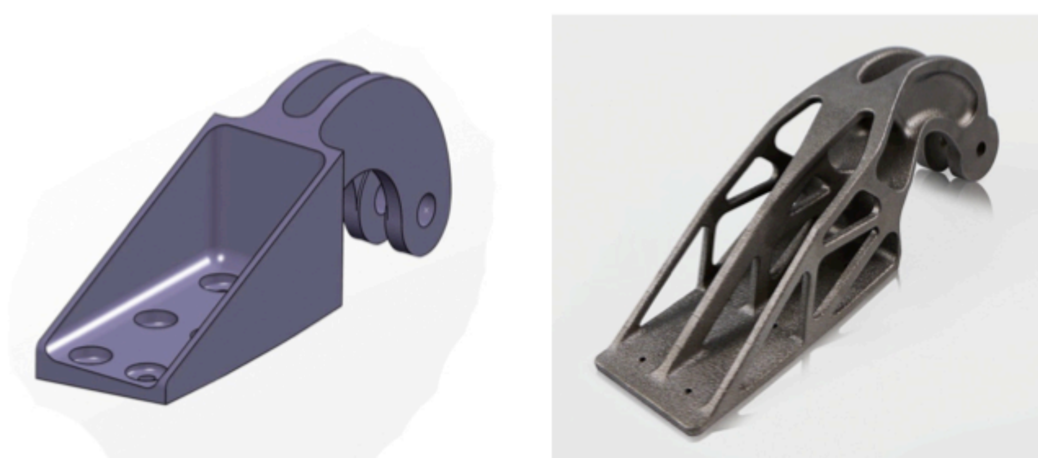


Figure 3: The segmented landscape of new product development.

3.1 Traditional

3.1.1 Characteristics

The traditional region of the new NPD landscape is what most closely resembles traditional new product development of era II. In this region, we see high complexity projects that are primarily driven by large, for-profit organizations. These can be high-risk, high-reward projects that are typically developed and commercialized by formal organizations. Companies such as Boeing, IBM, and Apple are examples of actors in this region. They are interested in developing intellectual property that can drive shareholder value. In order to accomplish this, the R&D organization is configured to focus on the innovation design and commercialization effort, to develop a specific product set. An example for this type of strategy are companies such as an aircraft component manufacturer that use advanced digital design and rapid prototyping fabrication technology in order to push the performance of their products to new levels (Figure 4) shows a redesigned component that provides similar strength at significantly lower part weight).



Conventionally designed and produced cast steel nacelle hinge bracket for an Airbus A320. source: EADS

Optimised titanium version of the nacelle hinge bracket made by DMLS additive manufacturing technology from EOS. source: EADS

Figure 4: Weight reduction of high performance components. Source EADS.

3.1.2 Opportunities and Challenges

The opportunities for firms operating in this region of the new NPD landscape present themselves in creating value by pushing the envelope of product performance. Technical possibilities also open up entirely new application areas, such as 3D scanning and printing of body parts for surgery preparation and training.

The challenges in the traditional sector are to build these technical capabilities in-house so that they are harder to imitate by competitors. This building of technical capabilities includes answering the question of how to attract and keep top-notch technical personnel. We see firms in various industries taking steps to in-source R&D and manufacturing to further strengthen core competencies and competitive advantage. Examples range from computer manufacturers such as Apple who develop their own central process unit (CPU) microprocessors to automotive firms designing and assembling their own battery packs and motors for electric vehicles. In case the capabilities have to be sought outside the company, one of the key challenges is to create the appropriate incentives and contracts for inter-company innovation.

3.2 Entrepreneurial

3.2.1 Characteristics

The entrepreneurial region of the segmented product development landscape combines both make and buy types of transactions with lower product complexity. Here many firms and individuals are entering the innovation business, sometimes jointly, often combining market-style transactions with some informal ones, e.g., mentoring. To support these new participants, an entire ecosystem of various economic actors has emerged. Some provide design tools (e.g., Google Sketch-Up) or design libraries (e.g., Thingiverse.com), others access to fabrication options (e.g., Makersrow.com), and yet others offer help in finding and selecting suppliers (e.g., Alibaba.com). As an example, consider Makerspace (makerspace.com), itself closely related to the maker movement. Makerspaces bring people and tools together to develop projects or prototypes. According to their mission statement: "Makerspaces come in all shapes and sizes. They all serve as a gathering point for tools, projects, mentors and expertise. A collection of tools does not define a Makerspace. Rather, we define it by what it enables: making." (Makerspace.com 2013) These spaces connect inventors, entrepreneurs, craftsmen, and students to coalesce around specialized interests with the goal of making an object or prototype.

3.2.2 Opportunities and Challenges

In this region there are clearly opportunities for service companies that can provide the ingredients that help the large number of small companies and individuals to start, improve, and complete their projects. With the rapid growth of application areas of the new design and fabrication tools, there will also be entirely new opportunities for service providers in this space. Following the needs of the entrepreneurs in this space is an important activity for anyone who wants to compete in it. An example of a company in this space is UTurn Audio (uturnaudio.com). Three students in Boston founded this new venture in 2012. They were able to leverage low cost rapid prototyping and communities of low cost manufacturing (100kgarages.com) to develop a high quality, low price record turntable for a growing niche market. To fund their effort, they turned to the crowdfunding site Kickstarter.com to raise over $200,000. They are currently manufacturing their products in downtown Boston.

One challenge that this region presents is the question of how to find scalable, non-niche markets. Many of the service providers benefit from network effects, so in some sub-areas of this region there might not be space for many rivals. For R&D managers of more established firms, this quadrant can allow small, entrepreneurial teams to develop new product ideas and test them at low cost. These internal ‘start-up’ teams can help seed traditional NPD concept funnels with ideas that are more advanced in terms of design and concept testing than traditional methods. Existing R&D teams can also become more ‘lean’ by using the techniques of resource constrained new ventures (Marion and Friar, 2012).

3.3 Community

3.3.1 Characteristics

Moving to the quadrant of the segmented NPD landscape that combines low product complexity and a sharing attitude brings us into the region we label ‘community.’ In this region, the setting of organizational and decision-making boundaries becomes substantially more fuzzy as sharing becomes an integral part for some business models. Relatively low complexity products, designed by communities of hobbyists or individuals with a keen motivation and interest in the intellectual (and monetary) pursuits of miscellaneous projects, exemplify this innovation mode. An example of a for-profit company in this region is Quirky (quirky.com). Quirky has established a community of participants that aid in suggesting, selecting, and designing of new projects. The community appears to include a large variety of expertise and interest levels, although the community is not a professional network per se. The economic model is a variation of licensing, in which the community selects and designs the inventor's product, and contributing members in return earn small monetary rewards, if the product is commercialized. The products are primarily low complexity consumer products, sold online or through large retailers. This is a relatively new space, and has attracted a great deal of attention. Quirky, for example, has received tens of millions of dollars in venture capital investment.

3.3.2 Opportunities and Challenges

The opportunities for firms operating in this region are potentially new forms of market development and user engagement. Both new ideas from and closer ties with consumers can be the result. For this very reason, GE recently invested $30 million in Quirky, and opened up some of its patent portfolio to the user community (Brustein 2013).

At the same time, several challenges are also present in this region. For example, the decision-making authority of the owners of a firm might be more constrained, if the opinion of 500,000 community members has to be considered. Also, maintaining a viable and contributing community over time is no simple feat and may require substantial resources to manage, and careful considerations of the type and scope of incentives. Finally, viable business models in which people pay for small volume productions, i.e., the opposite of scale, may be difficult to find.

One aspect to consider for R&D managers, weighting the pros and cons of establishing community design initiatives is how radical is the innovation they are trying to create. While open innovation and social networking are current buzzwords in the innovation space, our research indicates that this type of interaction is best suited for incremental product improvements or new ideas for simple products. R&D managers with branded lines of simple consumer products may look to establish these communities of co-design, but relying on these communities as sources of radically new ideas on complex engineered products may prove significantly more difficult.

3.4 Guild

3.4.1 Characteristics

Finally, the region of the new, segmented product development landscape that combines sharing interactions and complex products we label 'guild.' It is the least populated of the four regions. Nevertheless, there are several high-profile initiatives that leverage distributed communities working on complex, often high-tech projects, through collaborative environments. One example is the U.S. Defense Advanced Research Program Agency (DARPA) F.A.N.G. project. This project is using communities of amateurs and experts with a strong interest for the project to collaboratively design a new weapons system. According to the program Website: "DARPA, through the FANG program, is undertaking a radically novel approach to the design and manufacture of complex defense systems, and is hosting a series of prize-based design competitions. These are called the FANG Challenges, and their products will be progressively more complex vehicle subsystems, culminating in the design of a full Infantry Fighting Vehicle" (DARPA 2013). Another example is the case of Local Motors (localmotors.com), which uses communities and teams of decentralized individuals to design components and subsystems to design fully operable motor vehicles.

3.4.2 Opportunities and Challenges

If successfully managed, new product development in this region enables to create better product solutions and achieve new levels of process efficiencies. The challenges lie in how to successfully manage the processes. Building social norms, ensuring sufficient overlap, or at least information flow between designer and user communities, and orchestrating the actual work are no easy tasks. Another important challenge in this region – as well as the community region – is how to protect intellectual property (IP) while simultaneously maintaining the appropriate incentives for the participants. Fore example, an open source vehicle that allows user variation may not have the same standardized quality control and safety that a manufacturer who has all or most processes in-house desires. This may in turn affect government regulations, warranty transferability, and product lifecycles.

For R&D managers, the guild region – like the community region – is an attractive area to investigate. For example, companies like GE are experimenting in this space with aircraft component design. One issue is the parsing of components and subsystems. While it is straightforward to have a community give input on a mechanical bracket, it is another for these contributors to have visibility over an entire subsystem or total system. Even Local Motors, with a proprietary system of integration called 'The Forge,' does not engage the community for the more advance subsystems of the vehicle. The engine and drivetrain for their Rally Fighter off road vehicle are sourced from Ford Motor Company.

R&D managers, in considering this space, need to be conscious of the critical issue of design and systems integration.

4 CONCLUSION

Three major forces, digital design, rapid prototyping, and a share culture are forming a perfect storm that segments the NPD landscape into four separate regions. Each region comes with different but significant ramifications for users, consumers, communities, workers, and traditional firms. The locus of expertise is shifting from the human expert into the tool, allowing the experts to push technology frontiers outward in the traditional and guild regions of the new NPD landscape, and enabling non-experts to participate in product development activities like never before, especially in the entrepreneurial and community regions. At the same time, while economic transactions will remain the main form of exchange in the traditional and entrepreneurial regions, it will be complemented by social exchanges in the community and guild regions with significant challenges for designing incentives and ownership regimes.

Our research shows that there are many opportunities to leverage this new landscape, but all segments also have their challenges. We encourage firms to explore these different regions, but to do so with clear expectations and a firm grasp of the risk and reward potential.

ABOUT THE STUDY

This study represents the latest theoretical and practical implications from a longitudinal study of the impact of digital design on R&D. The study was begun in 2010 with the aid of PTC, a leading supplier of digital design software. Data has been collected from two surveys and through qualitative field research. In total, we have collected data from over 300 firms, which include traditional for-profit firms as well as new era III firms such as Quirky and UTurn Audio. Qualitative research has included structured interviews, panel discussions, and the organization of two design conferences on the subject of digital design, collaboration, and intellectual property.

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