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USING A "DARK HORSE" PROTOTYPE TO MANAGE INNOVATIVE TEAMS

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ABSTRACT: *Stanford University's design methodology program—a master's-level course in mechanical engineering—involves a prototype deliverable that explicitly prompts student design teams to investigate previously unexplored and potentially risky or intimidating corners of their design space. Each team carries out this exploration during a design mission known as the "Dark Horse Prototype." The prototype introduces a means of preventing premature convergence on an idea and forces teams to take a fresh look at their problem space. By reviewing case studies of projects in this course it can be seen that the Dark Horse prototype leads to most teams (1) replacing their vision with the Dark Horse vision or an element of it (2) adopting Dark Horse insights into their overall vision, or (3) using insights from the prototype to align as a team. We propose that the Dark Horse prototype is a powerful driver of innovation in any product development cycle, a useful tool for design space exploration, and a key asset in managing risk throughout the engineering design process.*

INTRODUCTION

Prototyping has become a staple of design work in Silicon Valley and is a focus of Stanford University's engineering and design programs. A hallmark of the Stanford design methodology program ME310 is the "Dark Horse" prototype. As a tool in the design process in the ME310 program, the Dark Horse prototype has had surprising results over the years, including many innovations and unexpected insights.

Stanford University's ME310 program, *Project-Based Engineering Design, Innovation, and Development,* is a yearlong master's-level course in design methodology. Taught since 1967, this mechanical engineering program leads teams of Stanford and international students (i.e. at partner institutions globally) through a product development cycle that focuses on innovation and engineering within design spaces proposed by external corporate partners (Carleton and Leifer, 2009). The curriculum strongly emphasizes design thinking principles related to physical prototyping and user testing. Over the course of nine months, the student teams explore a number of user needs and produce a variety of design solutions that are prototyped at varying degrees of refinement and resolution. The project cycle culminates in the presentation of a finely crafted product vision, the demonstration of a refined product prototype, and the summary of user testing results gathered along the way.

As part of the course curriculum, a number of prototype prompts (or design "missions") have evolved to push teams to explore different areas of their design spaces or encourage teams to tackle different challenges within the design

process. In 1999 Stanford Professor Mark Cutkosky created the "Dark Horse" prototype as part of this process. This prototype explicitly calls for the exploration ideas that may never otherwise be explored in an effort to "colonize" the design space, an idea set forth from the Design Space Colonization project (www.cdr.stanford.edu/DSC/) (Cutkosky et al, 1993) (Toye et al., 1993). The Dark Horse consistently results in interesting and innovative ideas, evaluated through physical prototyping and objective user testing.

The authors consist of five teaching team members for the 2012-2013 ME310 program who were responsible for coaching and evaluating design teams and have seen the positive impacts of the Dark Horse prototype. This paper presents three case studies personally witnessed from the ME310 program. This is followed by discussion of possible reasons for the positive impacts and possible uses of the prototype for design innovation and management of product development.

THE "DARK HORSE"

The title of this prototype is borrowed from the world of horse racing. Conventionally, a "dark horse" refers to a contender (such a race horse) who is little known and believed to be unlikely to succeed. However, if such a contender has an unexpectedly good performance, the payoff will be relatively huge. This is the guiding spirit of the Dark Horse design mission. By trying something "out there" or seemingly "impossible," Cutkosky explained that it "forced [teams] to take a fresh look." As described later in the case studies, this prototype will result in a revolutionary design innovation at best. At worst, teams have a chance to gain tremendous insights about their users, the design space they are working within, or the process they are following. In all cases, the Dark Horse prototype prevents the design space from shrinking too rapidly and fosters an improved framework for analyzing future findings.

There are three requirements for a Dark Horse prototype:

1. The prototype vision is "dark."

The prototype must explore a space that is "dark," meaning that it is risky, radical, infeasible, and/or in a direction orthogonal to previously explored solutions. The technical implementation, questionable user perception, or its departure from a plausible direction already converged on, should make the team feel uncomfortable in pursuing it as a direction.

2. It is initiated after a cohesive product vision has been formed.

In some ways all prototypes are "dark." For this reason, an already established product vision should exist as reference for what is radical and what is not. The Dark Horse is usually a clear departure from this vision.

3. It is refined enough to be objectively tested.

The prototype must be taken to a point where it can be tested with objective users. Assumptions and preconceptions of the design team cloud the whole prototyping process, so external testing is the only way to properly evaluate the prototype.

BACKGROUND & LITERATURE REVIEW

Physical prototyping stands as a significant and multifaceted tool within the iterative process of engineering design and development. In a very broad sense, prototypes "provide the means for examining design problems and solutions" (Houde and Hill, 1997).

Lim, Stolterman, and Tenenberg (2008) describe prototypes as "tools for traversing a design space where all possible design alternatives and their rationales can be explored." Lim et. al go on to describe how a prototype's "anatomy"—consisting of its material, resolution, and scope—can vary. This results in prototypes, or exploratory "tools," of varying styles and forms. They conclude that "the best prototype is one that, in the simplest and most efficient way, makes the possibilities and limitations of a design idea visible and measurable."

For the last 14 years, the Dark Horse prototype has served as an integral design space traversal tool within the ME310 program. Each year, as part of a two to three week mission, each ME310 design team is prompted to explore a direction that by most standards would be considered too risky, too radical, or even too technically difficult to complete. This prototype serves as an intentional (and somewhat forced) departure from any previously explored design path: "the dark horse gives designers the permission to think bigger and more creatively" (Carleton and Cockayne, 2009). Students enter this particular design cycle with many preconceived notions regarding their user group, their product vision, and the scope of their project. The Dark Horse explicitly releases teams from this vision, requiring an entirely new direction to be explored. Teams are asked "specifically to invest some time on a prototype that uses a concept or technology that they did not seriously consider in the [previous quarter]" (Cutkosky, 2000).

Rhinow, Köppen, and Meinel (2012) discuss the role of prototypes within organizations and go on to describe three major categories: "(1) the role of prototypes as a manifestation for user feedback, (2) the role of prototypes as a tool to improve team experience, and (3) prototypes as a force to converge thinking during the design phase." The Dark Horse prototype, along with each and every prototype built into the ME310 curriculum, fits within this categorization. As teams reflect on their process thus far, brainstorm potential prototypes, and create and test a tangible representation of their collective vision, the Dark Horse transitions amongst each of these three roles.

Finally, the Dark Horse aligns with the iterative process of divergent behaviors following converging behaviors for radical changes (Alexander, 1964), both because of its own prompt and because of its chronological placement during the ME310 program. As a prompt, teams are asked to diverge on a concept and converge on an idea for a prototype at the same time, adding a level of complexity to the cycle of design thinking (Eris, 2003). From an overall point of view, the placement of this prototype after an initial vision is formed helps to form new and different ideas, because the normally innovative space has already been considered, and that is what the "dark" innovation space *isn't*.

CASE STUDIES

The three case studies that follow are from the teaching teams' notes from the entire program cycle, the teams' documentation, and team member interviews. They describe the teams' early prototypes and initial project direction, the Dark Horse vision and prototype, and the impact of the Dark Horse on the team's product vision moving forward. The three exemplify common project outcomes of this prototype, which include:

1. The Dark Horse concept becomes the final prototype, as exemplified in the Thales case study.
2. An element of the Dark Horse prototype is carried through into the final product vision, as exemplified in the Swisscom case study.
3. The Dark Horse concept is not carried forward, but the team aligns on a new and different direction based on findings, as exemplified in the Audi case study.

CASE STUDY 1: THALES (2011-2012)

The Thales team of 2011-2012 is an example of a team for whom the successful implementation of a Dark Horse solution was received well enough to become the new product vision. The precision optics manufacturer Angénieux, a subsidiary of the French electrical systems group Thales, sponsored the project, a cooperation of Stanford and the Ecole des Ponts ParisTech. Initially given the prompt to "design the next-generation cinema/broadcasting imaging system," the team ended the year with an optical system that captures the entire 3D

information of a film scene, allowing directors to select from an infinite number of perspectives and camera movements post-filming. This technically impressive solution was arrived at in pursuit of a Dark Horse idea that seemed technologically infeasible on conception.

By the end of the first term of the project, the team had settled on a movie viewer-centric approach to the project prompt. They had great success with two early prototypes: 1) A focus-shifting prototype involving webcam motion-capture technology in a helmet and selective-focusing software to allow a viewer's eye movement to control an image's focus and 2) A perspective-shifting prototype involving infrared sensors in a pair of glasses to track a viewer's head movement and display an image in the corresponding perspective. They combined these prototypes into a single vision that they planned to move forward with: To create an immersive movie-watching experience in which the viewer's head and eye positions affect both the perspective and focus of a scene (Figure 1).

Figure 1 ParisTech and Stanford students test a helmet and glasses that shift the focus and perspective of an image based on the user's movement, elements of the team's initial product vision.

On being asked to pursue an orthogonal direction, for the Dark Horse prototype the team decided to return to a focus on assisting the filmmaker rather than the viewer, as their early user research had shown them that they had the greater need. They had heard in multiple interviews that directors are often constrained in their visions by their own filming equipment, and that they often feel "as though their vision of each shot risked being diluted or misinterpreted by their camera operators." To free directors of the burdens of their equipment, the radical idea that the team kept returning to was a movie set with no cameras at all: "We had often jokingly brainstormed about 'what if the camera could be everywhere?'" (Brero et al., 2012)

After much exploration, the team arrived at a Dark Horse solution that freed filmmakers from the limitations of needing to record scenes from an exact location. They called it the "OmniCam Studio": rigs of multiple Microsoft Kinects and software compilations that captured the 3D and color information of a film scene and allowed for post-capture scene manipulation (Figure 2).

The directors and actors who tried it were immediately excited and intrigued by the possibilities, and the team was off and running in the new direction, electing to refine their Dark Horse direction for their final product. In the final implementation, they integrated hardware and software into the technology developed for their Dark Horse to capture and replay movies.

Figure 2 A director tests a refined version of the Thales team's Dark Horse scene-capturing setup, including multiple Microsoft Kinects and a compilation of software.

Interestingly, the team later reflected in their documentation that manipulating the way a scene is captured was not as orthogonal from their perspective-shift and focus-shift prototypes as they thought, and in fact it touched on "many ideas that we have scribbled on our whiteboards over the course of the project." As most ME310 teams realize by the end of the course, in hindsight they are able to see the intrinsic relationships among their prototypes and how their seemingly disparate

learnings contribute to a final validated prototype. In most cases, such as the Swisscom case study that follows, the Dark Horse results in a selection of important and useful learnings that carry through to the final prototype; in cases like the Thales team, the successful and well-received implementation of a truly radical Dark Horse prototype can result in an innovative new direction.

CASE STUDY 2: SWISSCOM (2009-2010)

In 2009 a Stanford student team paired with the University of St. Gallen in Switzerland was working with Swisscom AG, a major Swiss telecommunications provider. The problem statement was to "reinvent video communication to make it more appealing to users in the consumer market." The team had begun an exploration into camera placement and viewing on each side with their initial prototypes based on user feedback. They found that screen distance and vertical placement were important, and that a single view was less distracting. The resulting overall product vision was an integrated system in a person's home that would capture video of the user in the room so that they were not restricted to a device in any one place. Figure 3 shows an image the team created to communicate their vision in a brochure.

Figure 3 The Swisscom team's initial product vision, a video-recording system that is ambient rather than restricted to a single location or device.

The team was then tasked with creating a Dark Horse prototype. They decided to create "Vid Zeppelin," an aerial telepresence blimp that a user could remotely control to move around a space and have a physical presence. The team documented that it was "conceived as a way to create a guest-host relationship by giving the guest a self-mobile, physical avatar in the host environment." The zeppelin can be seen in Figure 4 below.

Figure 4 The Swisscom team's telepresence blimp, a Dark Horse departure from their original product vision.

Constructing the prototype was a technical success, and the team found that the "dramatic presence" was exciting and interesting for users. Some findings directly from the team's documentation reveal key takeaways that carried through to the final project, such as the:

"•Guest's ability to see more allowed her to understand the context of the host's environment

•Guest felt more immersed in the environment through the self-mobility of the prototype

•Guest-host paradigm successfully freed from physical and interactive constraints."

The team then went on to create the "Viver" device (Figure 5), which had the primary innovation of user-controlled directional movement. Instead of flight, though, it was a device that sat on a table at home, with a guest-host user interface.

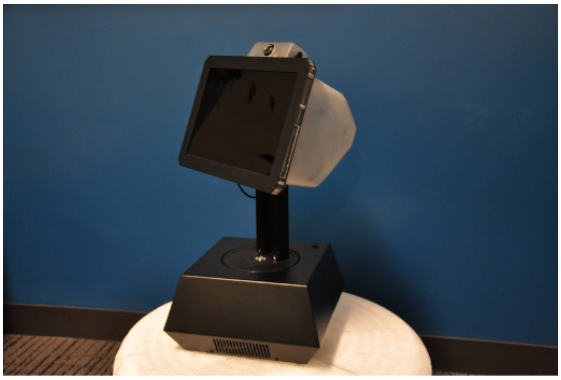

Figure 5 The Swisscom team's final functional prototype, a videoconferencing unit that allows participants to control the viewing angle remotely. This critical design element evolved directly from their Dark Horse prototype.

The team tried a radical idea of a flying blimp videoconferencing system and succeeded in creating it. They used the innovative ideas of user-controlled movement and a philosophical model of "guest" and "host" to focus their innovation. This is an example of the dark horse leading to a nugget of innovation that can be used in a real product.

CASE STUDY 3: AUDI (2012-2013)

The Audi team of the academic year 2012-2013 was a partnership between Stanford and Aalto University in Helsinki, Finland. Their prompt, from German automobile company Audi, was to design a cabin space for the autonomous car of 2035 that provides the driver with open space for entertainment or work and the ability to seamlessly resume manual control as desired.

The team's first significant prototypes were 1) a functional training interface that displayed visual cues to guide drivers to smoothly resume control of an autonomous vehicle and 2) a chair that simulated automatic position adjustments based on the rider's desired activity. These prototypes resulted in an abstract initial product vision of creating "adaptable cabin spaces suitable for many activities, in order to transform the journey into the destination."

When challenged with the Dark Horse assignment, the vision that followed, though still in the space of configurable cabin spaces, was dark because of the technical challenge: Pop-up pneumatic furniture that automatically morphs the cabin into a space completely customized to its occupants and their activities. "We didn't even prototype it. Not feasible," one of the team members described the engineering necessary to achieve the grand vision in two weeks. Instead, they were able to test the vision in a far faster manner with a clever simulated experience. The team rented a U-Haul van, presented passengers with an interface that allowed them to select their cabin configuration for a specified trip, and quickly outfitted the van with the desired configuration by the time the passenger opened the door (Figure 6). The concealed driver, voice masked by computer, asked passengers about additional desires (like food and magazines) en route, giving a personalized autonomous drive experience.

Figure 6 A user tests the Audi team's Dark Horse prototype, a simulated autonomous vehicle that allows for extreme "automatic" custom furniture configuration.

The team describes the impact of this Dark Horse prototype as "huge"—but unlike teams like Swisscom and Thales, it didn't define what the final product or any final features would be. Instead, the Dark Horse generated learnings that clarified the direction that the team should head next: "It helped us define the problem." They noticed that there was something interesting going on in the prototype with transitions, and the team aligned on a re-frame of the problem they were solving: "'Transition' until the Dark Horse meant transitioning between modes [of

autonomous and manual control]. After, it meant between activities."

For the Audi team, the Dark Horse enabled them to align on a vision. They discovered a part of the design space—specifically, transitions between activities in an autonomous vehicle—that they had not pursued in the Dark Horse, but that led them to a valuable problem reframe that they would carry through to their final product. The final product for the team was an anticipatory chair that responded to a driver's body movement, an open cabin space for activities, and a retracting steering wheel to regain control of the autonomous vehicle (Figure 7). It was a successful, highly technical solution that was received well by both sponsor and testers.

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Figure 7 A model of the final car cabin space built by the Audi team, the result of reframing their project prompt after exploring an alternative design space in the Dark Horse prototype.

In addition to aligning on the vision, the Audi team also gained process learnings from the Dark Horse mission, another common benefit of this prototype. In Audi's case, the main process learning was of the value of prototyping at a resolution that is only high enough to get valid user feedback and no higher. With prototyping that was lower resolution, but still high enough to convey their vision, they were far more agile than if they had engineered functional technical solutions in the exploratory prototyping phase: "We were able to try a bunch of different stuff really easily, which was a good thing." Process learnings vary greatly from team to team based on their experiences. Other examples of such learnings may include better understandings of a team's technical limitations and learnings related to team dynamics.

DISCUSSION

USING THE DARK HORSE TO SPUR INNOVATION

From the case studies we see that the Dark Horse formula works for creating innovation in a design team in a variety of ways. Whether the prototype is successful or not, and regardless of which category the project falls under, the Dark Horse prototype is a unique forcing function of innovation. By eliminating inhibition related to the fear of invalidity, in fact, by enforcing invalidity, the teams are able to focus on the needs of users and the design team, which is shown to be an indicator for success (Rietzschel 2007). One person involved in a project that continued after his program ended said "it made me less afraid of doing things that bother people, less nervous about taking risks on the final project."

The right combination of resource constraint and boundary-pushing can lead teams to innovation. The Dark Horse seems to effectively eliminate the intimidating "blank canvas" by requiring a prototype that is risky and letting teams operate freely within that safe zone. This is a tested method for creating breakthrough thinking (Coyne, K. et al 2007). A student reported that "[the Dark Horse] forced us to be more creative" and that his team decided to "choose a feasible and most creative idea" for their prototype. Without giving teams the context in which they have the freedom to fail safely, they will often strive for only what they know they can achieve. The more innovative projects in the class arise when teams are pushed to build visionary prototypes they have no confidence will succeed. Even if the teams do not achieve their original "dark" vision, where they end up is often far more innovative than if they had sought only the possible from the start. As is said in the class, "If you shoot for the moon, you may land among the stars."

MANAGERIAL IMPLICATIONS OF THE DARK HORSE

Because a Dark Horse prototype necessarily aims for something risky, it can be used to exaggerate risks for easier identification and management thereof. By requiring the creation of the prototype, a design team is forced to evaluate what is possible or not and dive into possibilities that may not be apparent, lending itself to a Heuristic approach to risk management as suggested in Grubisic et al (2011).

For planning, prior to the prototyping phase the estimations of resources required and the impact of a job can be optimistic (Dailey & Mumford 2006). When attempting something possibly unreachable, expectations can be managed and compensated for the team, whether they are unable to reach their goals or they in fact completed what they thought was an impossible task.

Lastly, the Dark Horse also exists as a tool for minimizing risk and fostering a viable prototyping "culture" within the program. Schrage (2006) discusses the implications of crafting such a culture. If an organization or group creates a culture where only safe, highly refined prototypes are shared amongst the team, advisors, and management, then prototypes become a tool to prove a point and the potential "design dialogue around emerging prototypes" may be lost. In a professional setting, Schrage implies that prototype information is then only shared with managers when it is too late in the design cycle and they are being "asked to approve—rather than to review or assist—new product creation." The Dark Horse ensures that teams are open with and accepting of their dance with ambiguous (and seemingly risky) design solutions. In this case, as Schrage concludes, "prototypes are as much a medium for managing risks as they are a medium for exploring opportunities."

CONCLUSIONS

The Dark Horse prototype as it is used in the ME310 has been a powerful tool for spurring innovation in the product design process. The placement in the sequence of prototypes and the prompt definition contribute to the effectiveness. The psychology of releasing the expectations while simultaneously pressuring teams to do the impossible pays off in nearly every project. This is even more significant because it occurs after the teams have already developed notions of what the product's potential value may be.

The case studies described above are not exhaustive, but do represent the majority of cases witnessed in the course. It needs to be noted that the cases are all derived from the academic setting of ME310 with graduate students at Stanford University. The students are operating with real budgets and are producing products, but going to market is not usually the responsibility of the team members. It should also be recognized that not every Dark Horse is a success. Teams sometimes fail to execute their prototypes or gain real insights for the project. This most often happens if a team does not push an idea far enough, or does not put enough effort into execution or user testing.

Future work on the Dark Horse prototype will involve more emphasis on iteration and user testing. The definition and best practices of the prototype develop with each year's iteration on the class and hopefully lead to better, more innovative projects with compelling results.

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