Single-Session Design:
Design Methodology in Compressed Timeframes
Derived from the *Robot Rivals* Television Series

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Abstract

The purpose of this study is to document the design process as it is adapted to compressed timeframes. I have termed this adapted design process single-session design. This study will also explore the application of this type of design methodology in industry where the research and development phases of products are continually being compressed.

The primary research for this study is extracted from the examples of rapid design observed repeatedly on the *Robot Rivals* television series on the Do It Yourself network. The scope of this television series is a competition between two teams of engineering students to design, build, and operate a robot in a single day. The show yields an ideal platform to study the design process in a highly adaptive and compressed form. This study will show how the design process can be adapted to function in a fast-paced situation.

The design process in general has been studied for quite some time. However, to date there is no focused research on a specific design methodology that is intended for extremely short-term projects. This research provides insight into the situation where significant time constraints stimulate creativity and ingenuity in designs.

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Chapter 1 – Introduction

The main purpose of this chapter is to introduce the topic of engineering design, especially the subjects of product design and development. Also presented is the focus of this study, single-session design, and the connection between this design methodology to the *Robot Rivals* television production. Finally, the research objectives and methods of analysis are discussed.

1.1 The Traditional Design Process

Efficiency and productivity have long been the aspiration of industry. Toward this goal, companies spend millions of dollars streamlining their processes to reduce product development times. In recent years, manufacturers have reaped the benefits of rapid prototyping and other new technologies, in efforts to speed up the process of bringing ideas into reality. However, the process of formulating design solutions continues to be a bottleneck, even in a streamlined company.

Product development is a set of activities that begins with the identification of a market opportunity and results in the production of a product. The success of development processes can be assessed according to five variables: (1) product quality, (2) product cost, (3) development time, (4) development cost, and (5) development capability. In regard to this research on single-session design, the development aspects of the process are of most interest. The development time of a product refers to the speed at which the product development phase is implemented. This metric assesses a company's responsiveness to competitive forces and technological advancements. Directly related to the development time metric, the metric for development cost evaluates the expense of the process. Typically, the longer a product takes to be developed, the more expensive it is. Finally, development capability assesses a company's capacity to improve the design process based on successive projects. This metric gauges a development team's ability to better develop future products.

Product development can be a daunting assignment. Notable success is rarely achieved more than half the time [2]. There are four main obstacles in the development process that contribute to these less-than-desirable odds. Primarily, designers must consider trade-offs—the continual campaign of evaluating benefits and side effects. A successful company effectively manages trade-offs throughout the entire design process. The next obstacle is the inherent dynamic characteristic of product development. Organizations must cope with ever changing technologies, evolving customer desires, competitive markets, and the economic climate. A seemingly minor part of the process that can actually lead to success or failure are design details. Decisions as small as whether to use screws or snap-fits have implications of millions of dollars in the scope of a product that is sent to market. Finally, one of the most formidable challenges to a design team is time. Each of these three aspects must be dealt with continually. Moreover, they must be dealt with efficiently in the competitive markets that exist today. Decisions that delay a company by a single day can result in a competitor's product reaching the market first.

Highly motivated and cooperative groups, composed of members with a wide range of training, experience, and perspectives, can adequately confront the challenges in the product development world. However, according to Ulrich and Eppinger [2], there are several conditions that will lead even the most well equipped team to failure. First and foremost, micromanaging is a detrimental activity that can stall team progress. This activity occurs when general managers and functional managers continually intervene in detailed decision making without full understanding of the whole process. Another counter-productive activity occurs when functional allegiances transcend the project goals. Sub-teams within the overall group may have personal agendas that influence decisions without regard to the complete success of the product. Inadequate resources are a common stumbling block for design teams. Mismatching skill-sets, inadequate staff, or lack of funding, tools, and equipment are all issues over which the team itself has little control. Finally, designs may fail to meet customer requirements due to a lack of cross-functional representation. Development decisions may be made without the guidance from key units within the company if these units are not initially included in the design team. For an organization to achieve success, these restrictive barriers must be reduced or eliminated.

The traditional design process is widely known in the engineering community. A requisite element of most engineering educations, the design process is often taught early in the undergraduate curriculum. Students work through examples and take part in projects where the traditional process is implemented. Figure 1-1 shows a flowchart representation of the traditional design process. By definition, a process is a sequence of steps that transform a set of inputs into a set of outputs. In the case of design, many of these steps are intellectual and organizational rather than physical. A defined process for product development is useful to organizations in several key ways. First, a structured process allows checkpoints to be implemented in order to assure product quality. As the product moves through the various phases of the process, its quality can be assessed along the way. A clearly defined process also helps the entire design team coordinate their activities. A well articulated plan informs the members of the team which activities are ongoing and what their contribution may need to be. Next, the defined development process aids the planning of the project. As the phases of the project are completed, the overall schedule becomes more defined. Finally, a clear process allows management to effectively determine areas that may need improvement by comparing actual events to those previously established. As a whole, a defined process aids in all of these areas by documenting the course of the development. This documentation often leads to the identification of opportunities for improvement in future projects.

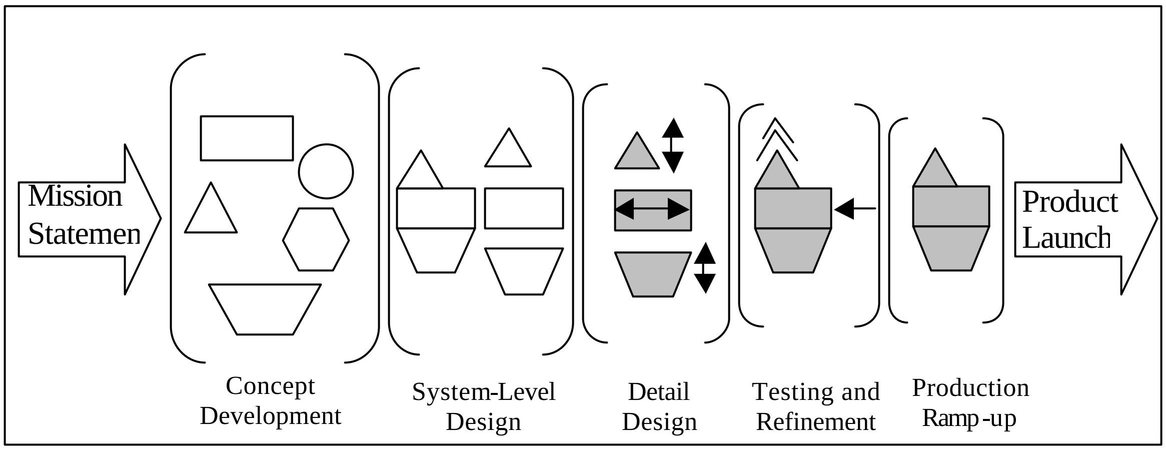

Figure 1-1: Generic process for concept development [2]

The initial phase of the development process diagramed in Figure 1-1 is concept development. This thesis will focus mainly on this front-end process. It is in the concept development phase that the needs of the target market are identified, that alternative concepts are generated and evaluated, and that a single concept is chosen for further development. Figure 1-2 graphically depicts this phase of the process. This particular phase of the development process essentially dictates the rest of the development procedure. Through the coordination of many of the functional groups, it is during this phase that the kernel for design is planted. There are eight main phases in the concept development phase. The first two are identifying customer needs and establishing target specifications based on those needs. Next, an analysis of competitive products takes place, and subsequently concept generation and concept selection procedures are completed. After a concept has been selected, target specifications are revisited and refined to reflect the chosen design. Finally, an economic analysis is performed, and a detailed project planning phase is implemented. Each of these phases is discussed and illustrated using a hypothetical design for a power drill as an example.

Defining the scope of the project, gathering and interpreting customer data, and organizing and ranking needs are the main steps in identifying customer needs. The output of this step is an organized hierarchical list, with importance weightings for each customer need. For the case of the power drill, customer surveys are implemented to ascertain desirable features of the drill. Construction site visits are performed to talk with workers that use drills every day. This data, along with features that the design team thinks will be useful, are compiled to create the list of customer needs.

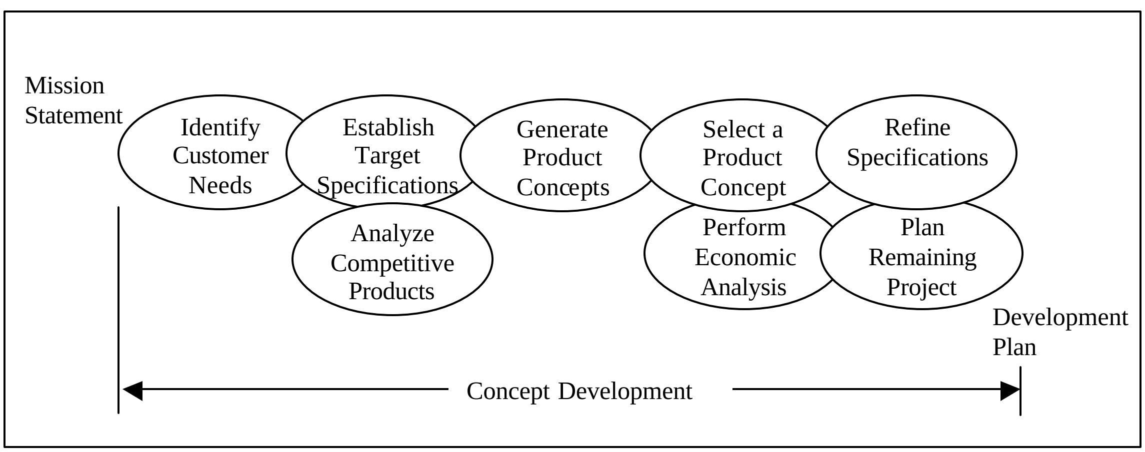

Figure 1-2: Concept development phase of generic process for product development [2]

The next step in this front-end process is establishing target specifications. This step involves translating the customer needs into metrics and corresponding values that describe in precise, measurable detail what the product has to do. A metric is a quantifiable aspect of the design. The value is the corresponding measurement of that metric. In the drill example, "Total Mass" is a metric, while "less than 2.5 kilograms" is the value associated with this metric.

Subsequently, designers perform competitive benchmarking in order to better understand the products already on the market. The analysis of competitors' products aids in the successful positioning of a new product. As a precursor to the concept generation phase of the process, this step also provides a rich source of ideas for spawning new products. In this phase, for the design of the power drill, many different styles and brands of power drills are tested to find strong and weak aspects. This information is then further considered in the new design.

The phase that requires the most effort and interaction, concept generation, occurs next. The goal in this stage is to explore numerous solutions to the problem that meet as many of the customer needs as possible. This stage can involve external searches, creative brainstorming, and systematic investigation of various partial solutions.

Naturally, once a substantial number of possible solutions are determined, there must be an activity dedicated to eliminating weak solutions. In the concept selection phase of the process, concepts are analyzed and sequentially eliminated until a single solution is identified. This step of the process can become cumbersome and several iterations may be necessary. New ideas are also spawned as solutions are analyzed. These new solutions must then go through the selection process as before, until one ultimate solution remains. A large roundtable discussion takes place in the example of the power drill design. The designers talk about each design in detail. Mockups are sometimes used to convey certain aspects of a design and to help convince others that a particular design meets the needs most effectively.

Once a concept has been selected, the target specifications are revisited. The chosen concept will force some values of the metrics to be fixed due to its design. At this point, designers constrain the values for all metrics so that the concept design begins to take shape. The power, size, weight, and many other variables are determined for the example design of the power drill at this stage.

A crucial step takes place next to try to ensure that the concept is successful. A design team performs an economic analysis to create a defined path to continue the development process. Many trade-offs are considered here to determine the economic impact of various decisions. Based on previous research efforts in regard to the needs for the power drill, certain aspects of the design are varied to find an optimal balance. The power of the drill may be lowered slightly in order to meet a defined weight metric that is determined to be very important.

Finally, a detailed development schedule is devised that optimizes development time and identifies the resources required to complete the project. In the project planning phase, designers create a contract book that contains the major results of the concept development phase. This book is a valuable document of the steps taken to generate the selected product concept that is being developed.

As can be determined from the discussion in this section, the generic process used in product development can be time consuming. Many steps require successive attempts that lead to increased expenditures of time and money. The following section describes the process that I have termed, single-session design. It will be shown that this process can be implemented in certain design situations to reduce product development time significantly.

1.2 Single-Session Design and *Robot Rivals*

The previous section described a common design process as it is known and practiced by many engineers. While this process is a useful foundation, it can be cumbersome or inappropriate for some design situations. An example of this occurs when the timeframe for implementing the design process and delivering a product is compressed into a few weeks or even days. Single-session design presents a unique approach to the design process—an approach based on the premise that necessity breeds innovation. A rapid approach to the design phase of products is introduced with single-session design. Whereas some design methodologies have cycle times of months or even years, single-session design is implemented in one week or less. This rapid process is a focused and intense session of resourcefulness with a defined objective. The demand for shorter development times and increased worker productivity are forcing design cycle times to be compressed. A number of new television series, such as *Robot Rivals*, serve as examples of this kind of design approach.

In recent years, television shows centered on design have become increasingly popular [3]. Programs such as *Monster Garage* on the Discovery Channel and *Junkyard Wars* on The Learning Channel have consistently garnered top ten status on their respective networks, according to Nielsen Media Research, a popular television ratings company [4]. These shows feature competitions where teams design various contraptions under severe time constraints. The origin of these two shows is a program that debuted in the United Kingdom called *Scrapheap*. First airing in 1998, it quickly became a hit in the U.K.

According to Cathy Rogers, the creator, co-producer, and co-host of *Scrapheap,* the initial idea for the show came from the Apollo 13 story.

The 1970 Apollo mission was marked by a series of near-disastrous catastrophes that were averted by the quick thinking on the ground at mission control [5]. Working under serious time constraints, the astronauts and NASA engineers on the ground were able to save the entire crew by using various items that happened to be onboard the space craft. This real-life application of necessity breeding innovation resulted in the miraculous safe return of the Apollo 13 crew. Shown in Figure 1-3 is an image from this incredible story that would not have been possible if not for the quick thinking and ingenuity that was present in this single, imperative session of design. Along with being a great story of swift creativity that saved lives, this idea has proved to be a successful kernel for a number of new television programs, including *Robot Rivals* on the Do-It-Yourself network (DIY). As well as being a competitor on this program, I have attempted to be an objective observer, examining the process of single-session design as it unfolds during the filming of each show.

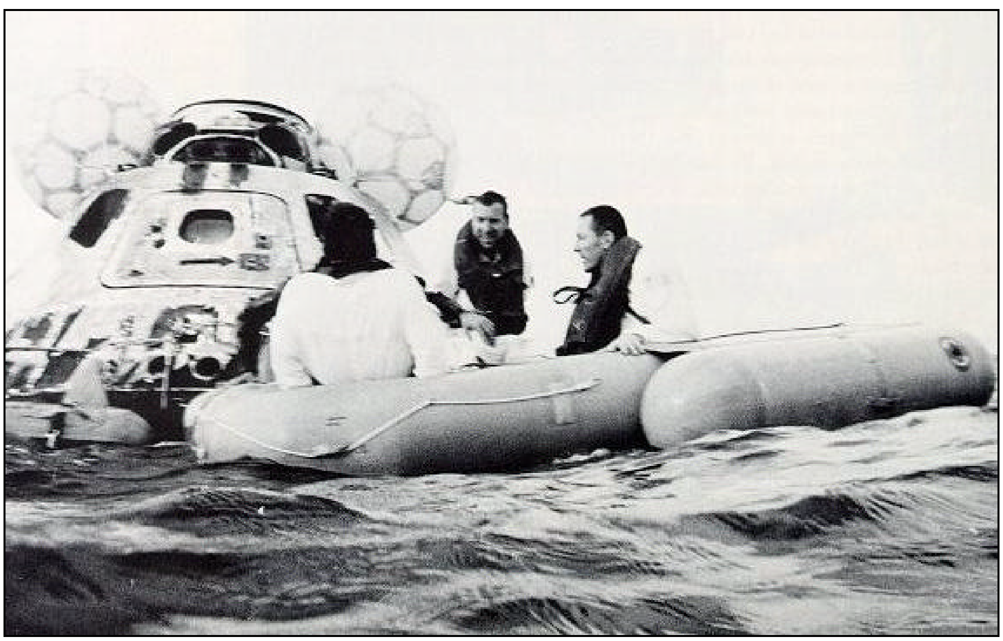

Figure 1-3: Image of Apollo 13 crew after splashdown in the Pacific [5]

Today, a number of television programs exist where the principal objective is a destructive competition between two technologically advanced machines. These shows, although intriguing to some audiences, offer little insight into the design of the machines. A new show on DIY, *Robot Rivals,* emphasizes the design process based on the ideas previously discussed concerning the Apollo 13 story. The focus of the program is the design of robot to accomplish a specific task. The robot must be designed and built in a single day on the set using components found in the warehouse.

Although not the initial intent of the network, this program and others like it are depicting the application of a different form of the traditional process used in design. The rapid nature of the shows forces the competitors to alter normal practices in engineering design and to move to a more focused and intense session of brainstorming and creativity. Necessity is the nature of this design process. For the teams participating in the television programs, the necessity is evident in the competition that will take place at the end of the day. For the individuals involved in the Apollo 13 accident, the necessity was the harsh reality that the astronauts had a limited supply of oxygen and thus a limited time to make it back to earth alive.

The *Robot Rivals* television show is used in this study to examine the process of single-session design. To date, there is no formal research to help us understand how designers function in compressed timeframes. The show provides a repeatable forum for this design process to take place and to be studied. The entire first season of production will be used in this research which, translates to 13 competitions. The following section describes how the analysis will take place and discusses the final goals of the research.

1.3 Research Objectives and Methods of Analysis

Discussed in this section are the objectives of this research on single-session design and the methods used in analyzing the single-session design process. Both qualitative analysis and quantitative analysis are performed to gather useful information for this study on the design process extracted from the *Robot Rivals* television show.

The major goal of this research is to shed light on a potentially beneficial design methodology that can be implemented in certain industry settings. This research will show how this rapid process of design can be achieved, and be used by companies to save time, cut costs, and to become more competitive. The team structure, time schedule, and other aspects of single-session design will be identified and discussed according to how this design process can be applied by companies. It will be shown that single-session design is not only an entertaining phenomenon on television, but a process that has the potential to become useful in industry and academia.

A fundamental understanding of the topic of single-session design is accomplished through surveys, film footage review, industry interviews, and robot assessment. Pre-competition and post-competition surveys are used to ascertain differences in design methods between normal and compressed timeframe projects. The pre-competition surveys generate information about the intent to alter the standard design process as a result of the short timeframe of the project. Post-competition surveys yield information about what aspects of the design actually changed. Team dynamics and time management issues are studied by examining the extensive production footage of the television show and by production visits throughout the season. Through the combination of these methods of analysis, a clear description of the process of single-session design will be presented.

The remaining chapters of this document develop single-session design as a viable process for use in industry and even the academic environment. The next chapter describes a number of current design methodologies and their applications. Chapter 3 gives a detailed description of the *Robot Rivals* television series and the design process that is evident in the show. Chapter 4 discusses each method of analysis in detail, while the final two chapters deal with the development and application of single-session design. The concluding chapter illustrates the application of single-session design in industry and academia and also discusses the potential for further research to refine and expand the ideas presented here.

Chapter 2 – Existing Methodologies

The main purpose of this chapter is to investigate different design processes that are currently implemented in industry. This investigation will be carried out by examining the processes implemented by the General Motors Corporation and IDEO. The investigation in this chapter was carried out through interviews with employees of each company.

2.1 General Motors Corporation Design Methodology

This section of the chapter deals with the design methodology implemented by the General Motors Corporation (GM). GM's longstanding reputation as a powerhouse in the automobile industry goes back to 1897 with the introduction of the first Oldsmobile. With over one hundred years of designing and building cars, GM implements a specific design procedure to help ensure its place as a leading car manufacturer.

The enormity of designing a car necessarily involves a multitude of design settings. Each distinct aspect of manufacturing a car at GM has an associated process that is used to keep the vast mission under control. In an effort to shed light on one of the design processes implemented by GM, the methodology used in one of GM's manufacturing plants is described. At the heart of design process is a specific procedure that is divided into seven main parts. The enormity of the task of producing a car is managed by adhering to the strict procedures that are outlined in this section. The seven phases of this design process are: (1) *selecting a theme*, (2) *analyzing the situation*, (3) *planning*, (4) *implementing*, (5) *evaluating*, (6) *institutionalizing*, and (7) *sharing opportunities*.

Selecting a theme, the first of the seven steps, is the process of characterizing the task at hand. According to the outlined procedure, the theme should be measurable, meaningful, narrow in scope, have clear starting and ending points, and have defined boundaries within the control of the team. The theme also defines the reason for the project.

The next step is *analyzing the situation*. One of the most intensive processes in the procedure, this step involves stages of problem solving and process improvement. Using statistical tools such as cause and effect diagrams, flow charts, pareto analysis, and a myriad of other analytical methods, engineers attempt to identify and understand the problem's scope. Using the statistical analysis, variations, errors, and root problem causes are identified and subsequently eliminated in the design. Other focus areas of this stage of the process regard meeting the customer expectations, eliminating waste, meeting process objectives, and improving process predictability.

Planning is the third stage is this GM design procedure. In this phase specific countermeasures to improve the process or eliminate the root causes are defined. Typically, engineers identify a set of countermeasures, with at least one countermeasure for each root cause of a problem. Ultimately, long-term and short-term gains are realized by addressing root causes as well problem symptoms.

Implementing the countermeasures from the third step is the next phase of the process. Staggering the implementation of countermeasures allows changes to be observed that are associated with each countermeasure. This stage is associated with a high level of documentation to record the affect of the work that has been done.

Statistical analysis comes into play once again in the fifth step of the procedure. In the *evaluation* stage, engineers determine the effectiveness of the implemented countermeasures by analyzing the data gathered during the previous step. The analysis is completed by comparing results to the initial analysis that took place in understanding the problem in the beginning of the design procedure.

The final two steps of the process, *institutionalizing* and *sharing opportunities,* involve measures taken to hold the gains realized through the design efforts. A plan for standardizing the design, including check points is documented. Finally the entire process is summarized, estimating the benefits of the endeavor in terms of cost reductions, time saving, and tangible business results.

To illuminate some of the procedures described above, an interview with Bradford Schreiber, a GM mechanical engineer at Milford Proving Grounds will be discussed. When asked about the specific products being developed at the facility, Mr. Schreiber indicated that some aspects of all the GM vehicles sold in North America are developed at the proving grounds. Mr. Schreiber's engineering work ranges from GM's small cars to their medium duty trucks. It is not surprising that an organized procedure for the design of those products exists at GM.

Mr. Schreiber related that there are specific and mandated steps that are followed throughout the life of a part that is developed at GM. These steps are all intended to make GM ISO compliant. The International Organization for Standardization (ISO) develops standards that are to be used consistently as rules, guidelines, or definitions of characteristics, to ensure that materials, products, processes and services are fit for their purpose. The GM design procedure that Mr. Schreiber follows at his facility outlines each step that is to be taken in the design process as to maximize the time utilization of the engineers.

The design process also dictates the size of the design team. Teams are organized at GM according to a particular vehicle or platform. These teams have hundreds of people that are involved. There are many areas within GM that contribute to the design of their vehicles. According to Mr. Schreiber, the two areas that are directly linked to the vehicles are the design teams and the development teams.

The design team is responsible for the individual parts' sourcing, modeling, validation, and release. Mr. Schreiber indicated that recently GM has design engineers who are responsible for both the math/modeling and the validation/release. These processes were allocated to multiple person teams in the past. Each part or systems of parts has someone who is fully responsible for that piece of the design. An emerging development within the industry is to lay a large portion of the burden on suppliers to design and validate the parts they deliver.

The Development side is responsible for the integration of several related parts or subsystems into the specific vehicles, such as ride and handling, Noise and Vibration, HVAC, or chassis controls. In some cases the development teams have to validate the entire system/vehicle to their specifications. Mr. Schreiber noted that the designers are intimate with the design and history of parts, but are not always privy to the larger scope of the problem. The development teams are generally more hands-on and are exposed to a wide variety of issues.

In regards to a question about the timeframe of the design process, Mr. Schreiber pointed to the fact that the timeframe was solely dependent on the extent of the design. The goal at GM is be able to go from drawing board to showroom in 24 months. Currently he stated that most programs operate on 36 to 48 months timeframes. Instances that reduce design times are spin offs of existing platforms. According to Mr. Schreiber, GM's new Pontiac GTO was created and modified in only nine months.

The last question involved the brainstorming processes at GM. Mr. Schreiber noted that brainstorming occurred at GM in many forms. He mentioned that an important point kept in mind in GM's design efforts was that careful attention be paid to the types of personalities and number of contributors on the teams. Disregarding this element can lead to stagnant design sessions and petty disputes, according to Mr. Schreiber.

In summary, General Motors prescribes to a structured means for the design of new products. A flow chart methodology outlines many of the processes that engineers may have to undertake in order to create a solution. The structured nature of GM's design procedure is contrasted in the next section by IDEO's philosophy of design.

2.2 IDEO Design Methodology

In contrast to General Motors, IDEO is considered in this section to investigate the design process in a different atmosphere. At IDEO, experts from a variety of fields work together to design new products, services, environments, and recently, digital experiences. The projects that IDEO undertake are as varied as the teams that work on them. Teams consisting of human factors experts, psychologists, industrial designers, and engineers work on a myriad of projects—from the first computer mouse for Apple to the Palm V to the Neat Squeeze toothpaste tube to train interiors for Amtrak to heart defibrillators [6]. A unique design process is implemented by IDEO in order to be successful in such a diverse design environment.

The core of the IDEO process is a five-step procedure for designing. First, they thoroughly investigate existing products and experiences. Known as the *understand stage*, this is an exhaustive look at products that are already being used by customers. Products are dissected, literally and figuratively to determine their strengths and weaknesses.

Next, a related exercise is implemented, known as the *observe stage*. This phase of the process involves using human factors experts to determine exactly how people interact with the products. This may also involve the designers putting themselves in the customer's shoes. The goal is to thoroughly understand the products from the clients' perspective.

The look and feel of new products is the focus of the third phase of the process. The *visualization stage* involves a creative approach to brainstorming borrowed from the television and film world called storyboarding. In storyboarding, design goals are kept in context by creating scenarios and characters that will use the products. This method allows the different designs to be easily differentiated by the particular story that goes along with the design. This phase of the process also involves numerous sketches, CAD drawings, and full-size mockups.

Nearing the final phase of the process, an IDEO team will enter the *evaluate and refine stage.* This stage incorporates the details of the design into the many ideas generated from observations and brainstorming sessions. Naturally, as the specifications of the product are added, some designs become obsolete. A continual process of evaluation occurs in this stage until an ideal solution is arrived at.

The final phase of IDEO's design process is the *implement stage*. Normally the longest and most technically challenging, this stage involves close communication with the various clients. Models, renderings, and specifications are delivered to the clients and modified as necessary. IDEO then works with the manufacturer that will create the product for the market.

This five-step process is bolstered by the company's corporate philosophy that teamwork is at the base of all innovation and creativity at IDEO. Being part of a team allows each member to engage in interdisciplinary, simultaneous innovation. An interview with Scott Underwood, an IDEO employee at the Palo Alto location, provides more insight into this IDEO design process and corporate philosophy. The entire text interview can be found in Appendix A-4.

When asked the initial question about the type of products that are developed at the facility, Mr. Underwood made the point that "facility" does not accurately describe IDEO. He illustrated that the Palo Alto location, as all IDEO locations, is more of a large studio environment. 150 people work in six studios at the Palo Alto location. The distinction between the term facility and the actual environment found at IDEO is central to their creativity. The term facility carries with it a strict and rigid connotation, while IDEO strives to keep ingenuity and freedom fundamental. Mr. Underwood went on to explain that most IDEO locations are capable of a myriad of design consultation roles—"from websites to medical instruments to service overhauls."

The next question posed concerned the size of typical design teams. Mr. Underwood explained that each stage of the five-step design methodology might involve different types of people. Hence, the total number of people on the design team shifts as the design progresses. He stated that a typical core team might involve between two and ten people, with a large number of people contributing at different stages of the project. Since IDEO performs many different kinds of design work, the number of people can also vary depending on the particular product.

In regard to a question about the structure of the design teams, specifically if a hierarchy existed, Mr. Underwood noted that, in general, the extent of a hierarchy is the project manager. This person monitors the big picture of the design and works closely with the particular client. Beyond the project manager, individuals take on responsibility for discrete elements of the project. This illustrates the openness in IDEO's design philosophy. Their process is tailored to allow for a maximum of ideas to flow throughout the process.

Next, the question was presented about whether a detailed design process was followed. Mr. Underwood answered by saying, "Only in a rough sense". It seems as though the brainstorming, observations, and prototyping occur in a structured format. However, freedom is always left for new ideas to come to the table at any stage of the process.

When asked about the timeframes for typical design projects, Mr. Underwood stated that the varied nature of the projects that IDEO works on make a typical timeframe for designs a hard number to ascertain. For projects that involve solely industrial design a typical assignment may only take three months, whereas two years or more may be needed for complicated devices such as medical equipment.

Finally, in an attempt to gather information about the abundance of creative solutions that begin at IDEO, a question regarding the methods of brainstorming was posed. According to Mr. Underwood, brainstorming sessions—the storyboarding events—are called formally throughout a project. However, as the philosophy of the company permeates through its employees, he notes that the same methods of brainstorming that occur in the formal session happen informally at desks all the time.

The contrast between these two companies is apparent. Whereas General Motors implements a structured approach to design, IDEO uses creativity and freedom to spawn its solutions. Both companies experience significant success even though their design processes are drastically different. However, one aspect remains similar in the midst of many differences, both companies exist in competitive markets where time is of the essence and is a driving force in any product design.

Chapter 3 – *Robot Rivals* Television Series

The main purpose of this chapter is to describe the *Robot Rivals* television series on the Do-It-Yourself (DIY) network. Specifically discussed is the scope of the program. The program's concept and target audience are investigated through the discussion about scope. Also presented is the team selection and specific composition of each team. Lastly, the competitions for each episode are revealed.

3.1 Scope of *Robot Rivals* Series

In this day and age, there are a myriad of television channels and programs available the public. Some programs even repeat the same ideas as others to capitalize on public interest trends. In recent years, technology and how-to shows have become increasingly popular. A particular aspect of technology television that has become popular is robotics. A few well-known programs, *Battlebots* and *Robot Wars,* capitalize on the public's robotics interests with shows that depict a veritable war scene between two technologically advanced machines. The DIY network strived to separate themselves from this type of programming with a new idea for a show called *Robot Rivals.* As Bill Sykes, VP of programming at DIY said in an interview with CableWorld, "Once you've seen these things [battling robots] destroy each other a couple of times, that's about all there is to it." [7]

Do-It-Yourself is taking a different approach to the robotics interest by creating a show about robots being built to accomplish a specific task. Targeted towards the male viewing audience who are interested in engineering and technology, it is specified that this task is not to destroy the other machine. Each show is centered on two teams of three engineering students who are pitted against each other to design, build, and operate a robot to accomplish a specified objective. The competition arises from the eight-hour time limit that is set for the teams once they reach the television studios in Knoxville, Tennessee.

Each team is given identical conditions and tools to work with. They are also assigned an expert to help them along with their design and construction. The two experts for the first season are Buzz Dawson and Brian Nave, both experienced *Battlebots* contestants and skilled robot designers.

The show progresses with the teams being filmed during the initial stages of their design on the drawing boards. Contestants are encouraged to describe each step of their thinking as the robot design takes shape in front of the cameras. There are plenty of drawing pads and markers to capture these initial stages. DIY strives to capture and depict the entire process of building a robot, not to simply show the final contraption. As the building begins, the filming becomes more intense. Significant components of the individual robots are shot as they are constructed and implemented on the machines. It is at this crucial stage in design that a twist is added to the show as the secret item is introduced to the teams. In each episode, a household item such as a sewing machine or bicycle must be incorporated into the design. The team that uses the most parts is rewarded with a starting advantage of some sort. As the building gets to its climax, there is time to let the contestants work and then film what is called the "expert corner" segments of the show. These "expert corner" segments focus on everyday examples of robotics in and around the home. The host, Chris Chianelli, or one of the two experts gives this discussion. Finally, the robots get to their testing phases and each one is filmed going through, often failing, its various routines. A focus of the show is to depict how all of the challenges are met and dealt with by the engineering student contestants. The finale of the show is the specific competition of each episode. At this point the teams and their respective robots go head to head to find out which team has what is takes to be *Robot Rivals* champions. The winning teams will have completed the task the quickest and the most successfully.

The next section in this chapter describes the teams that were selected to compete during this first year of production. The team's structure is described to show the types of background and experience that are found in a successful team.

3.2 Teams and Team Member Composition

This section describes each of the teams that took part in first season of *Robot Rivals.* Each team is broken down to reveal trends in college majors and experience levels of the contestants. This information is very useful in the determination of a specific, successful team structure that can be repeated and implemented in industry and academic design settings.

The first season of *Robot Rivals* consists of 14 teams vying for first place in 13 competitive events. Each team was selected from among the top engineering universities in the country. In this first season of production there was minimal effort given to the actual team composition. Professors at the individual universities were contacted and asked to recommend students that they deemed to be a good fit for the challenge. This somewhat random selection of competitors yielded a diverse set of engineers that would meet each other in each competition. Figure 3-1 shows the competition bracket for season one of *Robot Rivals.* Since the show depicts college students going head to head in competition there is a certain element of college sports atmosphere that is worked into the scope. The figure shows that Virginia Tech garnered a bye in the second round. This bye is a result of Virginia Tech's help and involvement with the pilot episode of the show that will not air on television. The numbers in front of the show dates refer to the episode numbers which will be used from this point on to differentiate the each television episode.

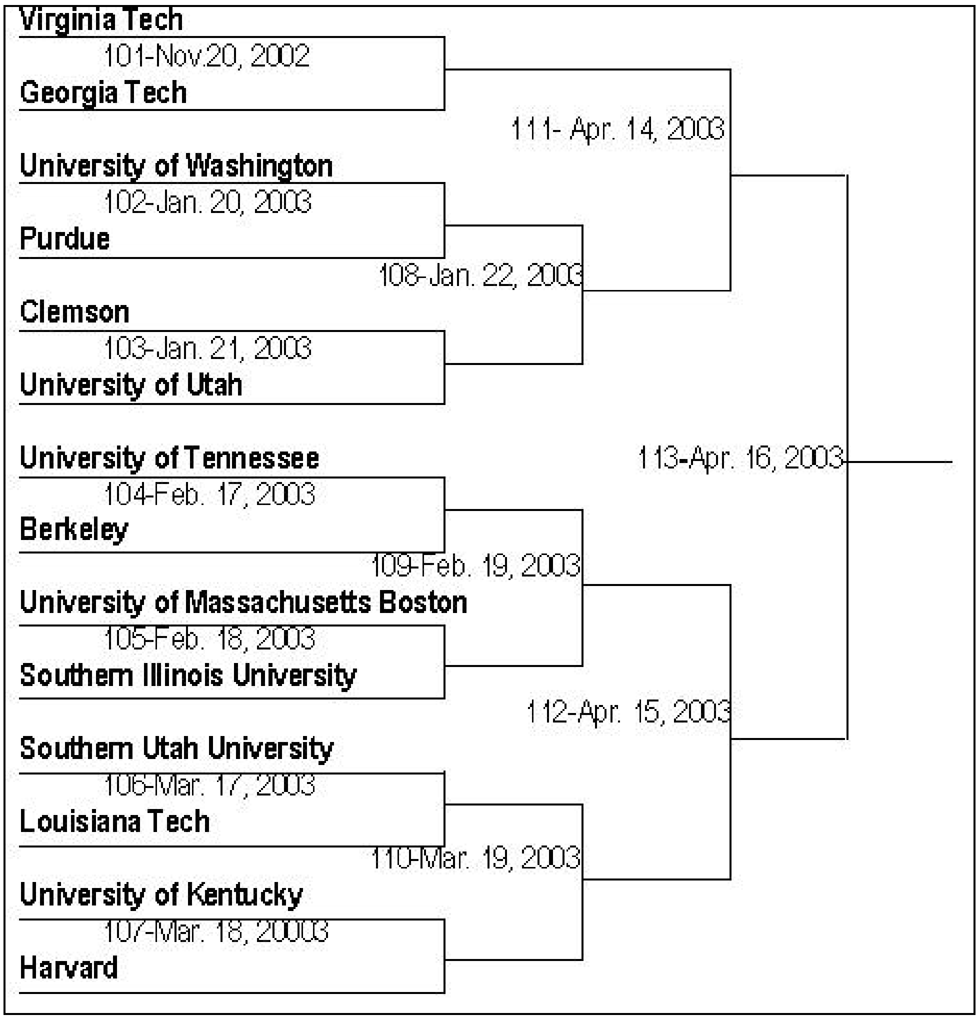

Figure 3-1: Competition bracket for first season of *Robot Rivals*

For this research, each team is given a pre-competition survey that among other things ascertains the makeup of each team. Figure 3-2 gives a breakdown of each team and its team member composition. Chapter 4 will go into more depth on team makeup using all the data gathered from both the pre-competition and post-competition surveys. A close look at the stacked bar graph in Figure 3-2 reveals that electrical engineering and mechanical engineering are the two majors with the most contribution with 14 and 9 contestants respectively. The relatively high number of electrical engineers seems somewhat surprising, since a major portion of the competition is the actual construction of the robot itself. This trend may be due to the random nature at which contestants were selected to be on the first season.

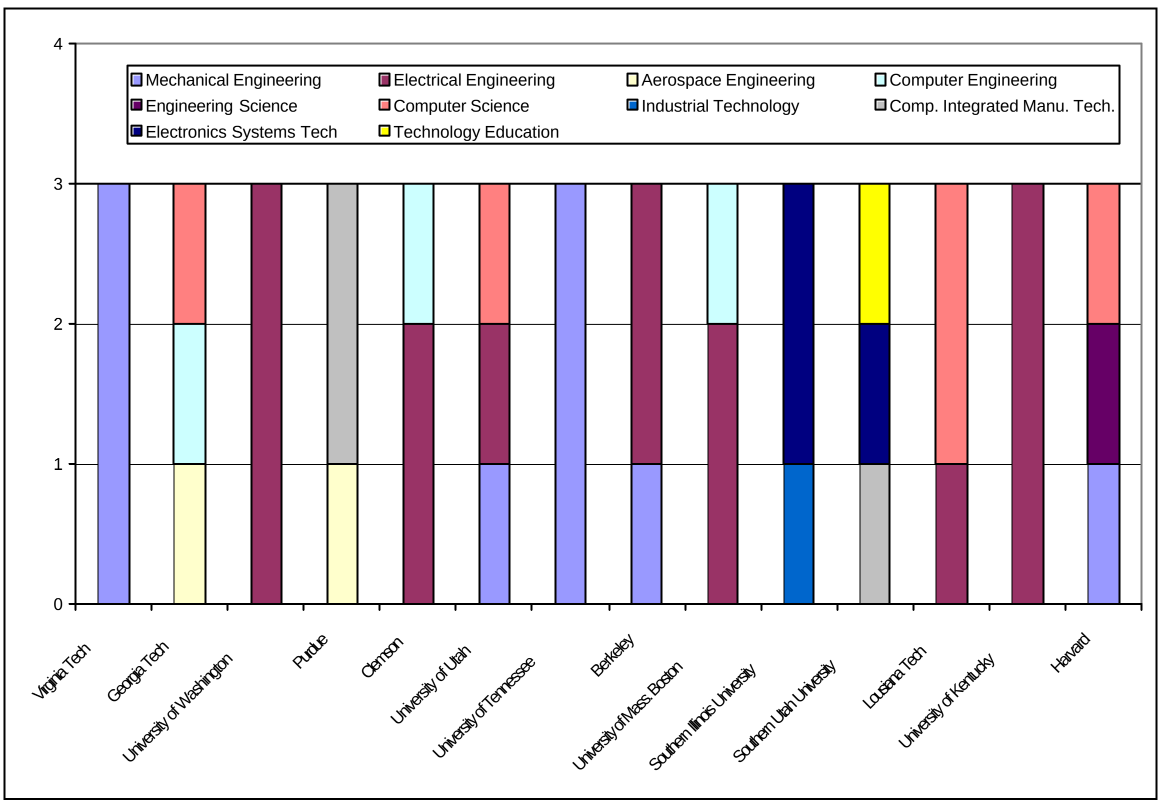

Figure 3-2: College major breakdown of *Robot Rivals* teams

The next figure that is seen shows the experience level for each team. Figure 3-3 is a graph that reflects the data that was collected from the first competition that each team took part in. In order to quantify such a nebulous criterion as experience, three separate questions were asked of the contestants. First, the question was asked whether the individual had ever taken a course on engineering design / methodology. Second, a question regarding completion of a class where constructing a device was a main component of the course outline, was asked. Finally, a question was asked whether the contestant undertook hands-on project in his or her own time. The first two questions have *yes* or *no* answers, while the third question has the option of three answers, *either all the time*, *sometimes*, or *never*.

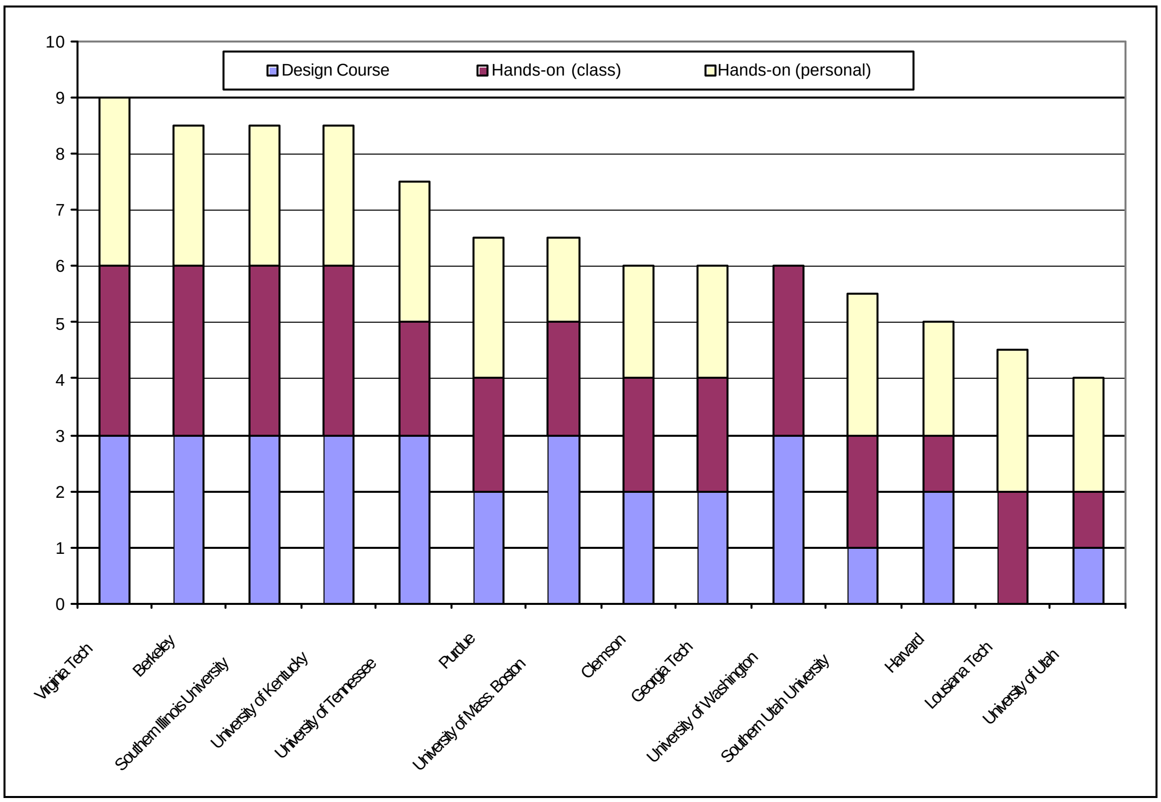

Figure 3-3: Calculated experience level of each team

In calculating a raw number that reflects experiences a single point is awarded for *yes* and *all the time* answers to questions, while a *sometimes* answer gets a half a point, and *no* or *never* answers receive no points. The combination of results from these three questions yielded the data shown in Figure 3-3 that gives a representation of the experience level of each team. This method of ranking experience gives Virginia Tech a slight edge of half a point over the competition.

The final section of this chapter reveals the competitive events for the first season of *Robot Rivals*. Episode 101 and 107 are specifically discussed to shed light on a show in which I was a competitor and one in which I was an observer.

3.3 *Robot Rivals* Competitions

This section of the chapter deals with the 13 competitions in the first season of the show. The specific task for each episode is revealed, and the technology that is needed for the solutions are described.

The technical nature of *Robot Rivals* competitive events makes the show an attractive vehicle to use in a case study for this design methodology research. As each episode is being filmed, the process of designing in compressed timeframes is repeated. In the first season of production there are 13 competitive events. Each competition is created to involve a specific area of engineering. Table 3-1 shows a list of the 13 competitive challenges used in the first season of *Robot Rivals*. To give a more detailed picture of the show, two episodes will be described according to the context previously discussed in section 3.1.

Table 3-1: Competitions from first season of *Robot Rivals*

Episode Number:	Title:	Overview:
101	Soccer Players	Locate, grasp and propel soccer balls into the opponent's goal.
102	Tree Cutters	Cut down up to five trees and stack them in a holding area.
103	Retrieval Robots	Break through a wall (cut or demo.) made of drywall and gather eggs on other side to be placed in a basket.
104	Toy Box Fillers	Pick up as many toys as possible and place them into a toy box.
105	Dorm Room Waiter	Open a door room fridge, remove three beverages and a pizza box and deliver them to teammates.
106	Stair Climbers	Ascend a set of stairs and burst a balloon.
107	River Traversing	Cross over a span of 2-ft. river with a bridge-type system and continue on the other side, bringing your bridge with you.
108	Exploration Robots	Utilizing two wheels or less, traverse a number of different surfaces (rocks/stones, wood/twigs, sand, water, marbles/balls) in the fastest time.
109	Driving Range Golfers	Launch golf balls over a distance to break targets.
110	Recycling Robots	Robots must crush aluminum cans flat and deposit them into a recycling bin.
111	Earth Movers	Robots must move a pile of mulch from one location into a wagon at a different location
112	Treasure Hunters	Operate in a sand pit, finding and obtaining "treasures" buried in the sand.
113	Water Transporters	Design and build a robot that can collect and move water from a one holding area to another.

As previously mentioned, in order to create an interesting show, it is the goal that each competition be different from the rest. In each competition, a different set of challenging issues must be managed. The common thread through each of the 13 episodes is that these challenges must all be met under strict time limits. This common thread yields the basis for this research in single-session design. To bring the concept of single-session design into a more tangible realm, episode 101, in which I was a part of on the Virginia Tech team, and episode 107, in which I was an objective observer, will be described in detail.

In episode 101, the first episode in the series, Virginia Tech and Georgia Tech were tasked with creating soccer playing robots. Given one week prior notice of the challenge, each team had to brainstorm potential solutions to the task at hand. The main guidelines for this competition were that the robots had to use some mechanical method to grasp, contain, and subsequently propel a 6-inch soccer ball into the opponent's goal. Similar to the real game of soccer, the team with the most goals against the opponent was the winner. Figure 3-4 shows the layout for the competition.

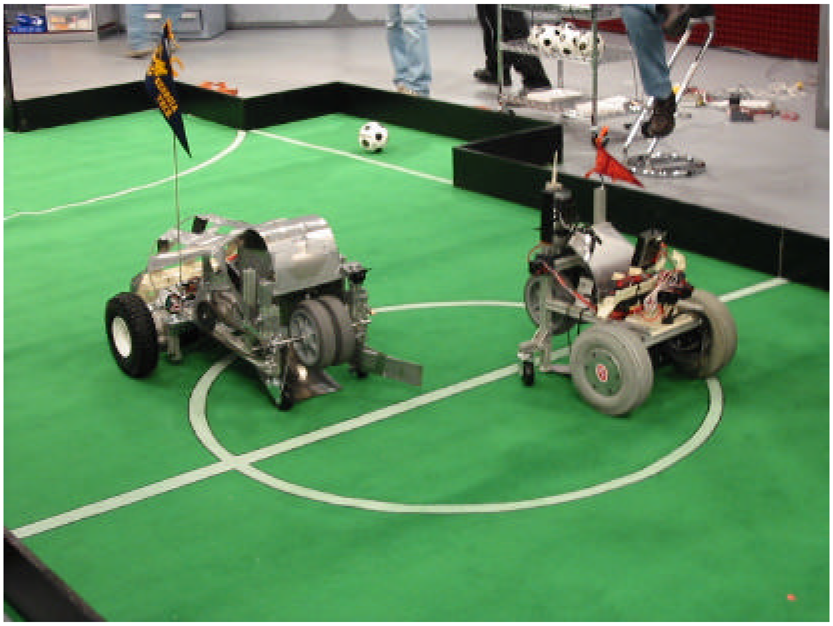

Figure 3-4: Episode 101 soccer field

With a general idea of a solution in mind, the fast-paced day on the set began with designing on drawing pads. Our concepts were sketched, discussed, changed, and ultimately a solution was selected. This stage of the process involved quick brainstorming and physical mock-ups, simply holding mechanisms and parts by hand to describe their function and orientation. Very quickly, potential solutions were discussed and discarded if it was obvious that there were serious shortcomings in the design. Motivation in this step of the process also arises from the desire to be the first to begin construction. Hearing the grinding of metal on the opponent’s side, while still attempting to converge on a solution increases the pace dramatically. The entirety of this process is completed with a full complement of television lights, camera, and action that all help to move the pace along.

After the members of our team and the technical expert, Buzz Dawson, agreed upon a design, construction quickly took over. A crucial understanding between team members must be made as construction begins. Each member of the Virginia Tech team possessed specific talents in areas that other members did not. Crucial to the success of our team was the distinction made of who possessed what talents. Chris Terwelp focused primarily on electronics and computer control aspects. I concentrated on mechanical design and systems integration while Ian Hovey utilized his talents in construction and manufacturing. It was not only critical that we divided our work to complete this task; we had to be competent in the area that we were to deal with. This idea may seem trivial, but previous experience with projects similar to this, but with longer scopes, have shown to be more accommodating with team member talents. Problems with long timeframes allow individuals to ‘catch-up’, whereas situations in compressed timeframes do not.

Midway through construction, after a design was decided upon, a twist was added by the producers of the show. The secret household item, a vintage sewing machine, was introduced. An additional challenge was then assigned—the team that could implement the most functional parts from the sewing machine would gain a five-second head start in the competition. Our agility and creativity was tested by this addition. Our design had to be modified to accommodate sewing machine parts to gain the five-second head start. Simple addition of parts was achieved by using the wiring and some switches for the electrical components of the robot. The sewing machine's external frame was then modified to act as a rack for those electrical devices. Finally, a few knobs from the vintage apparatus were bonded to existing safety switches on the robot to gain additional parts for the final count. Figure 3-5 shows a close up of the parts that were used. This ultimately garnered the five-second head start for the Virginia Tech team.

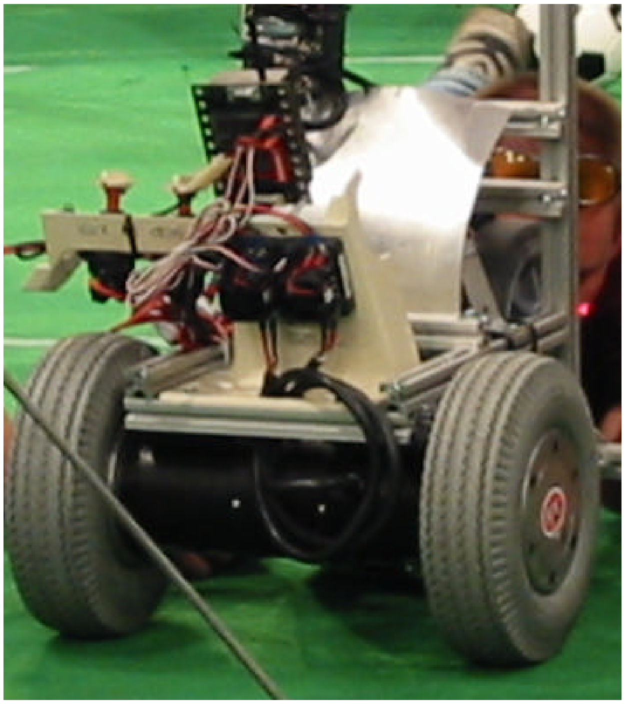

Figure 3-5: Virginia Tech's implementation of secret item parts

Building continued throughout the day for approximately seven hours. During this period, construction challenges continually surfaced, and were dealt with appropriately and rapidly. An issue arose when it was discovered that there were not sufficient connectors to assemble the extruded aluminum pieces. In a normal setting, construction would stop on that particular section and be started again once more parts were obtained. However, with time of the essence, waiting for parts was an unaffordable luxury. Instead, a solution using regular nuts was implemented to quickly resolve this issue. Situations such as this were commonplace, but the Virginia Tech team held their composure to keep a steady momentum of forward progress.

Finally, the soccer-playing robot was completed with time to test before the actual competition. This crucial step allowed Chris Terwelp to fine tune the computer controls of our device. This proved to be a deciding factor at the competition. The hurried day approached its end as the time for competition arrived. Our robot and Georgia Tech’s were placed in the competition area and filming began. It became immediately apparent that Georgia Tech’s robot was virtually uncontrollable. Virginia Tech went on to win the competition with a score of three goals to zero.

The previous description outlined a show as seen from the perspective of a contestant. Following is a discussion from the perspective of an objective observer of episode 107 that involved the University of Kentucky and Harvard. From this vantage point, key aspects of rapid problem solving on both sides were examined.

The task in episode 107 was creating a robot that could cross a two-foot gap over water. The challenge in building this robot was that it had to contain the method for crossing the gap to be able to repeat the process. Size limitations prevented the teams from designing robots large enough to simply roll over a two-foot span.

This particular task fell to the University of Kentucky and Harvard University. It was quickly obvious that the advantageous division of tasks was more functional on the University of Kentucky side. A level of autonomy of each Kentucky team member was observed that enabled separate construction of assemblies to occur simultaneously. While on the Harvard side, a clear leadership position of one member was observed. While leadership is needed for large-scale projects with adequate time to complete, in short time-frame situations each member must be able to assume responsibility quickly and effectively. Much deliberation with the assumed leader of the Harvard team used valuable time that was needed to adequately solve the task. The Kentucky team also showed agility in dealing with adverse conditions. When a thread-cutting tap broke off in a structural component, a quick solution was found by simply turning the member over and leaving the broken tap in the other end. The quick determination of whether this action would have an adverse affect on the operation of the robot was crucial in shaving minutes off construction time. The methods implemented by Kentucky allowed them to finish in time to test their final design. This testing led to refinements that led to the ultimate success of their machine in competition. The extent of the competition was Harvard's robot simply veering off course without control, and Kentucky's operating as planned.

Viewing the tapings of *Robot Rivals* was instrumental in the determination of the single-session design methodology. As each episode was filmed, trends were repeated that lead to successful designs. The next chapter discusses beneficial research obtained from these visits.

Chapter 4 – Methods of Design Process Analysis

The main purpose of this chapter is to discuss the analysis of the *Robot Rivals* television series and the development of single-session design from that program. Initially presented is a discussion on the filming visits of the television series production. Also presented is the analysis of competitor surveys administered throughout the first series of production.

4.1 Discussion on Filming Visits

A major portion of the research about single-session design was completed through filming visits on the set of *Robot Rivals* in Knoxville, Tennessee. Filming visits provided valuable insight of team dynamics and time management, as well as provide a vantage point to see the nuances of single-session design unfold. The time spent to film a show that will end up being an hour long on television takes many hours. An average filming visit lasted 13 hours on the set. This amount of time was sufficient to witness the design process as it evolved to function in the compressed timeframe of the television program. The first season of *Robot Rivals* consists of 13 episodes, three episodes being filmed each month, which translates to a total of 169 hours of research time.

The general schedule of events for each episode is previously described in Chapter 3. Following this schedule for each visit, I was able to view the teams' progress through each stage of design and construction as it rapidly unfolded. Among the many insights gained from this vantage point of an objective observer was the critical issue of team dynamics.

From the moment the teams arrived on the set, I was able to observe the dynamics that existed between the members. Taking into account the nervousness that understandably permeated the teams as they were thrust into the curious world of television, I was still able to gather important insights. As the teams arrived on set it became immediately obvious if there was an assumed leader. This leader was consistently the team member who did all the talking as the team arrived. They were the individual who could most effectively deal with the stress and nervousness realized from being on a television show. This person initially became the spokesperson for the group.

If there was an obvious leader at the start of the show this person kept that position throughout the episode. This was evident in all aspects of design and construction. In the design stage of the program, the assumed leader would consistently be the first to come up with ideas and make them vocal. In the construction phase, the leader would provide direction for the other members. The leader was given the task delegating duties and assumed an overseer perspective on the project. Witnessing this dynamic a number of times with different teams that competed on *Robot Rivals* I was able to see an important consequence; teams that had a defined leader often struggled to complete the task in the required amount of time. The time scale of the project and the team size can explain this consequence. In a situation with a team of four people, including the designated expert, and a time limit of a single day, every person must be free to contribute equally as a whole in most areas of the project. If a single member is required to take a management position, that person naturally becomes less able to contribute in other areas of the project.

A team dynamic that did involve distinctions between team members, but provided to be more beneficial than having a designated leader, was the pre-establishment of team roles in regards to design and construction. As each team came to competition, each member's strong and weak points were noted. Successful teams maximized each member's strong points and delegated responsibilities based on those qualities. A mechanical expert was defined and concentrated on mechanical design and construction. An electrical expert could also be defined that spent most of there time on computer controls and wiring. Teams that operated under these circumstances were more able to meet the time constraints. An important aspect that goes along with this approach is that team communication must also be maximized. As each team member performs duties in his or her expertise, a point in the design always arrives when all the pieces must be brought together. Successful communication throughout the design and construction phases ensures that all the individual pieces harmoniously fit together.

Another insight gained from filming visits relates to time management issues. Closely related to the team dynamics previously described, time management was crucial in the scope of each competition. The first indication of each teams' time management approach came in the design phase of the competition. As the competition began, I made sure to note how long each team spent deliberating until the first wrench was turned. The nature of the television show skewed this aspect of the process somewhat. Even if a team already had a set design in mind, it was critical to the success of the television program that some brainstorming and design was captured on film. Thus, sometimes teams were forced to spin their wheels while the producers caught the needed action for their program. However, it was obvious if teams did have an established design and a plan to accomplish the design when construction began.

With an effective team structure described previously, the construction phase of the project would progress rapidly. Each member would begin building his or her respective piece of the design. Teams without adequate variation in skills were observed to stumble initially at this point, as it had to be determined who would do what. Successful time management was observed in teams where design on many aspects of the robots occurred simultaneously. As individual parts were completed, they were tested and implemented together if possible. The ultimate success in dealing with the compressed timeframe was observed by teams that actually had time to test their robots before the competition. Robot designs that were tested and refined were almost always victorious in competition.

The next section in this chapter gives a quantitative description of some the issues that were previously discussed. Section 4.2 discusses the analysis of the competitor surveys that were administered before and after each competition. These surveys were used to compile charts that give meaning to the qualitative discussion in this section.

4.2 Analysis of Competitor Surveys

For a quantitative examination of the design process observed on *Robot Rivals* pre-competition and post-competition surveys were implemented. Examples of these surveys can be found in Appendix A-3 for further inspection. The complete data set that was used to create the charts in this section can be found in Appendix A-4. In this section, comparisons between teams are being made for first round competitions. By comparing this information each team is being sampled at the same level of experience with *Robot Rivals.*

A large amount of data was obtained from the two surveys that were given to the competitors. This data was broken down and analyzed in both MS Excel and a statistical software package called SPSS (Statistical Package for Social Sciences). This analysis shows that there are certain team characteristics that demonstrate an association with winning the particular *Robot Rivals* events. It is important to note that for statistical analysis, more data will always yield more accurate prediction results. Therefore, in this initial study of single-session design, it must be considered that there is a relatively small set of data being analyzed. General trends may be visualized; however care must be given in making concrete assumptions about associations.

The first characteristic of the teams that is analyzed is experience. Experience levels of each team member are determined by their answers three questions: the first regarding formal education about the design process; the second about hands on coursework; and third about the extent of their hands on activities outside of school. Figure 4-1 shows a plot of the data from the survey questions pertaining to this area. From inspection it is evident that the teams with a higher experience index seem more likely to be successful in the competition. This plot is also effective in depicting the contribution of the various aspects of experience that are being considered. In all teams except the University of Washington there is some level of hands on activity occurring outside of school. With a competition involving engineering students this characteristic is to be expected. In order to bring more significance to data shown in the figure further analysis was performed.

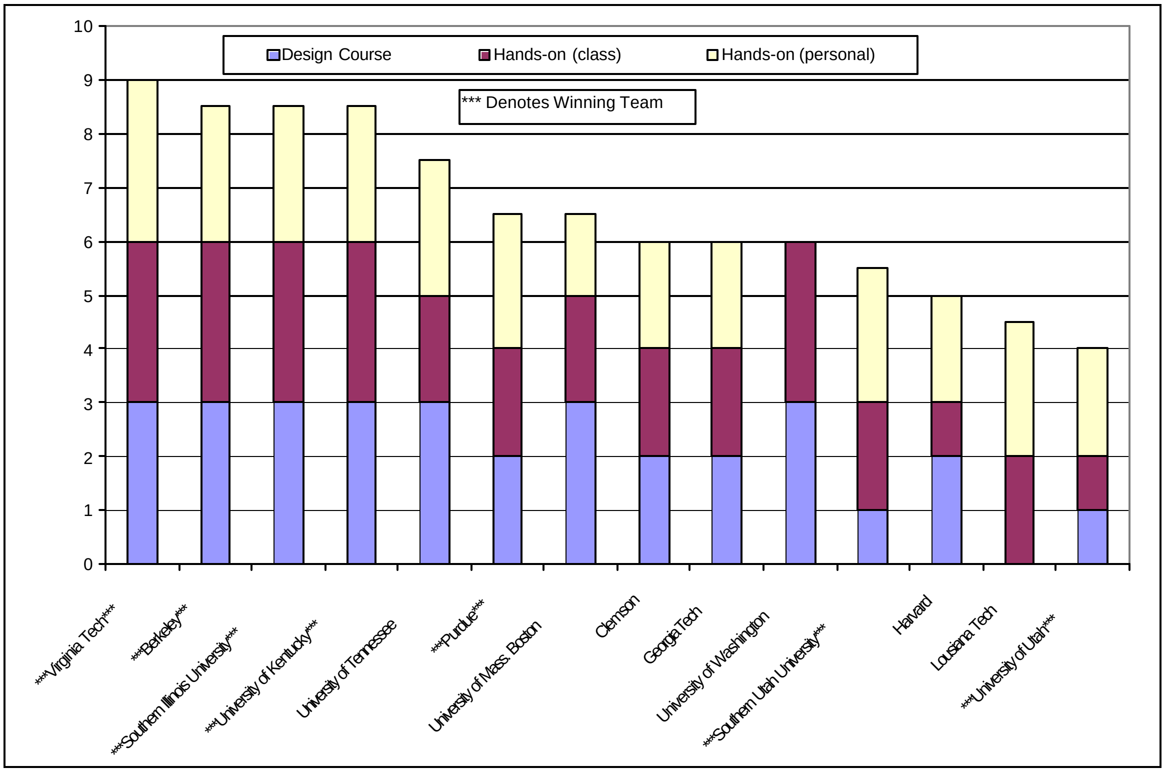

Figure 4-1: Experience Data from *Robot Rivals* teams

To give credibility to the assumption that increased levels experience are associated with a larger probability of winning, SPSS was used to analyze the data using logistic binary regression. This method of analysis is used to study the association between a binary response, which in this case is winning or losing, and an explanatory variable, which is the experience level of each team. This method of analysis is common in the medical field, where doctors seek to find associations between predictor variables and disease occurrence.

Although a host of information results from using SPSS to analyze the data, there are two main results from logistic regression analysis that are important here. First, SPSS returns a β_1 value, which measures the degree of association between the probability of the binary event occurring (winning) and the value of the independent variable (experience). This β_1 value is the slope of the regression line calculated by the analysis. β_1 values greater than zero indicate that the probability of winning increases as the value of the experience index increases. Next, SPSS yields a p-value which is an indication of the statistical significance of any linear association of the independent variable and the response. The p-value tests the assumption that $ß_1$ is actually equal to zero, indicating that there is no relationship between the independent variable and the response. For small p-values—less than 0.05—we can say that the indication of a relationship by the $ß_1$ value is real. By using 0.05 as a cutoff, there is a 5% risk that there is an indication of a relationship between the data when there is actually none. Therefore, as p-values increase towards one, there is less significance of the indication of association by the slope parameter [8].

Logistic regression analysis of the experience data yields a $ß_1$ value of 0.608. This is a strong indication of the association between increasing experience levels of the teams and the occurrence of a win. However, we must also consider the p-value of 0.109 which is not a very strong indication of the statistical significance of the outcome. Looking at the data, the lack of statistical significance may be explained by the University of Utah figures. According to their responses, they were the team with the least experience, but they won their competition. In this relatively small data set, the instance of this data point has a large effect on the statistics. Therefore, even though there seems to be a trend in the graphical representation of the data, the regression analysis indicates that there is not a high level of statistical significance to that trend.

The next variable from the surveys that is inspected is the existence of pre-determined roles on the team. This variable assesses whether or not a team has established a mechanical expert, an electrical expert and so on. From the qualitative analysis, it was apparent that teams that split up the tasks according to pre-established roles operated more effectively than teams that did not split up the tasks. Figure 4-2 shows a plot of this data. Inspection of the figure shows that there does seem to be an association of pre-established roles and winning teams. As before, SPSS is used to further investigate the association.

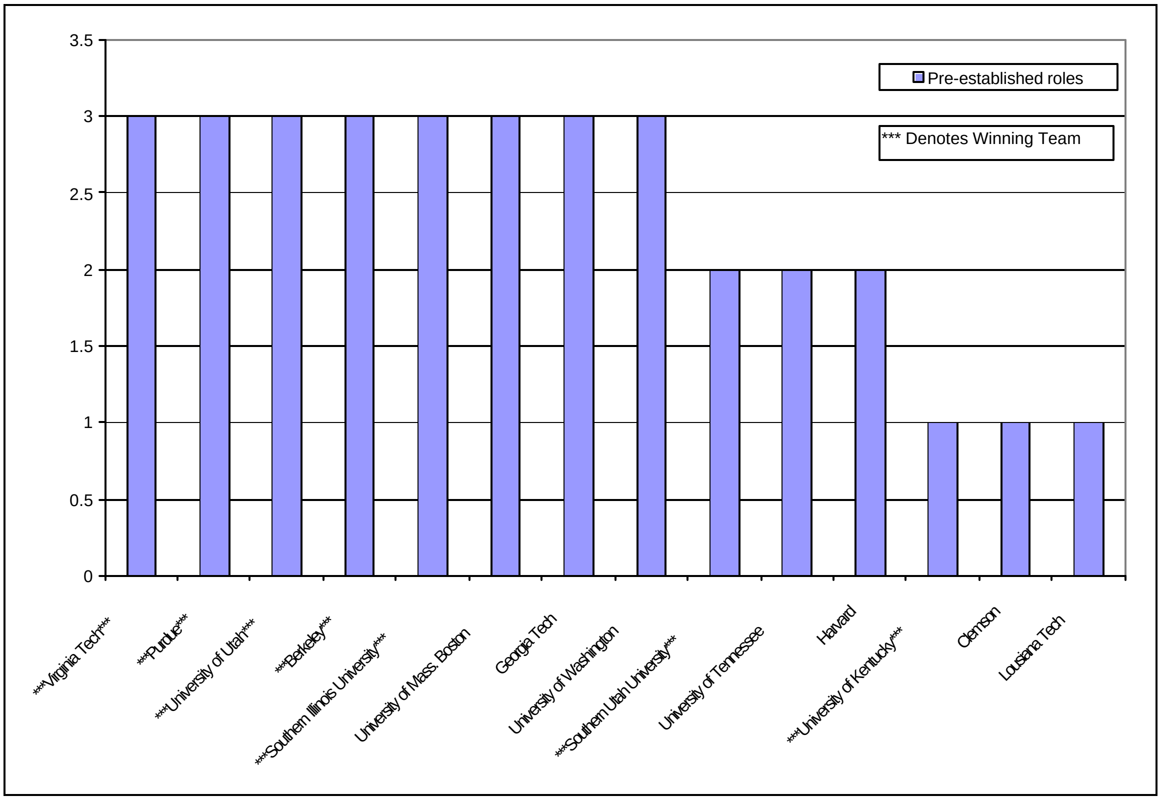

Figure 4-2: Pre-established Roles data from *Robot Rivals* teams

Using SPSS to analyze the pre-established roles data yielded a β_1 value of 0.683. This is an indication that teams having higher indices of the pre-established roles variable are associated with a higher probability for winning. However, as in the case of the experience data, a p-value of 0.323 indicates a lack of significant relationship between the two variables. Again, we see the existence of a data point that skews the regression analysis. Since the University of Kentucky won their competition, while having the lowest index of pre-established roles, the statistical significance of a positive association is minimal.

The issue of planning is the next variable that is considered. The pre-competition survey was used to ascertain the definition of a strategy or outlined plan by the teams. Again, qualitative analysis of the *Robot Rivals* episodes leads to inferences about this particular variable. It was observed that in the case of teams without a defined plan going into the competition, much time was spent orienting the group rather than designing or building. This inference is examined by looking at the plot of the data in Figure 4-3 and using SPSS analysis. Inspection of the plot reveals the trend that teams with a pre-existing plan faired better than those without a plan.

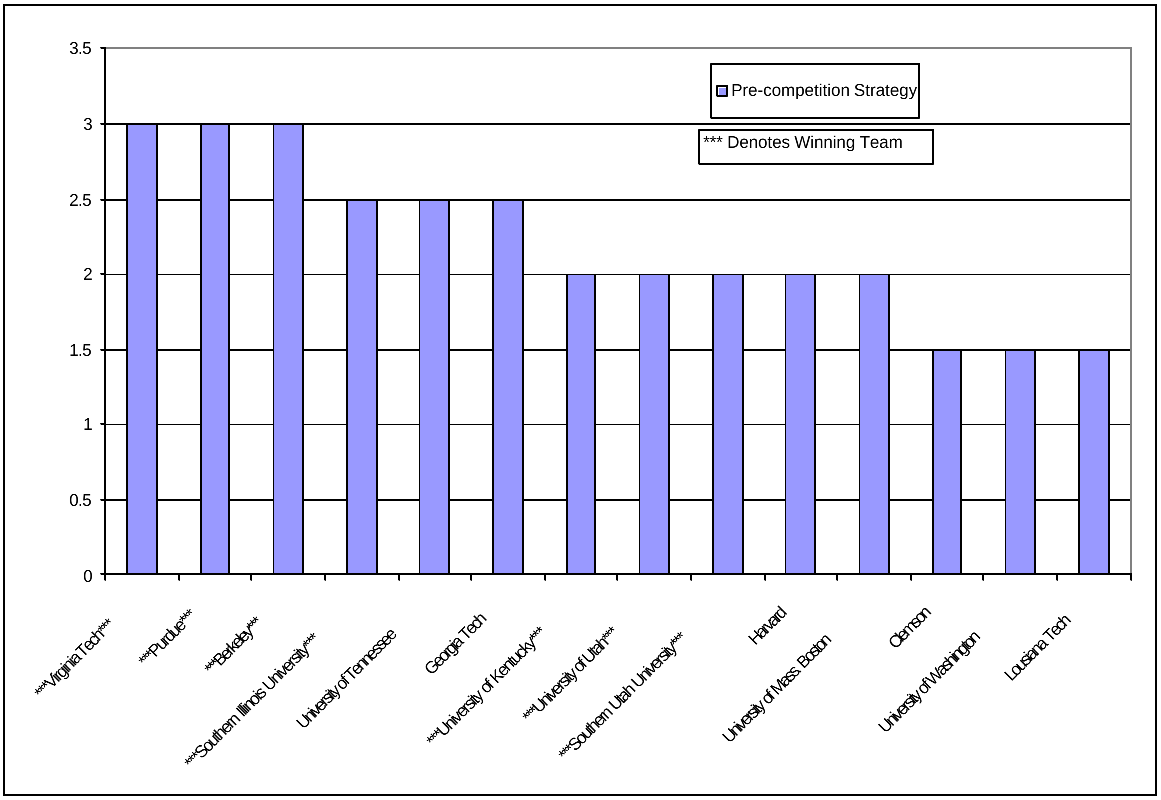

Figure 4-3: Defined Plan / Strategy data from *Robot Rivals* teams

The inference about an association of strategy and winning is examined further using the logistic regression model once again. SPSS reveals that the slope parameter, $ß_1$, is equal to 2.623. This number is a strong indication that higher probabilities of winning are associated with the amount of pre-planning. This association is further verified by a p-value of 0.042. This says that planning is significantly related to the probability of winning. Noticing that there are no significant outliers in this data further validates this result.

An indication of positive thinking is next considered. A question was asked of the teams before the show, whether they believed that they would win the day's competition. Although the teams were asked to be honest in their responses, it was surprising that some teams went into the competition without thinking that they would be successful. Figure 4-4 shows that the top five teams that won their competitions went in with all members confident that they would be victorious. It also shows that teams who competed with only a slight anticipation of winning were not successful.

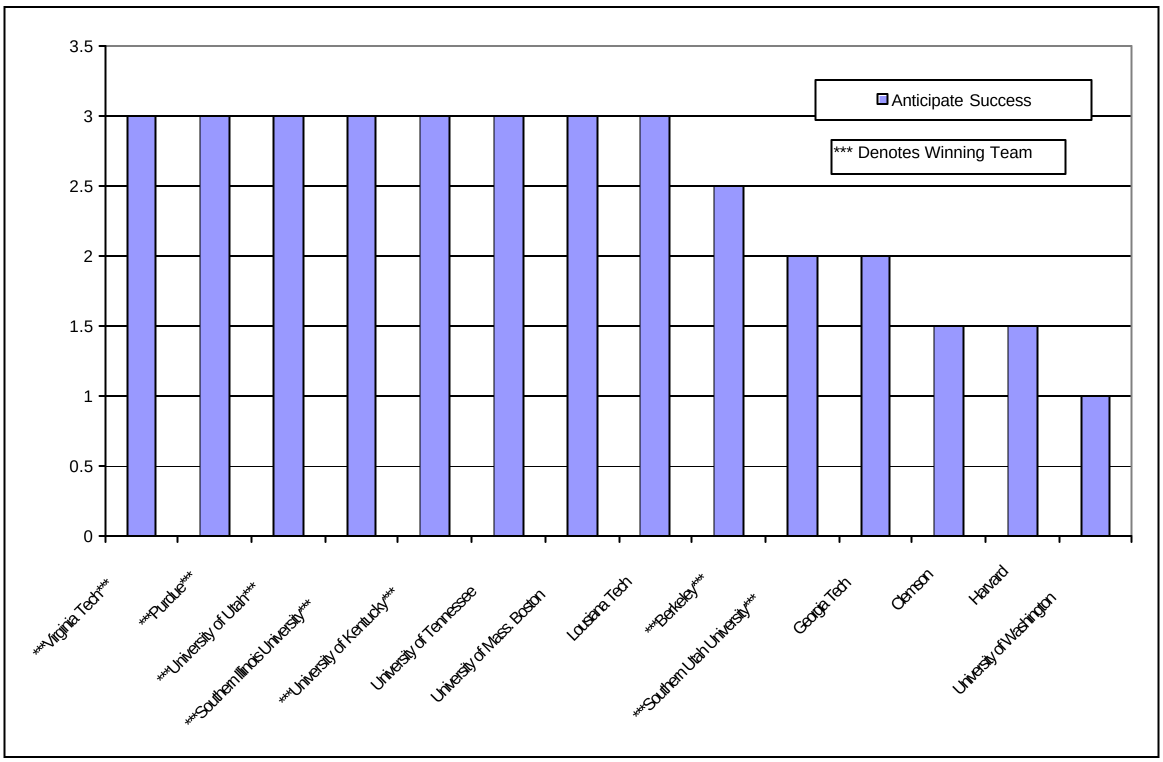

Figure 4-4: Anticipated Success data from *Robot Rivals* teams

SPSS is used to see if the results from the plot are significant. A β_1 value of 1.617 and a p-value equal to 0.083 tell us that there is an association of anticipated success with the probability of winning and that this association is relatively significant. From this analysis it seems that frame of mind plays an important role in the success of the team.

An assessment of the dependency on the assigned expert is covered next. After an episode was completed, one of the post-competition survey questions dealt with the amount of dependence on the assigned expert for the completion of the project. From the plot of this data seen in Figure 4-5, there does not seem to be any correlation between the dependency on the expert and winning. Whereas some winning teams relied very heavily on their expert, other winning teams did not. This may be a result of the particular competition for each episode. Some competitions may fit very well with the experience of the team, while others may require additional help from the outside source, that being their assigned expert.

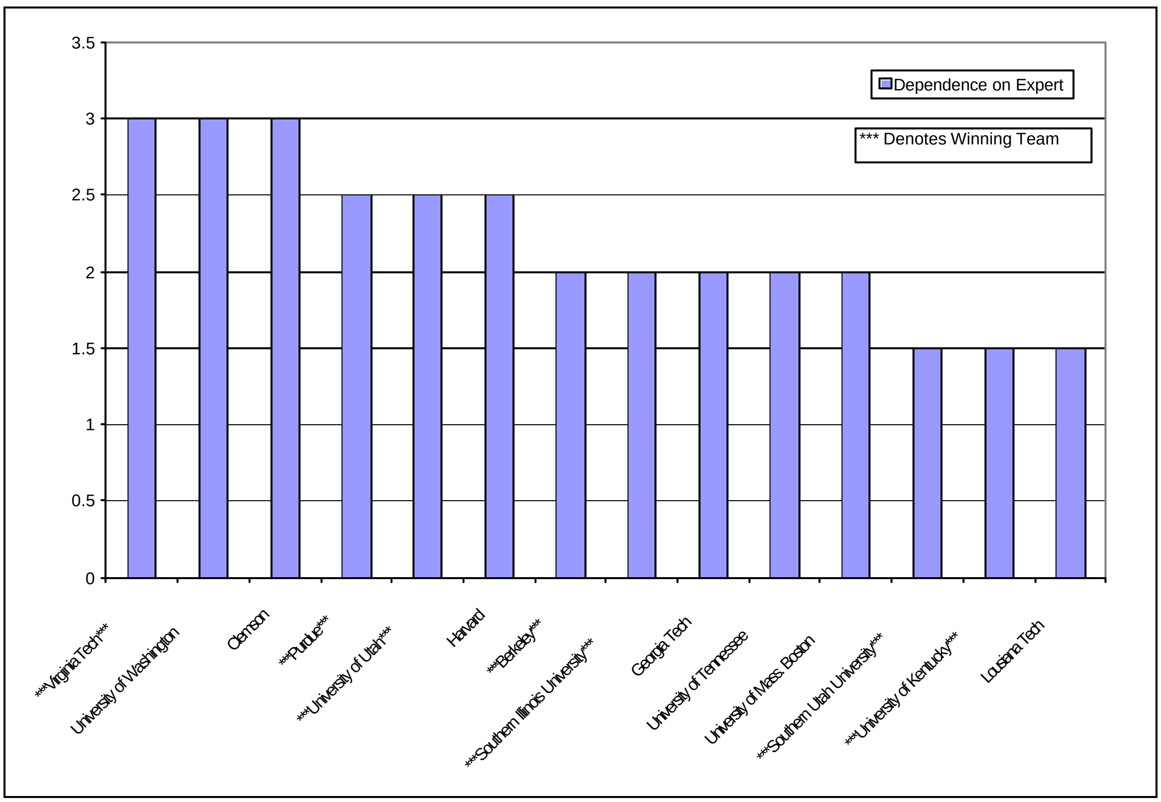

Figure 4-5: Dependence on Assigned Expert data from *Robot Rivals* teams

The assumption that no positive association exists between dependency on the assigned expert and probability for winning is supported by the SPSS analysis. For this variable, a $ß_1$ value of -0.525 is calculated. This is actually an indication that the probability of winning decreases as the dependency increases. This would be an important consideration; however, the p-value for this set of data is 0.611. A p-value of that magnitude leaves little significance of the independent variable on the probability of winning. It is therefore asserted that there is not significant evidence to associate the dependency on the assigned expert with any probability of winning or losing.

The last variable considered in attempt to find characteristics associated with winning, is whether the final solution was indeed the intended solution. Although it has been shown that having a plan is important to the success of the team, this variable shows that competitors must be able to cope with failures and design changes. Figure 4-6 shows that winning and losing teams alike had to change their solution in order to finish the competition. The fact that winning teams ended up with a solution different than their intended solution implies that there is no positive association between this variable and winning. It does however make the point that quick thinking and alternate plan making is important for a successful team. Again, SPSS is used to support this point. With a calculated $ß_1$ value of exactly zero it is determined that the probability of winning is not associated at all with having a different design that initially planned. The associated p-value is necessarily equal to one, indicating that there is no significant relationship at all between the two variables.

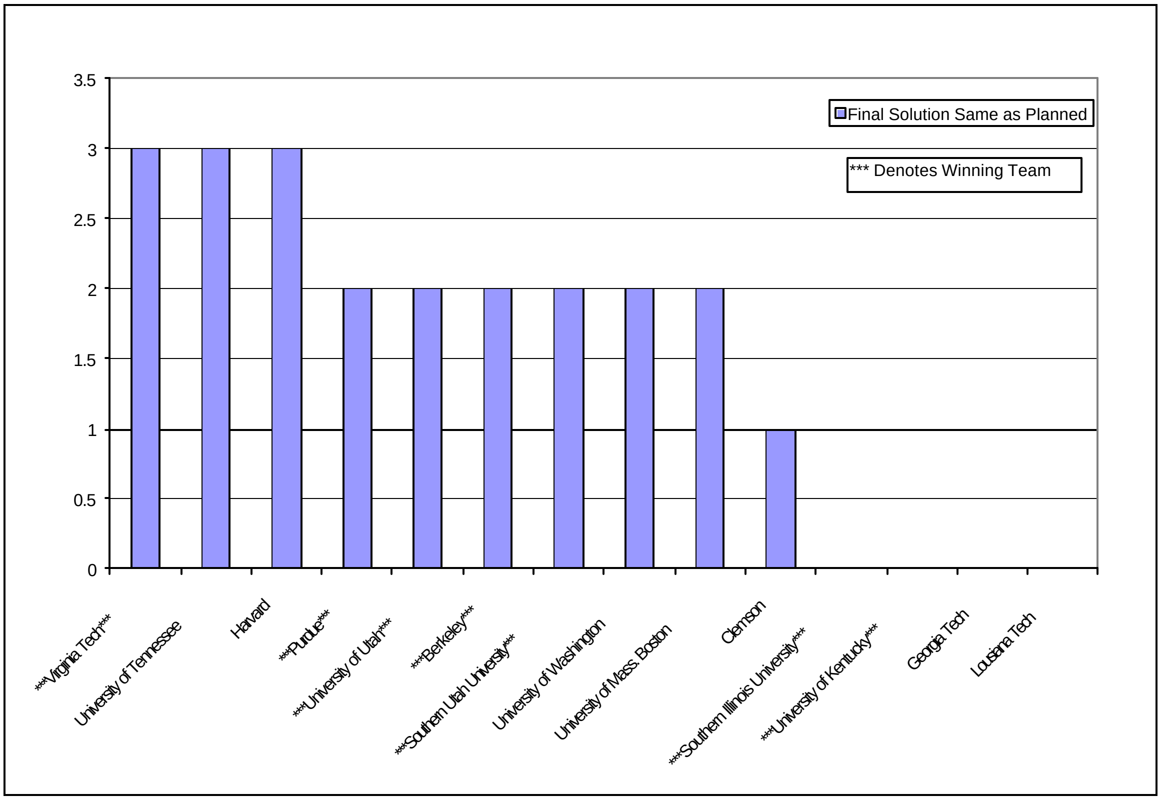

Figure 4-6: Final Solution same as Planned data from *Robot Rivals* teams

This analysis has provided beneficial information about characteristics of teams that can be associated with higher probabilities of winning. Chapter 5 will organize these characteristics into aspects of single-session design teams and its methodology. Once again, care must be taken in performing statistical analysis. The data sets in this initial study of single-session design are small compared to the ideal size. Statistical relevancy of future studies will be increased by having more samples, thus reducing the large impact that outliers have on the data. The research here is intended to outline a reliable method of assessment assuming an adequate sample size.

Chapter 5 – Single-Session Design

The main purpose of this chapter is to layout the single-session design methodology as derived from successful *Robot Rivals* competitions. Discussed in detail is a description of the methodology and the associated team structure, team dynamics, and time management.

5.1 Description of Single-Session Design Team Structure

Through observation and analysis, this research has successfully identified a few key characteristics that make up strong *Robot Rivals* teams. This section forms these characteristics into a succinct methodology; single-session design, a methodology that can be applied in industry and academia to expedite projects and inject ingenuity into designs.

First and foremost, the team structure in single-session design is crucial. The nature of single-session design requires a distinct group of individuals who wholeheartedly believe in the process. A team using single-session design requires a motivated group of leaders.

The normal hierarchy found in many conventional design methodologies does not exist in single-session design. Time constraints and the need to make the best use of each member's talents contribute to this. In a conventional design team, the normal team structure has a project leader or manager at the top. This person is in charge of overseeing the entire project and coordinating resources. Being so heavily involved in the management aspect of the process, this person is consequentially unable to contribute effectively as a designer. In instances where single-session design is implemented, there is not enough time for these cumbersome processes to be the sole responsibility of a single team member. Extended deliberation back and forth between project managers and team members is impossible in a compressed timeframe setting.

Another important reason that this hierarchy does not fit in the single-session design methodology is that single-session design teams are smaller than conventional design teams for reasons that will be developed later in this chapter. With a smaller team, each member must contribute a large fraction of their total effort to the design. Using smaller teams ensures that every person contributes to their maximum potential. Under-utilization of employees wastes time and money, and results in an inferior design.

To counteract the effect of the lack of a conventional hierarchy, a single-session design team should consist of individuals who are leaders in themselves. These team members are experienced in their respective fields, but more importantly, can act autonomously. Important decisions must be made quickly, without excessive deliberation. This is accomplished by having team members who are independent and technically competent, and can remain aware of the entire scope, while working specifically on their part of the project.

Observation of the *Robot Rivals* program repeatedly showed that teams that had a defined leader struggled to finish the competition. Typically, these teams also relied heavily on their assigned expert. Valuable time was robbed from one team member, the leader, to explain, direct, or motivate the other individuals. While this was occurring, the leader could not contribute to the actual design.

Another important aspect of single-session design is the educational breakdown of the individual members that follow this non-conventional approach. This aspect is necessarily project dependent. However, the theory remains the same for any project. As the general scope for a specific project will be known before any designing can be done, the relevant areas of expertise will be evident. Crucial to the success of a single-session design team is variety. All team members must bring a different, necessary facet to the composite team. Since the scope of the project is already known, single-session design teams can be composed accordingly.

Mechanical engineers are particularly well suited to this process. Mechanical engineers can be experts in areas such as controls, kinematics, or thermodynamics, while, as a result of their education, still be competent in many other aspects of engineering. This maximizes the effectiveness of all cross-functional activities. It is important that while all members can act independently on a specific part of the project, they can come together and generally understand the project as a whole. *Robot Rivals* interviews specifically indicated this. Some teams were composed entirely of electrical engineers, who had excellent solutions to the controls and electronic aspects of the designs. However, the nature of the projects necessitated that these solutions be implemented on a machine. A team of electrical engineers finds the implementation stage of the process difficult. This idea must be kept at the forefront in the selection of team members. Each facet of the project must have effective source of a design solution.

Another aspect related to the team member breakdown is the makeup of their experience. The definition of expert in industry is inadequate to determine if a person will make an effective single-session design team member. It has been found that technical knowledge is a crucial characteristic. Knowledge of fundamental processes and theories is important to the determination of solutions. However, many times, a team is comprised of members who solely posses this type of experience. In the small team structure of single-session design both fundamental knowledge and applied knowledge should be possessed by all members of the team. Not only should a single-session design team member know how to solve a problem, they should also know how to implement that solution.

A direct result of the analysis of *Robot Rivals* is that having pre-established roles is a key element of single-session design. An understanding of where each member of the team fits in the overall solution is critical to being successful. In some settings it is apparent that some team members have no key role in the solution, which dramatically reduces the effectiveness of the team. Single-session design maximizes efficiency by only having members on the team that directly bring a needed skill to the table. Again, this aspect is project dependent.

These are the key characteristics of a single-session design team. The small teams rely heavily on each member's significant contribution and ability to think both locally and globally, effectively. The next section describes the various interactions of a single-session design team.

5.2 Description of Single-Session Design Team Dynamics

A crucial part of any team is the way they interact. Here, team dynamics is defined by the interactions that characterize the way that the group functions, coordinates, and reacts to the task at hand. Specific design methodologies have distinct team dynamics that are apparent. Some of these interactions were revealed through the industry interviews of Chapter 2.

One of the most important interactions that a group can have is also one of the simplest. Often underestimated are the positive results that are the product of a group attitude of anticipated success. As shown in this research, anticipated success greatly affects the outcome of the event.

There is a fine line between anticipated success and being overconfident. Overconfidence can hurt productivity due to a false sense of ability. In contrast, when significant challenges are met along the way to a design solution, successful single-session design teams thrive on the increased pressure that the situation creates. Anticipating success means that a solution or better solution can always be found, or at least attempted. Failure is encountered many times by groups that consist of individuals who do not possess adequate problem solving skills. This is because the team moral falls when significant challenges are faced and no one can offer a solution. A positive attitude throughout the process is a key to a strong single-session design team.

Another important aspect of single-session design is directly related to the compressed timeframe. Compressed timeframes sometimes require designers to use non-conventional approaches to arrive at a solution. In the brainstorming phase of single-session design, it is crucial that the unusual solutions proposed by others be taken seriously. This is important because a creative solution can be reached through the successive connection of various manifestations of each member's contributions. A group must be able to accept and build on each others ideas on a continual basis throughout the project.

Another important team dynamic is the way that a specific plan is followed by a team. While single-session design relies on quick thinking, a planning stage is important. Effective communication starting in the planning phase must be kept throughout the entire process. Sketches and verbal discussion in the planning stage must clearly communicate the design. Once a solution is selected for development, it is important to clearly communicate that solution to all team members. Large sketches of the overall design and details of individual components must be located conveniently for all the members of the team to review.

A central location is essential to facilitate these beneficial dynamics in the single-session design. An advantage is gained when all stages of the process can occur in one room. Brainstorming is more effective when actual parts can be at hand. Physical brainstorming—rough prototyping—communicates much more effectively to every member on the team. The construction phase also benefits from a central location. Reference to sketches and an ongoing dialog among team members helps to keep the process moving.

Creativity and efficiency are at the heart of single-session design. The nature of the process is one that breeds creativity. Non-conventional solutions are devised as a direct result of the short duration of the process. Teams with open minds, positive thinking, and the capacity to thrive on pressure can create successful, speedy solutions to complex problems. The next chapter concludes this research with a discussion about the implementation of single-session design in industry and academia.

Chapter 6 – Conclusions and Future Work

The main purpose of this chapter is to discuss the application of single-session design in industry and academia. Specific industry and academic settings are presented that offer good platforms for the implementation of single-session design. Also presented are areas of further research and possible avenues for increased enlightenment of the process in which creativity is spawned by necessity.

6.1 Application in Industry

Each year, the competitive nature of industry becomes more apparent. Mergers and bankruptcies are commonplace and the business has become more uncertain than ever. To wage battle against the increasingly difficult conditions, businesses must become more effective. Be it through leaner manufacturing processes, or through improved design at the conceptual stage, companies are constantly striving to remain competitive. Companies use a variety of design methods as a means to encourage their competitiveness [9]. Saving time is a major area of interest for all businesses. Delivering a product solution before the competitor is a driving force in many industries.

Recent years have seen the advent and proliferation of rapid prototyping. From stereo-lithography to laminate object manufacturing, rapid prototyping has been used to get ideas out of the designers’ minds and into their hands more efficiently. Advancements in the technology have drastically improved its effectiveness as a tool for the creation of practical prototypes. In some cases parts can be conceptualized and built for testing in a matter of hours.

Another way that companies save time is through the implementation of a design methodology. Companies follow set methodologies to give direction to the projects and record their progress. Some company settings will provide good platforms for single-session design, while others will not. The nature of the work at a specific company dictates the best process to use in the designing stages. Some companies use an evolutionary approach to design that continually builds upon previous solutions. In an organization such as this, the single-session design process may not be a good fit. However, it needs to be understood that exclusively building on previous solutions can sometimes lead to a stagnant design. In such cases, using single-session might breathe new life into a product.

Companies could implement the single-session design process in a similar fashion to the approach seen on the *Robot Rivals* program. However, instilling a genuine sense of urgency may be hard to achieve when it is fabricated. This sense of necessity might be achieved, as it is on the television program, by playing on the competitive nature of people. Instead of the normal design teams consisting of a large number of people, multiple groups can be created and pitted against one another to determine a solution. The company can set up the time structure, but the effect of competition between teams could generate solutions more quickly. It is evident that this approach requires individuals who truly embrace the challenge.

A beneficial aspect of using this approach in industry is that ideas from opposite sides may be subsequently integrated. Whereas on *Robot Rivals* this is obviously not possible, in an industry setting the end goal is to create a superior product for the company. After the competitive stage of the process is completed, and both teams demonstrate their design, certain aspects of each can be brought together to achieve the ultimate solution. Another benefit that is realized in industry that is not apparent on the television program, is that shortcomings can be fixed. Competition is an effective way to uncover hidden defects in the design. On television, these shortcomings can lead to the defeat of a team. However, in industry, these shortcomings can be analyzed and worked on to create an even better solution.

An ideal setting for single-session design is a consulting firm, an organization set up with the purpose of devising solutions for other companies. The varied nature of this work necessitates that the employee profile be substantially varied. This is advantageous for the implementation of single-session design. As problems are generated, teams are organized consisting of the relevantly skilled employees. A consulting firm implementing this process would be capable of devising solutions in a multitude of areas. Again, the company structure must be conducive to the process. Employees implementing the process must embrace the competitive nature of the procedure.

The diverse work that consulting firms attract is the main advantage for single-session design. Different problems yield a different set of specifications and an entirely new competition. Creativity is maximized in this setting as solutions must continually be different.

Ultimately, any company can implement this procedure for design. In some instances, it may be used as a starting point to generate a number of feasible solutions from which to begin another specific design process used to develop a product. In other cases, companies may approach problems using single-session design alone, using the process to generate rapid, creative solutions. The next section discusses the implementation of this process in academic settings, where the rigid structure of industry is not so apparent.

6.2 Application in Academia

Previously discussed was the application of single-session design in industry. The most challenging aspect of implementing a new process in industry is the associated risk. New methods and processes may face considerable resistance in companies where a specific process is already being used and is deemed adequate. The university setting is somewhat different. The environment at a university is one where innovative ideas are created and tested.

The design process is fundamental in an engineer's formal education. In recent years, much criticism has existed about the ability of engineers to succeed outside the academic setting. Much of this criticism is centered on curriculum, particularly its neglect of engineering design [10]. Many schools do have courses teaching the design process, and some schools even have capstone courses where the process is implemented. One such school is Virginia Polytechnic Institute and State University.

In the Mechanical Engineering department at Virginia Tech, an undergraduate course called Mechanical Engineering Design and Economics (ME-2024) is required in the sophomore year. In this course, the general process for design is taught as described in the first chapter of this report. Subsequently, in the senior year of undergraduate mechanical engineering, a capstone design course is required. In this course, the student chooses a project to work on ranging from Hybrid Electric Vehicle Design to Human Powered Vehicle Design. A full academic year is allotted to the capstone course. These courses give students a taste of 'real world' engineering. A problem is presented, and the students are charged with developing and manufacturing a complete solution.

This setting is ideal for the implementation of single-session design. Whereas in industry the sense of urgency may need to be fabricated, the typical academic assignment spans a day or two. The competitive environment is also naturally present in the university setting. Single-session design can be used as a means to inject new spirit into these difficult and sometimes frustrating engineering tasks.

The implementation of the process in academia would be similar to the industrial process described in the previous section. In fact, single-session design used in universities would bring the process closer to its origins, which are the *Robot Rivals* competitions between engineering students. Universities are rich sources of new ideas, which make them an appropriate place to put single-session design to the test. The final section in this report discusses the ways in which this process can be further developed and subsequently implemented more effectively in the workplace or in academia.

6.3 Recommendations for Future Work

This research has broken ground on an innovative approach to engineering design. The unique opportunity to use *Robot Rivals* as a case study in single-session design has been crucial to its initial development. As with any work, especially concerning methodologies, further studies are needed to verify the basic premises in this thesis and to further develop this process.

The progression of this research has shown the critical importance of psychology. Increased involvement of psychologists from the early stages would be beneficial to any further research. Psychologists can aid in the understanding of the behavioral aspects of those involved in the design process. Greater understanding of the human interactions that occur during intense periods of design could lead to improved insight into the eventual team structure of a single-session design group.

Further insight into single-session design can also arise from subsequent studies of intense problem solving situations. Observations of military operations in the field, where quick solutions to problems are needed to ensure successful missions, can lead to important inferences. Beneficial aspects of the process may also be deduced from observing emergency service personnel at work, where their quick thinking saves lives every day.

Another avenue for further research may involve the observation of *Robot Rivals* in its second season, or other design programs. The intensity and rapid nature of the competitions on these programs yields an ideal setting for observing the design process as it must be adapted to be effective in a compressed timeframe.

Ultimately, the interactions of people that are involved in intense problem solving situations, and their solutions to the tasks presented before them, will lead to a greater understanding of how necessity can be used as a catalyst for design solutions. The theories and methods developed in this research can be expanded upon and improved to refine a methodology that may prove to be useful to engineers, those learning the trade and those applying what they have learned.

The door is now opened for single-session design to be put to the test. Students and companies who are willing to take a different, exciting approach to engineering can realize significant reductions in design times with the benefit of creative solution approaches. Although time is of the essence, only time will show the true benefits of single-session design.

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Appendices A-1, A-2, A-3, A-4

A-1: General Motors Corporation Design Process Interview

(1) What types of products are developed at the facility?
All vehicles sold in North America are developed at Milford Proving Grounds (MPG). From small car to medium duty trucks. Within a year all the design/engineering will be consolidated at the Warren Tech Center.

(2) How big are the typical design teams?
What do you mean by design teams? People are typically grouped by the commodity or area they work in, but each is assigned to a particular vehicle or platform. Platform/vehicle teams have hundreds of people on them (see below for more detail).

(3) Is there a structured hierarchy in the team?
There are several areas of GM. There's R&D, portfolio/showcar, high perfromance/special vehicles, and powertrain to name a few. The two which are directly linked to the vehicles are the design and development areas.

The Design side is responsible for the individual parts' sourcing, modeling, validation, and release. Today we have designing engineers who are responsible for the math/modeling AND the validation/release. This used to be a multi-person process. Each part (or in some cases systems) has someone who is fully responsible for that piece. However, the craze in the industry is to lay a large portion of the burden on integrated suppliers to design and validate.

The Development side is responsible for the integration of several realted parts or subsystems into the specific vehicles, such as ride and handling, N&V, HVAC, chassis controls, etc. In some cases these folks have to validate the entire system/vehicle to their specs.
Many argue which is more important and more fun. Ultimately it's a matter of personal preference. The designers are initmate with the design and history of parts, but a not always privy to the larger scope. However, it's their name that goes on the part. The development guys are hands-on and get exposure to a wide variety of issues, but have to react and respond to several other folks.

(4) Is a detailed design process followed?
There are specific and mandated steps that are followed throughout the life of a part, all intended to make GM ISO compliant.

(5) What are the timeframes fro typical designs?
The move is to go from drawing board to showroom in 24 months. However, most programs are on a 36 to 48 month process. As platforms become more established, iterations can be spun off faster. In some cases vehicles have been created and modified in as little as 9 months (GTO).

(6) What methods of brainstorming and problem solving occur?
Brainstorming is done in all manners. The problem, as with any group, is to be careful of the types of personalities and number of contributors in order to avoid getting bogged in details and petty dispute. Problems can be solved through informal investigation or detailed 5 Phase processes, depending on the magnatude and seriousness of the issue.

A-2: IDEO Design Process Interview

(1) What types of products are developed at the facility? "Facility" does not really describe our offices in Palo Alto, where more than 150 people work in 6 studios, and then the rest of the company is in 7 other cities around the world. Most offices are capable of doing all of the types of work we do, from websites to medical instruments to environments to service overhauls, etc.

(2) How big are the typical design teams? Because the work is so varied, and involves different types of people at different phases, the number can change too much to make a reasonable answer. A core team could be from two to ten, with a large number of people contributing at different times.

(3) Is there a structured hierarchy in the team? There's generally a project manager, who keeps the big picture and works with the client closely. Beyond that, on a large project there may be people who take prime responsibility for discrete elements.

(4) Is a detailed design process followed? Only in a rough sense. Brainstorming, user observations, prototyping.
This website has some info that might help you. It outlines a project we did for Evenflo for a Simthsonian exhibit called Invention at Play:
http://www.inventionatplay.org/inventors_ide.html

(5) What are the timeframes fro typical designs? Sorry, again it's too varied. Three months for an ID-only project to two-plus years for a complicated medical device. So, say 12-18 months.

(6) What methods of brainstorming and problem solving occur? Brainstorms are called formally throughout a project, and the same methods of brainstorming happen informally at desks all the time.

A-3: Competitor Surveys

Robot Rivals Single Session Design	**Pre-Competition Survey**	Name: University:

1. Do you anticipate being successful in this round and moving on to the next round?

   Definitely   Somewhat   Probably not

2. What is your college major and area of interest?

   ----

3. Have you ever taken a course on engineering design / methodology?

   Yes   No

4. Have you ever taken a course where constructing a device is a main component of the course outline?

   Yes   No

5. Do you undertake hands-on projects on your own time?

   All the time   Sometimes   Never

6. Is the device being developed for this competition likely to be the most complex device you have ever worked on?

   Yes   No

7. Have you previously participated in a compressed time-frame design setting similar to Robot Rivals?

   3 + times   1 or 2 times   Never

8. Do you have a defined plan / strategy for the solution to the problem?

   Very defined   A few ideas   No plan

9. In your opinion, how much time is needed to form a working solution to this problem?

   1 Day   1 Week   1 Month +

10. Are there pre-established roles on your team? (team leader, mechanical expert, computer expert…)

    Yes   No

11. Do you intend to rely on your assigned expert?

    A lot   Somewhat   Never

Robot Rivals Single Session Design	**Post-Competition Survey**	Name: University:

1. Were you successful in this round and now moving on to the next round?

   Yes No

2. Was a pre-defined plan / strategy followed throughout the design of the device?

   Completely followed Somewhat followed Not followed

3. Was the final design solution the same as the initial planned solution?

   Yes No

4. Given more time, would the final design change?

   Greatly Some minor aspects Not at all

5. In your opinion, how much time is needed to form a working solution to this problem?

   1 Day 1 Week 1 Month +

6. Did your team have the adequate skills and background to solve this problem?

   Yes No

7. Did your formal education contribute to the solution of the problem?

   Greatly contributed Slightly contributed No contribution

8. Was the device developed for this competition the most complex device you have ever worked on?

   Yes No

9. Did you rely on your assigned expert?

   A lot Somewhat Never

10. In your opinion, is this single-session approach to engineering design useful / effective in creating design solutions to problems.

    Very useful Slightly useful Not useful

A-4: Data from Competitor Surveys

Team	Major
Virginia Tech	
Graham Henshaw	Mechanical Engineering
Chris Terwelp	Mechanical Engineering
Ian Hovey	Mechanical Engineering
Georgia Tech	
Stephen Stephes	Aerospace Engineering
Daniel Scheafer	Computer Science
Kyle Howell	Computer Engineering
University of Washington	
Justin Wahlborg	Electrical Engineering
Tho Nguyen	Electrical Engineering
Jon Gosting	Electrical Engineering
Purdue	
Ross Walberg	Comp. Integrated Manu. Tech.
Joe Taylor	Aerospace Engineering
Chris Noble	Comp. Integrated Manu. Tech.
Clemson	
Charly Hermanson	Electrical Engineering
Iris Johnson	Electrical Engineering
Jamey Holcomb	Computer Engineering
University of Utah	
Ben Newton	Computer Science
Dan Flickinger	Mechanical Engineering
Amji Danutpan	Electrical Engineering
University of Tennessee	
Jason Lange	Mechanical Engineering
Landon Messal	Mechanical Engineering
Jason Fulgram	Mechanical Engineering
Berkeley	
Daniel Lehrbaum	Mechanical Engineering
Bharathwaj Muthuswamy	Electrical Engineering
Eric Park	Elec. Eng. / Comp. Science
University of Mass. Boston	
Ananta Sinha	Electrical Engineering
Rohit Sirohi	Computer Science
Kalyam Sunkara	Electrical Engineering
Southern Illinois University	
Jeff Cummins	Industrial Technology
Mike Palik	Electronics System Tech
Matt Berry	Electronics System Tech
Southern Utah University	
Jared Hammel	Electronics Engineering Technology

David Kerksiek	Technology Education
Tracy Day	CAD/CAM Engineering
Lousiana Tech	
David Briscoe	Electrical Engineering
Louis Landry	Computer Science
Nick Tullos	Computer Science
University of Kentucky	
Casey Harr	Electrical Engineering
Richard Conner	Electrical Engineering
Darren Brown	Electrical Engineering
Harvard	
Trevor Williams	Mechanical Engineering
Mike Sullivan	Computer Science
Benjamin Peirce	Engineering Science

	Experience (pre)			
	Design Course	Hands-on (class)	Hands-on (personal)	Educational & P
*****Virginia Tech*****	3	3	3	
*****Berkeley*****	3	3	2.5	
*****Southern Illinois University*****	3	3	2.5	
*****University of Kentucky*****	3	3	2.5	
University of Tennessee	3	2	2.5	
*****Purdue*****	2	2	2.5	
University of Mass. Boston	3	2	1.5	
Clemson	2	2	2	
Georgia Tech	2	2	2	
University of Washington	3	3	0	
*****Southern Utah University*****	1	2	2.5	
Harvard	2	1	2	
Lousiana Tech	0	2	2.5	
*****University of Utah*****	1	1	2	

Strategy (pre)

	Pre-competition Strategy	win/lose (1/0)
*****Virginia Tech*****	3	1
*****Purdue*****	3	1
*****Berkeley*****	3	1
*****Southern Illinois University*****	2.5	1
University of Tennessee	2.5	0
Georgia Tech	2.5	0
*****University of Kentucky*****	2	1
*****University of Utah*****	2	1
*****Southern Utah University*****	2	1
Harvard	2	0
University of Mass. Boston	2	0
Clemson	1.5	0
University of Washington	1.5	0
Lousiana Tech	1.5	0

Strategy Adherence(post question 2)

	Strategy adherence	win/lose (1/0)
*****Virginia Tech*****	3	1
*****Purdue*****	3	1
*****University of Kentucky*****	3	1
University of Tennessee	3	0
Harvard	2.5	0
*****University of Utah*****	2	1
*****Southern Utah University*****	2	1
*****Berkeley*****	1.5	1
University of Mass. Boston	1.5	0
Clemson	1.5	0
University of Washington	1.5	0
Lousiana Tech	1.5	0
*****Southern Illinois University*****	1	1
Georgia Tech	1	0

	Anticipate Success	win/lose (1/0)
*****Virginia Tech*****	3	1
*****Purdue*****	3	1
*****University of Utah*****	3	1
*****Southern Illinois University*****	3	1
*****University of Kentucky*****	3	1
University of Tennessee	3	0
University of Mass. Boston	3	0
Lousiana Tech	3	0
*****Berkeley*****	2.5	1
*****Southern Utah University*****	2	1
Georgia Tech	2	0
Clemson	1.5	0
Harvard	1.5	0
University of Washington	1	0

Time

	1 Day	1 Week	1 month +	Total
Virginia Tech	3	0	0	3
Georgia Tech	3	0	0	3
University of Washington	3	0	0	3
Southern Illinois University	2	2	0	4
Lousiana Tech	2	2	0	4
University of Kentucky	2	2	0	4
Purdue	1	4	0	5
University of Tennessee	1	4	0	5
Berkeley	1	4	0	5
Clemson	1	2	3	6
University of Utah	1	2	3	6
University of Mass. Boston	0	6	0	6
Southern Utah University	0	6	0	6
Harvard	0	6	0	6

Pre-established roles

	Pre-established roles	win/lose (1/0)
*****Virginia Tech*****	3	1
*****Purdue*****	3	1
*****University of Utah*****	3	1
*****Berkeley*****	3	1
*****Southern Illinois University*****	3	1
University of Mass. Boston	3	0
Georgia Tech	3	0
University of Washington	3	0
*****Southern Utah University*****	2	1
University of Tennessee	2	0
Harvard	2	0
*****University of Kentucky*****	1	1
Clemson	1	0
Lousiana Tech	1	0

Reliance on Expert

	Intent to rely on expert	Post-Competition assesment
Virginia Tech	3	3
University of Washington	3	3
Clemson	1.5	3
Purdue	2	2.5
University of Utah	1.5	2.5
Harvard	1.5	2.5
Georgia Tech	1.5	2
University of Tennessee	3	2
Berkeley	2	2
University of Mass. Boston	1.5	2
Southern Illinois University	1.5	2
Southern Utah University	1.5	1.5
Lousiana Tech	1.5	1.5
University of Kentucky	1.5	1.5

Dependence on Expert (post)

	Dependence on Expert	Win/Lose (1/0)
*****Virginia Tech*****	3	1
University of Washington	3	0
Clemson	3	0
*****Purdue*****	2.5	1
*****University of Utah*****	2.5	1
Harvard	2.5	0
*****Berkeley*****	2	1
*****Southern Illinois University*****	2	1
Georgia Tech	2	0
University of Tennessee	2	0
University of Mass. Boston	2	0
*****Southern Utah University*****	1.5	1
*****University of Kentucky*****	1.5	1
Lousiana Tech	1.5	0

Single Session Design Usefulness

	Single Session Design Usefulness	Win/Lose (1/0)
Virginia Tech	3	1
University of Utah	3	1
Purdue	2.5	1
Southern Illinois University	2.5	1
University of Kentucky	2.5	1
University of Tennessee	2.5	0
Harvard	2.5	0
Southern Utah University	2	1
University of Washington	2	0
Clemson	1.5	0
University of Mass. Boston	1.5	0
Lousiana Tech	1.5	0
Berkeley	1	1
Georgia Tech	1	0

	Experience (post)		
	Adequate Skills	Education	Usefulness of Experience
*****Virginia Tech*****	3	3	6
*****Southern Illinois University*****	3	3	6
*****University of Utah*****	3	2.5	5.5
University of Tennessee	3	2.5	5.5
*****Southern Utah University*****	3	2	5
*****Purdue*****	3	2	5
University of Mass. Boston	3	2	5
*****University of Kentucky*****	3	2	5
Lousiana Tech	3	1.5	4.5
Harvard	3	1	4
Clemson	1	2.5	3.5
*****Berkeley*****	2	1	3
Georgia Tech	2	1	3
University of Washington	1	1.5	2.5

	Resulting Solution	
	Final Solution Same as Planned	Win/Lose (1/0)
*****Virginia Tech*****	3	1
University of Tennessee	3	0
Harvard	3	0
*****Purdue*****	2	1
*****University of Utah*****	2	1
*****Berkeley*****	2	1
*****Southern Utah University*****	2	1
University of Washington	2	0
University of Mass. Boston	2	0
Clemson	1	0
*****Southern Illinois University*****	0	1
*****University of Kentucky*****	0	1
Georgia Tech	0	0
Lousiana Tech	0	0

Design Change Given more time

	Change Design Given More Time	Win/Lose (1/0)
Virginia Tech	0	1
University of Tennessee	0	0
Harvard	1	0
University of Washington	1.5	0
Purdue	2	1
University of Utah	1.5	1
Berkeley	2	1
University of Mass. Boston	2	0
Southern Utah University	1.5	1
Clemson	2	0
Georgia Tech	2.5	0
Southern Illinois University	0.5	1
Lousiana Tech	1.5	0
University of Kentucky	1.5	1

Graham Robert Byrne Henshaw

Education:

Virginia Polytechnic Institute and State University, Blacksburg, VA

M.S., Mechanical Engineering, May 2003

Research in Single-Session Design

Overall GPA: 3.85 / 4.00

B.S., Mechanical Engineering, Cum Laude, May 2002

Minor, Industrial Design, May 2002

Overall GPA: 3.52 / 4.00

M.E. GPA: 3.73 / 4.00

Graduate Research:

Rapid design methodology derived from *Robot Rivals* Television series. Analyzing design processes adapted to compressed timeframes and investigating their application in industry.

Related Course Work:

•Manufacturing Processes Laboratory •Mechanics of Deformable Bodies •Statics •Dynamics •Materials Science •Industrial Electronics •Thermodynamics •Fluid Mechanics •System Dynamics •Vibrations •Heat Transfer •Industrial Design Materials Laboratory •Industrial Design Technology •Advanced Technology Vehicles •Land Vehicle Dynamics •Fuel Cell Systems•Advanced Kinematics

Computer Skills:

AutoCad •Mechanical Desktop •Unigraphics •3-D Studio •Matlab •Mathematica •C++ •MS Office •Minitab