Design Collaboration in Industry: When, Why, and How

Steven Thomas O'Shields
Clemson University

Follow this and additional works at: https://tigerprints.clemson.edu/all_theses

Recommended Citation
https://tigerprints.clemson.edu/all_theses/2534

This Thesis is brought to you for free and open access by the Theses at TigerPrints. It has been accepted for inclusion in All Theses by an authorized administrator of TigerPrints. For more information, please contact kokeefe@clemson.edu.
DESIGN COLLABORATION IN INDUSTRY: WHEN, WHY, AND HOW

A Thesis
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment
of the Requirements for the Degree
Master of Science
Mechanical Engineering

by
Steven Thomas O’Shields
December 2016

Accepted by:
Dr. Joshua Summers, Committee Chair
Dr. Georges Fadel, Committee Member
Dr. Oliver Myers, Committee Member
ABSTRACT

This research compares how practicing engineers and designers collaborate in industry work on design projects as compared to how academic textbooks teach design. Information from design literature textbooks was compared with in-person and over-the-phone interviews from practicing engineers and designers in industry. A case study was conducted through interviews, which allow for live interactions between the researcher and the interviewees to retrieve targeted information specific to the collaborative design research that may be more difficult to attain in written documents. A total of ten interviewees volunteered from three companies to participate in an interview related to design projects, processes, tools, and meetings. Interviews were then deconstructed to quantify results based on specific topics discussed, such as, informal and formal meetings, and collaborative tools used throughout a project. This research gives insight into how, when, and why the interviewees typically design at the three interviewed companies. Results show that only one of the interviewees mentioned the benefits of a design tool but did not apply it during their projects. This contradicts what textbooks suggest by using design tools as the means from which to collaborate. Additionally, the purpose of collaborative design from the perspective of the interviewees is also discussed through the use of formal and informal meetings. According to the interviewees, each meeting type employs a different set of needs when used in the design process. Additional research questions are provided to continue research into the design practices of additional companies and what resources academia can provide for individual designers.
DEDICATION

To my family and friends, for their support and love over the years.
ACKNOWLEDGEMENTS

I would like to thank my family and friends because without their support over the years, this research would not have been possible. My parents, Steve and Maryann, brothers, William and Zachary, grandmothers, aunts, uncles, and extended family have provided me with unconditional support over the years through both my successes and failures.

Thank you to my committee members for providing their critiques and experience to my research. Thank you to my advisor and committee chair, Dr. Joshua D. Summers for his assistance and guidance throughout my research. His support to help better my research, teaching, and coaching skills have been invaluable to my development as a professional engineer. Thank you to Dr. Georges Fadel and Dr. Oliver Myers, for providing your perspectives to enhance my research.

Thank you to the CEDAR lab and my lab-mates in EIB 134 for their help with reviewing my research, thesis, presentations, and for all the discussions we have had over the years.

Thank you to Dr. Winfried Zanker for his input to help my research and for his feedback on my lecturing techniques. His help has been invaluable and I will forever use the techniques learned to be the best speaker and lecturer I can be.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Content</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>II</td>
</tr>
<tr>
<td>DEDICATION</td>
<td>III</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>IV</td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td>V</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>VIII</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>X</td>
</tr>
<tr>
<td>CHAPTER 1: INDUSTRY COLLABORATION RESEARCH MOTIVATION</td>
<td>1</td>
</tr>
<tr>
<td>1.1 Textbook Review of Design Processes</td>
<td>1</td>
</tr>
<tr>
<td>1.2 Tools of the Design Process</td>
<td>5</td>
</tr>
<tr>
<td>1.3 Collaborative Design</td>
<td>11</td>
</tr>
<tr>
<td>1.4 Research Questions</td>
<td>15</td>
</tr>
<tr>
<td>1.5 Thesis Outline</td>
<td>16</td>
</tr>
<tr>
<td>CHAPTER 2: CASE STUDY RESEARCH THROUGH INTERVIEWING</td>
<td>18</td>
</tr>
<tr>
<td>2.1 Case Studies in Engineering Research</td>
<td>18</td>
</tr>
<tr>
<td>2.2 Interviewing as a Data Collection Method</td>
<td>19</td>
</tr>
<tr>
<td>2.3 Interview Planning</td>
<td>21</td>
</tr>
<tr>
<td>2.4 Interview Question Structure</td>
<td>23</td>
</tr>
<tr>
<td>CHAPTER 3: INTERVIEW DESIGN</td>
<td>26</td>
</tr>
<tr>
<td>3.1 Company Profiles</td>
<td>26</td>
</tr>
<tr>
<td>3.2 Interviewee Profiles</td>
<td>28</td>
</tr>
<tr>
<td>3.3 Interview Questions, Topics, and Triangulation</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>Name</td>
</tr>
<tr>
<td>---</td>
<td>------------</td>
</tr>
<tr>
<td>B.2</td>
<td>A.ME.2 – Brad</td>
</tr>
<tr>
<td>B.3</td>
<td>A.ME.3 – Chris</td>
</tr>
<tr>
<td>B.4</td>
<td>A.ME.4 – David</td>
</tr>
<tr>
<td>B.5</td>
<td>A.IE.1 – Erin</td>
</tr>
<tr>
<td>B.6</td>
<td>B.ME.1 – Frank</td>
</tr>
<tr>
<td>B.7</td>
<td>B.ME.2 – Grace</td>
</tr>
<tr>
<td>B.8</td>
<td>B.EE.1 – Hank</td>
</tr>
<tr>
<td>B.9</td>
<td>B.ID.1 – Isaac</td>
</tr>
<tr>
<td>B.10</td>
<td>C.ME.1 – Jordan</td>
</tr>
</tbody>
</table>
LIST OF TABLES

Table 1.1: Design phases as described by the associated design textbook and simplified phases of product planning (PP), conceptual design (CD), embodiment design (ED), and detail design (DD) are shown. ........................................ 2

Table 1.2: The number of collaborative (col.) and individual (ind.) tools recommended for use in each phase of the design process ................................................. 6

Table 1.3: Percent of tools discussed across multiple textbooks, based upon which phase(s) the tool was suggested for use. ............................................. 10

Table 2.1: Interview design process ................................................................. 21

Table 3.1: Basic information of each company interviewed. ....................... 27

Table 3.2: Interview participants, experience, and highest education completed. .... 28

Table 3.3: Topics and questions used for semi-structured interview. ................. 32

Table 3.4: Interview triangulation matrix ......................................................... 38

Table 4.1: Interview summary for Alex ........................................................ 41

Table 4.2: Interview summary for Brad ........................................................ 42

Table 4.3: Interview summary for Chris ....................................................... 43

Table 4.4: Interview summary for David ....................................................... 45

Table 4.5: Interview summary for Erin ......................................................... 47

Table 4.6: Interview summary for Frank ....................................................... 48

Table 4.7: Interview summary for Grace ....................................................... 49
Table 4.8: Interview summary for Hank ................................................................. 51
Table 4.9: Interview summary for Isaac ................................................................. 53
Table 4.10: Interview summary for Jordan ............................................................ 54
Table 5.1: Designers’ use of the design process or tools ........................................ 55
Table 5.2: Intent and content of informal/unscheduled meetings ......................... 59
Table 5.3: Intent and content of formal/scheduled meetings ................................. 61
Table 6.1: Areas of application for research conclusions based on company type. .... 70
Table 6.2: Comparisons between what is taught in textbooks with what is practiced in industry .......................................................... 70
Table A.1: Initial interview questions ................................................................. 79
Table A.2: Second iteration of interview questions .............................................. 80
Table A.3: Third iteration of interview questions ................................................ 81
Table A.4: Fourth iteration of interview questions .............................................. 83
Table A.5: Fifth iteration of interview questions ................................................ 84
Table A.6: Final iteration of questions used for interviewing .............................. 86


## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1.1: The average percent of the reviewed textbooks dedicated to the four general phases of the design process.</td>
<td>4</td>
</tr>
<tr>
<td>Figure 1.2: The number of tools described in each phase of the design process for (a) collaboration and (b) individuals.</td>
<td>9</td>
</tr>
<tr>
<td>Figure 1.3: Unique tools discussed at each phase of the design process.</td>
<td>10</td>
</tr>
<tr>
<td>Figure 1.4: Collaborative design dependencies based upon established taxonomy [21].</td>
<td>13</td>
</tr>
<tr>
<td>Figure 2.1: Example of triangulation questions during an interview.</td>
<td>24</td>
</tr>
<tr>
<td>Figure 3.1: Corporate hierarchy at Company A.</td>
<td>30</td>
</tr>
<tr>
<td>Figure 3.2: Corporate hierarchy at Company B.</td>
<td>31</td>
</tr>
<tr>
<td>Figure 3.3: Corporate hierarchy at Company C.</td>
<td>31</td>
</tr>
<tr>
<td>Figure 4.1: Company A's design process (a) illustrated by David and (b) recreated.</td>
<td>45</td>
</tr>
<tr>
<td>Figure 5.1: Perceived time expended in each phase of the design process according to (a) &quot;non-management&quot; and (b) managers.</td>
<td>64</td>
</tr>
</tbody>
</table>
CHAPTER 1: INDUSTRY COLLABORATION RESEARCH MOTIVATION

The purpose of this research is to understand how engineers and designers in industry work together to complete design projects. To establish the need for this research, engineering design textbooks are reviewed to understand how current design processes are explained and what tools or methods they involve. Moreover, literature that discusses collaboration is reviewed for its associated impact on industry. These create a basis from which to develop research questions.

1.1 Textbook Review of Design Processes

Current textbooks provide various methods and tools to assist engineers in completing the design process of a product. Textbooks provide a surrogate for what may be taught to undergraduate engineering students, thus this provides information for what engineers may bring into industry. A design process is defined as a series of steps, actions, or methods that are carried out throughout the development of a product. The process can be performed either in series or parallel [1]. Design processes are not only limited to new product design, but these can also include reverse engineering and redesign product development processes [2].

Nine textbooks were reviewed to understand the current state of design processes and their phases (Table 1.1). Phases were then simplified to show the focus of each textbook in terms of product planning (understanding the problem and generating requirements), conceptual design (generating and evaluating concepts), embodiment design (further developing and adding a body to concepts), and detail design (defining all remaining
details of concepts for production) [3]. This provides a foundation for understanding what these authors believe to be of most importance in the design process.

Table 1.1: Design phases as described by the associated design textbook and simplified phases of product planning (PP), conceptual design (CD), embodiment design (ED), and detail design (DD) are shown.

<table>
<thead>
<tr>
<th>Text</th>
<th>Author Defined Phases</th>
<th>Simplified Phases</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2. Develop Concept</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>3. Implement Concept</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>2. Conceptual Design</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>3. Embodiment Design</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>4. Detail Design</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>2. Understanding the Problem</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>3. Concept Generation</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>4. Concept Evaluation</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>5. Product Design Phase</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>6. Product Generation and Evaluation</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>2. Gather Information</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>3. Concept Generation</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>4. Concept Evaluation</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>5. Embodiment Design</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>2. Gather Information</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>3. Concept Generation</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>4. Concept Evaluation</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>5. Configuration/Parametric Design</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>6. Detail Design</td>
<td>✓</td>
</tr>
<tr>
<td>Dym &amp; Little [7]</td>
<td>1. Problem Definition</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>2. Conceptual Design</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>3. Preliminary Design</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>4. Detail Design</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>5. Design Communication</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>2. Design Development</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>3. Optimization Phase</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>4. Verify Capability Phase</td>
<td>✓</td>
</tr>
<tr>
<td>Author Defined Phases</td>
<td>Simplified Phases</td>
<td></td>
</tr>
<tr>
<td>-----------------------</td>
<td>------------------</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PP</td>
<td>CD</td>
</tr>
<tr>
<td>Voland [9]</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>1. Needs Assessment</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>2. Problem Formulation</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>3. Abstraction</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>4. Synthesis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Analysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Implementation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hyman [10]</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>1. Recognizing Need</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>2. Define Problem</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Gathering Information</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>4. Conceptualize Alternatives</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>5. Evaluate Alternatives</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>6. Selecting the Best Alternative</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

Each textbook provides a process to follow, which begins with the problem generation stage. This phase includes the gathering of information to better understand the problem and generating requirements for said problem. Conceptual development is also focused in each textbook through generation and evaluation. These textbooks use both collaborative and individual tools, such as brainstorming [2–4,6–10] and the Pugh Method [2,5,6,8]. Further, previous research has shown that in product development, early phases of the design process through conceptual design accounts for almost three-quarters of the total life cycle cost of the product [11]. This could explain the emphasis on these early stages of the design process, which is to generate concepts to the problem before adding a body to a design that can needlessly increase costs for aspects of the design such as production and materials.

As highlighted in Table 1.1, two textbooks do not explicitly mention the embodiment phase of design [2,10] while five textbooks do not mention detail design [2,4,5,9,10]. The
inconsistency between authors shows a disagreement in each textbook’s focus. In terms of the sections mentions, embodiment and detail design appear to be of lesser importance to the process, potentially due to undergraduate students being exposed to these aspects of design in their engineering curriculum. These findings will be further analyzed by determining how much the reviewed textbooks discuss each of the four simplified phases of the design process.

The average percentage of the product planning, conceptual design, embodiment design, and detailed design phases of the design process were calculated to help determine the focus of each author (Figure 1.1). This was accomplished by counting the total number of pages of the textbook being dedicated to a specific phase of the design process and dividing that by the total number of pages dedicated to the discussion of the design process.

![Figure 1.1: The average percent of the reviewed textbooks dedicated to the four general phases of the design process.](image)
Figure 1.1 shows that one-quarter of pages within each textbook were dedicated to the product planning and concept development phases of the design process. Contrary to the findings from Table 1.1, the most emphasis was placed upon embodiment design of 45%, while detail design had only about 5% of the total focus. This could be explained as one textbook dedicated 60% of their text to embodiment design, while only 1% was on detail design [3]. This equated to one subsection of a chapter being dedicated to detail design. The textbooks that specifically mentioned embodiment design as a section emphasized this phase of the process greater than other textbooks emphasized product planning or concept development.

**Takeaways:**

- *Product planning and conceptual design are discussed in each textbook to properly establish a problem before progressing into concept details.*
- *Embodiment and detail design are not discussed across all textbooks, potentially because of the emphasis of these phases in undergraduate curriculums.*

### 1.2 Tools of the Design Process

The processes illustrated in each of these texts can be simplified to product planning, conceptual design, embodiment design, and detail design [3].

The number of tools each textbook recommends to be considered for collaborative or individual use in each generalized phase are displayed in Table 1.2. For this research, collaboration is defined as tasks or tools that occurred both concurrently and co-located. While a design method helps the designer to generate new solutions, manage the design
process, or to represent information and knowledge, a tool is defined as a more specific implementation of that method [1,12–15]. Tools are used to physically or psychologically for the gathered information. This allows for the tool user to create deliverables within a given format or to develop results from mental exercises. Design tools can be software or hardware and usually produce a specific outcome from its use, such as generated concepts or prototypes [1,15,16].

To determine what tools were used in a collaborative or individual effort, textbooks were reviewed to determine what tools they stated required one or more people for use in a project. If a tool was not described explicitly as requiring more than one person, the tool was assumed to be for individual use. Further, collaboration is defined as “the presence of mutual influence between persons, open and direct communication and conflict resolution, and support for innovation and experimentation” [17]. The most important aspect of the definition is that it requires direct communication and conflict resolution, while teamwork can be indirect and thought of in terms of being parallel instead of series [18,19].

Table 1.2: The number of collaborative (col.) and individual (ind.) tools recommended for use in each phase of the design process.

<table>
<thead>
<tr>
<th>Text</th>
<th>Product Planning</th>
<th>Conceptual Design</th>
<th>Embodiment Design</th>
<th>Detail Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Otto &amp; Wood</td>
<td>4</td>
<td>3</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>Pahl &amp; Beitz</td>
<td>0</td>
<td>1</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Ullman</td>
<td>1</td>
<td>0</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>
A total of 176 tools exist between the four phases of design. Note that all of these tools are not unique and can be repeated between each textbook. These are broken down to 59, 92, 23, and 2 tools for product planning, conceptual design, embodiment design, and detail design, respectively. Overall, almost 34% of the tools described are for product planning, while 52% are for concept development. Conversely, detail design accounts for little more than one percent of the total number of tools. This suggests there could be a greater importance on concept development than there is on the other three phases of the design process, although this disparity in the number of tools likely means that the authors believe those latter phases of the process do not need as many tools to complete those phases. Also, this could be due to the course not covering these topics as most other engineering courses cover aspects of the embodiment and detailed design phases.
Product planning, conceptual design, and embodiment design each had more collaborative tools than detail design. This leads to the possible conclusion that collaboration is used more throughout these phases than they are in detail design, where it is possible that designers of a given specialty will be given control on that aspect of a project. Consider a capstone design project that the author participated in where the group of undergraduate engineers worked together to solve a problem that required them to insert filler material into a hollow tube. The group used tools such as brainstorming, morphological chart, and gallery method to develop concepts through collaboration. Once concepts were completed, each was analyzed for their overall feasibility by separating the group into two subgroups and constructing high-level prototypes. One solution was selected and prototypes continued to be constructed and improved throughout the remainder of the project by the single group. This phase of product design required that each individual be responsible for a specific subsystem, thus completing the project through concurrent, dislocated collaboration. This process is similar to those presented in textbooks.

To continue the discussion on the use of concurrent, co-located collaborative tools through the design process, Figure 1.2 visually represents the total number of tools discussed within each phase of the design process.
Figure 1.2: The number of tools described in each phase of the design process for (a) collaboration and (b) individuals.

Figure 1.2 shows that 52% of all tools for both collaboration and individuals were provided in the conceptual development phase, while detail design had less than three percent of focus for both individual- and collaboration-based tools. This shows a focus from the textbooks on the early phases of the design process to properly understand the problem and generate appropriate concepts. Specifically, 90% of all collaboration-based tools are designed for use in product planning and concept development. In total, collaborative tools accounted for 64% of the tools discussed by the text, which shows a focus on the need for collaboration throughout the design process.

Although Figure 1.2 shows the total number of tools described for visual reference of the emphasis on each phase of the design process, this illustration includes duplicates of
the tools described in each textbook. Therefore, it is beneficial to remove the duplicates and count unique tools to determine the amount of crossover there is between textbooks (Figure 1.3). The percent change of the number of unique tools discussed in each phase of the design process was also calculated and is presented in Table 1.3.

![Number of Tools](image)

**Figure 1.3:** Unique tools discussed at each phase of the design process.

**Table 1.3:** Percent of tools discussed across multiple textbooks, based upon which phase(s) the tool was suggested for use.

<table>
<thead>
<tr>
<th>Text</th>
<th>Product Planning</th>
<th>Conceptual Design</th>
<th>Embodiment Design</th>
<th>Detail Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent Repeated</td>
<td>22.85</td>
<td>18.52</td>
<td>20.41</td>
<td>10.00</td>
</tr>
</tbody>
</table>

Although there were decreases in the total number of tools presented for product planning, conceptual development, and embodiment design, the number of unique collaborative tools continues to outnumber the individual tools described in each phase. This could mean that more prior research has focused on tools for collaborative use than
for individual use. It would be beneficial to understand how designers use these tools while designing products. Note that collaborative tools under detail design was signified with a “--” because initially, there were no collaborative tools so including a 0% change could be misleading.

The review of the textbooks (Figure 1.1) show an emphasis on embodiment design, which is contrary to what was analyzed from Figure 1.2, where most of the tools were provided for product planning or concept development. This reveals that more assistance from the use of tools may be required for engineers to better initialize their projects while more discussion through the use of various methods is needed to successfully complete embodiment design.

**Takeaways:**

- *Product planning and concept development appear to need most collaboration.*
- *Most prior research in tools appears to focus on collaborative tools.*

**1.3 Collaborative Design**

Current literature describe the importance of collaboration through the design process [20–24]. More specifically, multi-disciplinary collaboration can be of great benefit as this allows for greater efficiency and to cover a more broad range of products without consisting of a single type of engineer or designer [22]. The inclusion of a variety of designers that bring their core competency to the group allows business to satisfy the need to be responsive in the fast-paced business of customer satisfaction and manufacturing needs [23,25].
Figure 1.4 provides a visual interpretation of the complexity of collaboration in design from a developed taxonomy. For instance, the leadership of a collaborating group is shown to indirectly affect its culture, thus why it is connected with a dashed line. Moreover, solid lines reflect a direct connection between two objects, such as how the design approach taken will determine what tools are used [21]. This mapping is useful in that it shows how these aspects affect each other, but it does not show any direct or indirect connections between the team and communication, information, or design approach, which could be beneficial to better understand in industry applications.
Increased efficiency is only seen when designers cooperate and maintain an appropriate level of communication, current information is shared amongst various companies and departments as it becomes available, and customer specification changes
are included into the appropriate documentation as quickly as possible [22]. Of note, all three of these points focus on the communication aspect of the team through documentation, not specifically about the process or tools involved in it, although the tools are another method of communication. Most important is that these actions affect manufacturing, product cost, and product quality, all of which are needed for a design team to be considered effective [22,26].

Some published literature tend to discuss collaboration in the form of design reviews [20–22]. One example is previous research shows how design reviews are affected by group familiarity and the amount of information shared amongst the other meeting attendees. In particular, greater common knowledge within the group would lead to more information being shared, which is averse to the general purpose of design reviews [20]. Also, group familiarity is stated as a potential factor of design review effectiveness, one such example being “groupthink,” which is a high level of group familiarity and pressure to reach a decision [20,27].

Project structures are also discussed and subdivided into five categories [28]. These project types account for a variety of functional or specific multi-disciplinary groups where assignments are project specific. Additionally, the paper discusses that each of the five project categories are beneficial to specific project types or to a specific phase of a project. In short though, while the use of collaborative groups in industry has been observed and discussed, an individual working through a design has not been as discussed and is more difficult to find in literature.
Takeaways:

- Literature on industry projects focus on communication through design reviews.
- A group collaborating has been more prevalent in research than the use of individuals.

1.4 Research Questions

This research focuses on the following questions to provide a better understanding of how practicing engineers in industry collaborate through the design process. Each question is followed by its reasoning and what the expected research benefits are.

**Research Question 1:** When do practicing engineers in industry work together in design projects?

This will help provide a comparison of when in the design process engineers work together in industry as compared to what is expected from published literature. By understanding when in the process engineers work together, improvements can be made to the design process to assist in facilitating further collaboration at this stage of the process. Further, this can affect how a design process course is instructed with regards to potential course formats where working together is encouraged or discouraged.

**Research Question 2:** Why do practicing engineers in industry work together in design projects?

Answering this question is necessary in that it provides a perspective into understanding how engineers in industry work together to complete a project. This can
provide information on the purpose of working together and how that compares with current understanding. Situations where engineers working together can also allow for academia to disseminate this knowledge to students and provide examples where working together is typically required.

**Research Question 3:** How do *practicing* engineers in industry work together in design projects?

Answering research question 3 will determine if engineers in industry work together in the same manner as published literature suggests. Textbooks present tools as the outlet that engineers and designers work together and communicate through the design process. This research will determine if work is completed together in the concurrent, co-located definition of collaboration or if there is a difference in industry collaboration.

**1.5 Thesis Outline**

This thesis is organized into five chapters. This chapter has focused on the motivation and background for this research. Chapter 2 focuses on the use of interviewing as a data collection method for use in engineering research. This will provide support and credibility for the research method used to complete this thesis. Chapter 3 focuses on the design of the interview conducted to complete this research. This will provide the questions used, abstracted information on the companies, and participants that volunteered for this research. A foundation to understand the triangulation between companies, participants, and questions will be formed.
Chapter 4 will provide concise summaries of each participant’s responses and general information about the interview. Chapter 5 will analyze the participants’ answers and provide details on how each response positively or negatively triangulated with each other. An understanding of how, when, and why each participant collaborates will be formed. Chapter 6 will give conclusions to the interviewing results and provide potential future work to further explore this research. The appendix includes the evolution of the interview questions to understand their development and transcripts from each participant’s interview.
CHAPTER 2: CASE STUDY RESEARCH THROUGH INTERVIEWING

Interviewing is used for this research as a method of case study data collection. Information on the interviewing method, its benefits, the construction of an interview, and interviewing triangulation is provided to establish confidence in this data collection method.

2.1 Case Studies in Engineering Research

Case studies have been employed by researchers to answer questions about engineering design. Specifically, case studies are useful in that they provide a systematic method for conducting research. This process adds credibility to the research and helps ensure the results are valid and accepted [29–32]. Characteristics of case studies that design researchers find useful are that variables and influences are interconnected, engineers need a process from which to justify decisions, and sample sizes are statistically invalid [29,31,32]. This allows for results to be generated from smaller populations that do not require as many time, financial, or mathematical resources as a statistically valid study would. Case studies also allow for “How” and “Why” questions to be answered [29]. Interviewing is a specific research tool to support case study research that is generally accepted to achieve qualitative results, but can also provide quantitative results [31,33]. This will be further discussed in the following section.

Takeaways:

- Case studies provide a systematic method to add credibility and ensure results validation.
2.2 Interviewing as a Data Collection Method

The use of interviews to collect data from participants has been growing in research to understand social and cultural occurrences within a given workplace [31,34]. Interviews allow for the researcher to directly interact with their participant in-person, by phone, or through the Internet to ask specific and targeted questions regarding the topic that is being researched; thus is it imperative that the research be focused enough to create appropriate interviews [31–35]. A benefit from this technique is that it allows for the researcher to ask leading questions which then lead to more penetrating questions. These help the researcher to retrieve the information they need directly from those involved in a project. In-person interviews also allow for richer data to be collected through nonvisual or nonverbal cues, which can affect the intent of a statement [31,34,36,37]. These include one rolling their eyes, hand gestures, or the use of sarcasm, which is difficult to interpret in a transcript. In other research techniques that review past history of a project, researchers are limited by the information the original participants recorded instead of the live interaction of an interview.

Although interviewing is primarily observed as a qualitative method of data collection, it can also be used for quantitative data [31,35,38]. For example, the number of times a participant states a specific phrase or the number of times a group of people repeat the same phrase can be used to determine patterns across a specific population. Moreover, this can be repeated across various unique groups to determine similarities and differences. This is further discussed in the triangulation of interviewing.
Interviews can be subdivided into three categories: question seeking interviews, question answering interviews, and verification interviews [33]. Initially, this research began as a question seeking interview type where the purpose of the research was exploratory and to develop a general understanding of industry collaboration. As this research progressed, verification interviews became the method of data collection because interviews were conducted with multiple personnel at the same company and also at different companies to verify and potentially triangulate responses. Additionally, interviewing is conducted until nothing new is learned, thus reaching a “knowledge asymptote” [33].

The interviewing process (Table 2.1) requires the researcher to understand the problem they are studying before they create their interview. This will then be followed by a selection of interviewees. Careful consideration must be given to those that are to be interviewed as resources could be wasted on potentially useless interviews. The interviewees must then be contacted with basic information on the research purpose. Once the participant gives their approval, the interview can be conducted. A summary must be created immediately after an interview to ensure interview notes are the most accurate since the interview is most fresh in the mind of the interviewer. The interview itself needs to be transcribed to have a complete documentation of the interview. The interviewee must be contacted with a thank you note for their participation in the research and a copy of both the interview summary and completed transcript. Lastly, an analysis can be performed on the interview transcription to provide the relevant results for the research question(s) [31,33,34].
Further details on the planning process, interview question structure, and triangulation are provided in the following sections.

**Takeaways:**

- Interviews are used for both qualitative and quantitative data collection.
- Interviewing allows for direct, penetrating questions to collect information specifically related to the research.

### 2.3 Interview Planning

Research interviews are highly dependent on the type of research that is being conducted. Exploratory research may need the interviewee to be at the highest comfort level possible while targeted research may require that an interviewee be stressed, anxious, or tired [33]. This research is considered exploratory and the participants should be relaxed and unstressed to give unbiased responses, thus data collection will be discussed from this perspective.
Exploratory research should occur on a mutually agreed upon location, date, and time for both the interviewer and interviewee. This will help ensure that the data collected is of the highest quality by creating a minimal disruption to the interviewee’s day. The time an interview is conducted should be carefully considered, as some people’s responses could be affected by the time of day they participate due to people still “waking up” in the morning or those that may be eager to leave an interview if it is late in the business day [33].

An interview location is an important selection that must be appropriately determined, as this affects the comfort level of the interviewee and can set the tone of the interview from one of a conversation to that of an interrogation [33]. For the interviewer, it is beneficial to have a quiet and private location to conduct the interview. This will ensure that the interviewer can record the interview (if permitted) and that there will be minimal distractions from colleagues that may be interested in the research or in business related questions [31]. Additionally, the question structure must be appropriately defined as to better collect the information needed to answer the research questions. This will be explained in the next section.

**Takeaway:**

- *Interview planning is detailed: location, timing, and the interviewee can each have an adverse effect on the research.*
2.4 Interview Question Structure

A fully developed interview must provide questions that require the interviewee to think about their response; otherwise, survey questions are being asked if simple yes/no answers can be given. For this research, questions were formatted into four topics and presented in a semi-structured manner. This helps to provide more of a conversation instead of a talk that can become rigid or out-of-order from an interviewee’s perspective. A semi-structured interview was used due to the difficulty in predicting an interview as the interviewer will not always know what the interviewee is planning to say [31,33].

For a semi-structured interview, topics provide an alternative to help ensure an interview maintains its relevancy such that it does not become a chat. Through this process, the interviewer can listen to the responses being given and then provide relevant follow-up questions. This also provides the needed questions to produce triangulation for an interview while also keeping a constant flow to the interview. The conversation can potentially tangent into an unexpected direction, but these can be beneficial to the interviewer since further information can be pulled from these tangents. It should also be recognized that these interview tangents need to be controlled for timing considerations, with respect to the interviewee.

2.4.1 Triangulation

Triangulation is the process from which a research related issue or study is observed at least twice to determine if there is a level of consistency between sources [31,35,39,40]. In interviewing, this is typically used to add credibility to a statement
provided from a participant by ensuring they are providing as complete an answer as possible. For instance, Figure 2.1 shows a series of questions that can be used to produce triangulation of responses. These questions are provided for illustrative purposes and were not used for the research.

1. What resources were used to complete the project?

2. What software do you use while working?

3. How often do you email your colleagues?

**Figure 2.1: Example of triangulation questions during an interview.**

The basis of the first question is to understand what resources a designer may use throughout their project. Resources can refer to people, software, or hardware, but when the question is asked in this manner, it allows the participant to think in depth of the resources they used and provide an initial, unbiased response. A follow-up question to this can focus on the software used, including CAD modeling, word processing, or email clients. A final question that can be asked on this topic is specifically on the frequency that one emails their colleagues. This triangulates with the first two questions as emails
are sent with some software client while also providing the basis of more questions regarding communication frequency and type.

Further, triangulation can be divided into four categories: methods, sources, analytical, and theory/perspective triangulation [35,39,40]. Each of these are effective based upon the project’s research and budgetary scope and add a source of credibility to interviewing research. This research, in part, uses the sources triangulation method, which is to examine the consistency of data sources within the same method [40]. The method of collecting data through interviewing will remain constant, but the interviewee data sources with their different backgrounds and companies of employment will be used for triangulation. This will help to further the understanding of how engineers and designers collaborate in industry across a more broad population instead of focusing solely on manufacturing.

*Takeaways:*

- *Interviews should be structured based on the research goal.*
- *Triangulation is used to find repetition in responses for credibility and/or statistical analysis.*
CHAPTER 3: INTERVIEW DESIGN

Three companies and ten interviewees volunteered to participate in this study. To provide a diverse group of participants, each company is of varying size and develops or manufactures different products. Moreover, the participants are of varying levels of experience and educational backgrounds to provide a larger basis from which to triangulate their responses. Specific details of each company and interviewee are provided in this chapter.

3.1 Company Profiles

Three companies were contacted to participate in this research. Additional companies would have been sought if not for limited new findings. Dissimilarities in company function and sizes were intentional to better understand the differences and similarities between each. General company information is shown in Table 3.1. An industrial company’s size is defined based upon their number of employees as small (<50), medium (50-499), and large (>499) [41,42]. Although medium sized companies were not intentionally omitted from participating in this study, the interviewed companies were selected primarily based on preexisting contacts. Additionally, the company’s age is listed and when paired with the company’s size, it will help demonstrate correlations with how well structured a company’s processes are, if they have established one.
Table 3.1: Basic information of each company interviewed.

<table>
<thead>
<tr>
<th>Company</th>
<th>Function</th>
<th>Size [41,42]</th>
<th>Company Age (Yrs.)</th>
<th>Primary Product Customers</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Manufacturing</td>
<td>Large</td>
<td>140</td>
<td>Corporate Utilities</td>
</tr>
<tr>
<td>B</td>
<td>Product Development</td>
<td>Large</td>
<td>30</td>
<td>Consumer</td>
</tr>
<tr>
<td>C</td>
<td>Research &amp; Development</td>
<td>Small</td>
<td>10</td>
<td>Government</td>
</tr>
</tbody>
</table>

To ensure participant confidentiality, the companies’ information is abstracted to provide a basis of comparison of each company to triangulate responses. Company A manufactures specialty products for other, large corporations. These products are not for the everyday consumer, thus they cater to specific corporate customers. Company B’s primary function is in product development. Their products are designed for the public and can be purchased in local stores. Lastly, Company C performs research and development for government products. This research is primarily in the form of generating code to optimize and verify a design with specified requirements. Thus, this is the product that the company creates for their government customers. The various functions and customers for each company provide additional information to potentially triangulate across a broader range of engineers and designers that are employed by industry.

**Takeaway:**

- Three companies of different functions, product design, and sizes were contacted to conduct interviews.
3.2 Interviewee Profiles

Interviews were conducted with ten engineers and industrial designers (interview participants) of varying years of experience, education backgrounds, and corporate hierarchical levels. These participants were specifically selected because of their differences due to this providing a basis from which their responses can be triangulated either with their peers, within the same company, or at other companies that perform different functions. Naturally, the background and experience of a participant affects their opinions, thus this information is also included. Each participant is listed in Table 3.2.

Table 3.2: Interview participants, experience, and highest education completed.

<table>
<thead>
<tr>
<th>Participant Identifier</th>
<th>“Name”</th>
<th>Total Experience (Yrs.)</th>
<th>Position</th>
<th>Highest Education Completed</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.ME.1</td>
<td>Alex</td>
<td>6</td>
<td>Manufacturing Eng. Manager</td>
<td>BSME</td>
</tr>
<tr>
<td>A.ME.2</td>
<td>Brad</td>
<td>16</td>
<td>Lead Manufacturing Engineer</td>
<td>MSME</td>
</tr>
<tr>
<td>A.ME.3</td>
<td>Chris</td>
<td>14</td>
<td>Manufacturing Engineer II</td>
<td>MSME</td>
</tr>
<tr>
<td>A.ME.4</td>
<td>David</td>
<td>15</td>
<td>Manufacturing Engineer Manager</td>
<td>BSME</td>
</tr>
<tr>
<td>A.IE.1</td>
<td>Erin</td>
<td>5</td>
<td>Manufacturing Engineer I</td>
<td>BSIE</td>
</tr>
<tr>
<td>B.ME.1</td>
<td>Frank</td>
<td>6</td>
<td>Engineering Manager</td>
<td>BSME</td>
</tr>
<tr>
<td>B.ME.2</td>
<td>Grace</td>
<td>3</td>
<td>Project Engineer</td>
<td>BSME</td>
</tr>
<tr>
<td>B.EE.1</td>
<td>Hank</td>
<td>33</td>
<td>VP of Engineering</td>
<td>BSEE</td>
</tr>
<tr>
<td>B.ID.1</td>
<td>Isaac</td>
<td>35</td>
<td>Industrial Designer</td>
<td>BSID</td>
</tr>
<tr>
<td>C.ME.1</td>
<td>Jordan</td>
<td>2</td>
<td>Computational Analyst</td>
<td>MSME</td>
</tr>
</tbody>
</table>

The participant identifier is formatted such that the first letter represents the company they work for, the next two letters represent the major for their highest completed
education degree, and the final number is sequential based upon their interview relative to their peer(s) within the same company and education. The name listed in the table is not their legal name but a pseudonym for easier comprehension for the reader of this text. Each pseudonym was generated in alphabetical order, based on the order of the participant identifier, and associates a gender with the participant. The use of a pseudonym will allow for summaries and discussions to be read easier and possibly provide empathy toward the results. The years of experience and level of education are also provided to showcase the variety of participants considered in this research’s findings.

With respect to the interviewee’s position at their place of work, for Company A, Manufacturing Engineer I (Erin) is the entry-level engineering position with the subsequent promotion being a Manufacturing Engineer II (Chris). Manufacturing Engineering Managers (Alex and David) supervise all manufacturing engineers (Brad) and the Lead Manufacturing Engineer. This is shown in Figure 3.1. Note that Alex and David work in different departments, so a dashed line represents this.
At Company B, the VP of Engineering (Hank) oversees the Engineering Manager (Frank) who oversees the Project Engineer (Grace). The Industrial Designer (Isaac) is separate from this structure. Lastly, Company C’s Computational Analyst is an “entry-level” position for Jordan, although they do not focus as much on titles. This will be explained in further sections. The findings from interviewing these engineering levels should provide information on knowledge flow from upper-level management to entry-level engineers. The corporate affiliations for Company B are shown in Figure 3.2. The connection between Isaac and Hank is represented with a dashed line because they work in separate departments, but Isaac’s projects are typically reported to Hank and distributed to his subordinates.
All interviews with participants from Company A and B were performed in-person and their choice of locale. These were either in meeting rooms that the participant would reserve or would be in their personal work office space, if they were assigned one. All interviews with these participants were held on weekdays, typically around lunchtime. Company C’s interview was conducted on a workday evening and over the phone.

**Takeaways:**

- Ten interviewees, ranging from entry-level to company vice-presidents,
participated in the research.

- Interviewee expertise, background, and experience levels were varied.

### 3.3 Interview Questions, Topics, and Triangulation

The final interview questions and topics were generated to provide a semi-structured approach to the interview. Each question and their associated topic are in Table 3.3. The evolution of the interview questions is explained in Appendix A to understand the development process. It is important to recognize that the questions evolved before the first interview and slight moderations were made throughout. Note that specific questions regarding major milestones were not asked as these interviews were used for information gathering instead of attempting to prove a preexisting understanding of collaboration in industry.

<table>
<thead>
<tr>
<th>Topic</th>
<th>#</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>1</td>
<td>What is your position title and description? How many years have you been in this position?</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Briefly describe your previous design experience with the company? Describe your education background.</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Describe the most recent project you have completed.</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Describe a challenging project that you best remember from your past experiences with the company.</td>
</tr>
<tr>
<td>Project Description</td>
<td>5</td>
<td>What type of projects have you worked on? Tooling design, fixture design, etc.</td>
</tr>
<tr>
<td></td>
<td>5a</td>
<td>How would you classify your most recent project and your challenging project?</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>How many design projects per year are you assigned?</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>What resources did you use throughout your project? (Technical, electronic, software, people, etc.)</td>
</tr>
<tr>
<td>Topic</td>
<td>#</td>
<td>Question</td>
</tr>
<tr>
<td>-------</td>
<td>---</td>
<td>----------</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>Did you follow a structured procedure?</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>What software was used?</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>Who all assisted with the project? (Including engineers, machinists, operators, outside sales, managers, etc.) What type of feedback did you receive from these resources?</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>How many of these projects were team based? (Number of co-workers directly assigned to the project)</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>How would you describe the size of the project you worked on? Why did you describe it as that size? How many man-hours were required to complete the project?</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>Describe the complexity of the project (simple, complex)? Why? How?</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>How challenging would you say this project was? Why? What was or was not challenging?</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>Project Challenge: Could a co-op, intern, or entry-level engineer complete the project on their own? Why or why not?</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>What tools did you use with your resources to communicate your design concepts or ideas?</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>How were you introduced to the projects (Email, formal documentation, verbal, etc.)? Is this common? Why do you think you were introduced in this manner?</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>How was the project defined in the method of introduction?</td>
</tr>
<tr>
<td>Design Meetings</td>
<td>19</td>
<td>How many meetings do you typically have for a project? What were the purposes of these meetings?</td>
</tr>
<tr>
<td>Design Meetings</td>
<td>20</td>
<td>What type of meetings were performed and with whom? (Formal meeting with management, informal meeting with shop personnel, design discussion with engineering colleagues, discussion with operators)</td>
</tr>
<tr>
<td>Design Meetings</td>
<td>20a</td>
<td>Do you have design development meetings?</td>
</tr>
<tr>
<td>Design Process</td>
<td>21</td>
<td>If a structured procedure was followed, did you follow a structured procedure provided by the company or your personal experience?</td>
</tr>
<tr>
<td>Design Process</td>
<td>22</td>
<td>If yes, describe your design procedure. What was this based on? Experience, textbook, a class, etc.</td>
</tr>
<tr>
<td>Design Process</td>
<td>22a</td>
<td>How much time do you tend to spend in each phase of the design process?</td>
</tr>
<tr>
<td>Design Process</td>
<td>22b</td>
<td>What differences in meeting type and duration in various phases of the design process?</td>
</tr>
</tbody>
</table>
Interviews begin with an introduction of the interviewer to help relax any reservations of the interviewee and also to assist in providing value to them the purpose of the research, in person. Specifically, the interviewer then states they are from Clemson University and the research is on design collaboration in industry with respect to how, when, and why collaboration occurs. Also, the potential value of this research to the participant would be described, such as possible new resources being generated for assistance in helping the designer perform their work more efficiently. This technique was used to aid in gaining the most information from the interviewee as possible.

Question 1 asks for the interviewee’s position within the company to determine their standing within the company. The description of their position was also asked to better understand their daily responsibilities. This will help provide the required information to triangulate between different corporate levels within the company or companies. The interviewee’s previous design experience was also asked to gather information on their background, whether it was primarily from school or from their experience at work. Further, information on their education was requested to have a record of this.

Questions 3 and 4 focus on a recent project and a challenging project, respectively. These provide the interviewer and interviewee with specific projects to discuss while the subsequent questions are asked. This gives the interviewee something specific to discuss,
based on their actual experiences instead of providing hypothetical responses. The interviewer also gains value because they can reference specific projects to better organize the interview.

Question 5 begins the “project description” topic and narrows down what type of projects the interviewee has worked on to help determine differences in what way the project is completed. This then leads into question 5A where the two projects asked previously are briefly discussed. The number of design projects is asked in question 6 to gather an understanding of the amount of work the interviewee does. This helps provide their need for resources throughout projects, which is asked in question 7. Questions 9, 10, and 11 triangulate with question 7 by directly asking for the people and software that were used in a given project. These questions also help researchers understand where, how, and with whom communication was achieved throughout a project. To determine when communication takes place within a project, question 8 asked about a structured procedure.

Questions 12 and 13 focus on the project size and complexity, respectively. Further, questions 14 and 15 focus on the challenge of a project. These questions provide knowledge of the different types of projects and allow for comparisons to be made between each. Specifically, comparing the size and complexity of a project to determine if there are patterns with the associated amount of resources, time, or processes to complete a project.
Question 16 requests further information on the interviewee’s process in designing for a project. This question focuses on the tools used to determine how a tool is used, when, and for what purpose. The introduction of a project was asked in questions 17 and 18, as some projects could be introduced with tools, or from other sources. This also allows for a better understanding of how designers understand the problem they are given and what they do to better understand their problem.

Question 19 asks about what design meetings the interviewee participates in. Specifically, design reviews were not of primary focus to eliminate the interviewee from fixating on design reviews when other, informal meetings can be used for collaboration. Questions 20 and 20A are follow-ups to determine what formal (scheduled) and informal (unscheduled) meetings are held, with whom, where, when in the process, and what the purpose of these are.

Questions 21 through 24 focus on the process undertaken by the interviewee in a project. The topic begins with asking if a process is used and where they got the process. This helps with the understanding of how much their experience level or company affected their design process. Question 22, 22a, and 22b are strictly for explaining the process from which a project was completed. Previous questions are enhanced by gathering information on when certain topics, tools, or personnel were of importance in each process phase. Question 23 is only asked if the response to question 21 is a “no.”

The purpose of the three interviewing topics was to help understand how aspects such as the challenge, resources allocated, or size of a project affected its role in
communication amongst other designers. The design meetings and process are of particular interest since this is where specific details of collaboration are discussed in terms of when, why, and how. Using the design process as a catalyst to discuss collaboration and communication was determined to be particularly useful to systematically review previous projects and how projects theoretically should proceed.

Questions were asked in no pre-determined order (with the exception of questions marked with an associated letter next to the question number, e.g., 22a) to ensure the interview became a conversation instead of an interrogation.

A triangulation matrix was created to visually demonstrate how the questions are related to each other and used to better understand the responses of each interviewee. The matrix is formatted such that on the first column and row, numbers are inserted to represent the question number, which corresponds to what is shown in Table 3.3. Questions do not triangulate with themselves, thus the diagonal is filled with “--”. Each instance of triangulation is indicated with an “X”. The matrix is shown in Table 3.4.
Table 3.4: Interview triangulation matrix.
Four questions triangulate with one other question, while all other questions provide at least two instances of triangulation. Additionally, topics were highlighted in the triangulation region. This provides a visual representation of how questions across topics triangulate. For instance, the introductory questions triangulate heavily with the project description questions, but these do not provide direct triangulation with the project process or meeting questions. This helps provide more robust questions that not only triangulate within topic, but also between other topics. Also, this shows the questions are related to each other, which can help ensure the interview remains on topic.

Takeaways:

- 27 questions were developed and separated into four topics for interviews.
- A matrix visually shows each question and topic’s triangulation.
CHAPTER 4: INTERVIEW SUMMARIES

Each interview is summarized to provide a concise review of the interviewee’s response and to understand their unique perspective. Each interviewee is divided into a separate section for clarity and ease of reading. A table is provided at the end of each summary to provide background information for the interview. The relation column is included to show the connection between the interviewer and interviewees. Complete interview transcripts are included in Appendix B for full disclosure of the raw results.

4.1 A.ME.1 – Alex

On April 10\textsuperscript{th}, 2015, Alex was interviewed in his office for his perspectives on design and collaboration in industry. He is a Manufacturing Engineer Manager and has held that position for about six months. Before this position, he worked with Company A for five years, honing his skills in manufacturing. From Alex’s perspective as a manager, he sees things differently than his subordinates do as he sees each engineer working to complete a subproject, which then feeds to an overarching project that provides collaboration in industry. He states that his design process is that of understanding the problem, sketching concepts, developing these through CAD programs, and also reviewing these with operators and machinists. Concepts are then presented in a design review where the presenter will explain his or her idea, how it will be implemented, and then used by personnel in terms of maintenance, ergonomics, and efficiency. If the design was approved after this review, the designer can then purchase materials and begin the implementation process of the design. If the design was not approved, an additional review would be held.
Table 4.1: Interview summary for Alex.

<table>
<thead>
<tr>
<th>Date</th>
<th>Duration (HH:MM)</th>
<th>Location</th>
<th>Time of Day</th>
<th>Relation</th>
</tr>
</thead>
<tbody>
<tr>
<td>04/10/2015</td>
<td>01:00</td>
<td>Alex’s Office</td>
<td>1:30pm</td>
<td>Former Co-Worker</td>
</tr>
</tbody>
</table>

**Major Takeaway**
Management position provides an administrative perspective relative to other engineers at Company A.

### 4.2 A.ME.2 – Brad

This interview of Brad, a Lead Manufacturing Engineer with Company A, was performed on April 17th, 2015 in his office. He primarily developed his insight into engineering design through his experience in industry with the foundation having been set with the courses he took in college. He worked at multiple companies working on design projects using CAD, data collection, fixture design, etc. Brad believes that the use of a checklist to help guide the designer through the design process would be beneficial. This would outline the needs of the project including safety, materials, and dates of completion. A potential recommendation for Brad is the combination of the requirements checklist tool and a project definition specification (PDS) worksheet could be useful to include these. Moreover, Brad suggested that a tool should focus as a guide but not be restrictive. This can decrease innovation in the design as well as place too much of an emphasis on the process for the designer instead of the product.

Brad’s design process tends to be similar to that of the Pahl and Beitz design process. The difference is the addition of informal and formal design reviews with various resources including engineers, machinists, operators, and technicians. Although informal design reviews were performed at regular intervals throughout the process, formal design
reviews would be used to notify management of general progress with estimated time for completion, man-hours required, and to address budget concerns. Lastly, groups composed of multiple engineers with similar backgrounds were not assigned to the same aspect of a product development project. These were typically reserved for process design projects, as these required more engineers and a more holistic review of the problem.

Table 4.2: Interview summary for Brad.

<table>
<thead>
<tr>
<th>Date</th>
<th>Duration (HH:MM)</th>
<th>Location</th>
<th>Time of Day</th>
<th>Relation</th>
</tr>
</thead>
<tbody>
<tr>
<td>04/17/2015</td>
<td>00:51</td>
<td>Brad’s Office</td>
<td>11:00am</td>
<td>Former Manager</td>
</tr>
<tr>
<td>Major Takeaway</td>
<td>Brad’s experience at Company A has not included the use of many tools but he identifies where interviewer suggested tools can be useful.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.3 A.ME.3 – Chris

Chris is a Manufacturing Engineer II with Company A and was interviewed on April 10\textsuperscript{th}, 2015 in the manufacturing department’s meeting room. He has both a bachelor’s and a master’s degree in mechanical engineering and has worked with Company A for almost seven years. He initially started in the research and development group but transferred to manufacturing engineering, so his observations span across both domains. He does not use a formal design process provided by the company but his own style of process where he tries to best understand the problem, then develop a concept with some light sketching, and further the design in a CAD (computer aided design) program. Once his design is complete in CAD, he will informally review it with shop personnel to receive their perspective on the design and to determine where any improvements can be made.
Once he has completed his initial design, he will have a design review with additional engineers and designers, primarily within his group of mechanical engineers. Design reviews provide him with feedback, and sometimes approval, needed to continue with the design. Since he says there is not a specific design process provided by Company A, he does not need the signatures for a typical manufacturing project, but still provides updates to the project with his direct manager, David. Chris also states that he works as the primary on his projects, unless an engineer with another specialty is assigned alongside him for the project. Otherwise, he is the only mechanical engineer assigned to his projects to prevent overlap. Chris also prefers to prototype novel concepts that he has not designed or experienced before. Prototyping usually consists of 3D printing the parts and assembling them instead of using the final design’s materials as this is more affordable and is faster. His prototypes are for understanding how a design works and feels, which is also why he finds benefits in prototyping through 3D printing.

Table 4.3: Interview summary for Chris.

<table>
<thead>
<tr>
<th>Date</th>
<th>Duration (HH:MM)</th>
<th>Location</th>
<th>Time of Day</th>
<th>Relation</th>
</tr>
</thead>
<tbody>
<tr>
<td>04/10/2015</td>
<td>01:07</td>
<td>Meeting Room</td>
<td>11:00am</td>
<td>Former Co-Worker</td>
</tr>
</tbody>
</table>

**Major Takeaway**

Although he was introduced to a design process while in school, he has modified it to work best for him while searching for feedback from others.

### 4.4 A.ME.4 – David

David’s is currently a Manufacturing Engineering Manager at Company A and earned his bachelor of science in mechanical engineering. He has held the Manufacturing Engineering Manager position for almost six years and has a total of fifteen years
experience with the company. He was interviewed on May 29th, 2015 in his office. David is the same corporate level as Alex and has many of the same perspectives as him such as the group collaborating more at an overarching project level instead of at the subproject level, where each manufacturing or test engineer is assigned.

Instead of him creating his own design process, he says the company has provided a process for them to follow which is to define the problem as received from marketing and/or research and development, determine the feasibility of that problem, design, validate, and sustain. Although David is involved at all of these stages, his manufacturing engineers begin their involvement at the third stage titled design. David continues ownership of the project through validation and sustainability. Additionally, David stated that project definition absorbs about five percent of a total project’s time, feasibility is fifteen percent, design is fifty percent, validation is thirty percent, and sustainability is carried on throughout the life of the designed product. David’s example of Company A’s design process can be seen in Figure 4.1.
David typically works on administrative items for a project, such as the problem definition and feasibility of a design, before handing it off to manufacturing engineers to complete. He converses directly with the research and development (R&D) and marketing departments, while the manufacturing engineers do not typically need to converse with them as much due to the different nature of the problem.

**Table 4.4: Interview summary for David.**

<table>
<thead>
<tr>
<th>Date</th>
<th>Duration (HH:MM)</th>
<th>Location</th>
<th>Time of Day</th>
<th>Relation</th>
</tr>
</thead>
<tbody>
<tr>
<td>05/29/2015</td>
<td>01:12</td>
<td>David’s Office</td>
<td>11:00am</td>
<td>Current manager of Alex, Brad, &amp; Chris</td>
</tr>
<tr>
<td><strong>Major Takeaway</strong></td>
<td>As an engineering manager, David uses the company’s design process and converses directly with onsite R&amp;D, but does not always filter to his employees.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4.5 A.IE.1 – Erin

Erin is an industrial engineer with Company A. Her interview was conducted on June 29th, 2015 in a large meeting room used for factory continuous improvement meetings that she was heavily involved in. The bulk of her projects were based upon process improvements for the factory. These would include improving manufacturing line organization, updating work instructions, and improving efficiency of bulk material transportation. Unlike the mechanical engineers at Company A (with the exception of David), Erin has a written process she follows when working on projects. Her process is as follows: planning, kickoff, product review matrix, product cycle time review, product labor and production review, likes/dislikes analysis, change and analyze, inspire, advanced cell analysis, discussion, feasibility analysis, proposal, survey, and implementation. She also includes a list of tools used for this process including a likes/dislikes sheet, brainstorming, and visual equipment and machine costing display.

When Erin applies this process, she is normally in a group between five and ten people, which consists of operators, engineers, technicians, and management. She believes that having a project consist of more people of various backgrounds is to generate the best final product possible while also giving a sense of ownership to each group by giving them a voice. These projects tend to take several months to complete and are generally monitored by upper-level management because of its broad impact across entire manufacturing lines instead of a single station.
Table 4.5: Interview summary for Erin.

<table>
<thead>
<tr>
<th>Date</th>
<th>Duration (HH:MM)</th>
<th>Location</th>
<th>Time of Day</th>
<th>Relation</th>
</tr>
</thead>
<tbody>
<tr>
<td>06/29/2015</td>
<td>00:48</td>
<td>Meeting Room</td>
<td>1:00pm</td>
<td>Former Co-worker</td>
</tr>
</tbody>
</table>

**Major Takeaway**
As an industrial engineer, Erin’s projects are mainly process based, which include her to work with more employees of varying expertise.

4.6 B.ME.1 – Frank

Frank earned his bachelors in mechanical engineering and has been employed by Company B as an Engineering Manager for three years. He was interviewed on October 14\textsuperscript{th}, 2015 in a meeting room on the company’s premises of his choosing. His responsibilities include managing project engineers and ensuring their projects are completing on time. This process begins by receiving projects from product development (or marketing) and then determining whom in his group will be responsible for completing the project. These projects are typically introduced via in-person discussion instead of emails or specific problem statement formats. This encourages more of a conversation instead where questions can be asked of the project instead of simply receiving a document without any other interaction.

At this stage, the assigned engineer on a project will be the sole assignee to that project. It is their responsibility as the designer to determine whom they will need for assistance on a project and to contact those people, as needed. Otherwise, the responsibility on completing a project is entirely on the one engineer/designer. Informal/unscheduled meetings are held on an as needed basis from the engineer assigned to the project with Frank. These are typically to discuss and better understand the
problem, to discuss concepts that are developed, and to gain a more focused idea of the direction of the project.

Company B’s design process consists of stage gates, which are ordered as follows: 1) product development (marketing) request, 2) concept freeze, 3) engineering CAD, and 4) engineering build. At each of these stages, a formal meeting is scheduled to discuss the project updates and to approve or iterate the existing design for the next stage of design. At each meeting, various personnel attend including industrial designers, quality personnel, and engineers from other groups including mechanical, electrical, and computer.

<table>
<thead>
<tr>
<th>Date</th>
<th>Duration (HH:MM)</th>
<th>Location</th>
<th>Time of Day</th>
<th>Relation</th>
</tr>
</thead>
<tbody>
<tr>
<td>10/14/2015</td>
<td>00:38</td>
<td>Meeting Room</td>
<td>4:30pm</td>
<td>Existing contact through research group</td>
</tr>
</tbody>
</table>

**Table 4.6: Interview summary for Frank.**

**Major Takeaway:** Frank manages several employees and assigns projects to each of his employees but does not assign multiple employees to each project.

### 4.7 B.ME.2 – Grace

Grace has been working with Company B for the last year as a project engineer and has three years of engineering experience total. She was interviewed on November 18th, 2015 in one of Company B’s meeting rooms. Since Grace is a project engineer, she is a subordinate of Frank and explained the company’s design process in the same manner as Frank, including the various stage gates. She states that even though she is relatively inexperienced compared to her peers, she is not directly assigned to projects with other
engineers or designers. It is her responsibility to meet with those that she needs that specialize in areas outside of her expertise.

She also discussed an idea generation (IG) program that the company runs which is established to generate concepts to problems that the company’s employees may see. These ideas can come from problems experienced using specific products or issues they would like to see resolved as a potential customer. There is no tool for them to generate new ideas, but each IG program participant can review another’s submission, which can include both text and figures. In a way, this is a form of brainwriting or C-sketch where text or figures are used to convey ideas and participants can then generate new concepts from these [43,44]. This appears to be a digital form of collaboration but without a set list of rules to encourage designs.

Table 4.7: Interview summary for Grace.

<table>
<thead>
<tr>
<th>Date</th>
<th>Duration (HH:MM)</th>
<th>Location</th>
<th>Time of Day</th>
<th>Relation</th>
</tr>
</thead>
<tbody>
<tr>
<td>11/18/2015</td>
<td>00:45</td>
<td>Meeting Room</td>
<td>5:00pm</td>
<td>Frank’s Subordinate</td>
</tr>
</tbody>
</table>

**Major Takeaway**

Grace has relatively low experience to her peers but is assigned projects individually. She also discussed their required idea generation tool.

4.8 B.EE.1 – Hank

Hank is the Senior Vice President of Engineering for Company B and was interviewed on March 2\textsuperscript{nd}, 2016. He earned his bachelors in electrical engineering and has been working in industry for the past 33 years. He has been a vice president at Company B for the previous six years. His interview was beneficial in providing
engineering details from an administrative level. In addition to Frank and Grace’s descriptions of Company B’s design process, he stated there are specific forms for understanding the problem, briefly communicating information, and providing authorization to continue onto the next gate. The company uses these documents to guide designers through the process and to provide a record that can be traced if problems arise.

Beginning with the initial product development stage, Hank states that vice presidents are typically the major party involved here. Projects are received from product development or from a separate concept-engineering group that will then be filtered through the vice presidents to the project engineers and industrial engineers to begin work. Meetings at this stage are typically informal to allow for those assigned to the project to meet with others, as needed, to best understand the problem at hand.

The second stage of the design process is concept freezing, which takes approximately four weeks to complete. This is typically initiated and maintains a formal, biweekly meeting including project engineers, industrial designers, and quality personnel. These meetings tend to include more than just the project engineer and industrial designer assigned to the project as this allows for additional communication amongst interested parties to correct any potential problems before they start any engineering build. Industrial designers typically complete their work at this stage of the design process.

The next stage is for engineering CAD, which also takes about four weeks, where tooling is designed and constructed. This primarily involves formal meetings with project engineers where they electronically communicate with other groups, typically out of
country, to perform detail design. The engineers at the facility where Hank works then become the users of the product and return their feedback to the international engineers.

The final stage is reserved for engineering builds where operators will become involved in the process to build prototypes. This duration of this stage is between four and twelve weeks, depending on the project and how well the build satisfies requirements. Project engineers will use information from these prototype builds to better understand how to manufacture a product and how users in the field react to the new design. Quality become further involved by running lab and field tests. Once the products completes pilot, assembly, contractor, and packaging testing, a formal meeting will be held at the conclusion of the fourth gate where a “release to ship” form must be signed by the project engineer involved, product manager, safety/risk personnel, regulatory department, and quality. This is the most extensive signing off on a product.

Table 4.8: Interview summary for Hank.

<table>
<thead>
<tr>
<th>Date</th>
<th>Duration (HH:MM)</th>
<th>Location</th>
<th>Time of Day</th>
<th>Relation</th>
</tr>
</thead>
<tbody>
<tr>
<td>03/02/2016</td>
<td>00:53</td>
<td>Meeting Room</td>
<td>2:00pm</td>
<td>Frank and Grace’s Manager</td>
</tr>
</tbody>
</table>

**Major Takeaway**

Hank’s perspective as a vice president thoroughly explained the design process for Company B while explaining what is generally expected at each stage gate.

4.9 B.ID.1 – Isaac

This interview of Isaac with Company B was performed on November 4\textsuperscript{th}, 2015 in one of Company B’s meeting rooms. He developed his insight into engineering design through some training courses and his experience in engineering and design. The process
his designers follow is one that he has modified from general design processes. The overall steps are as follows: Problem definition, Concept development, Prototyping, Refinement, and Conclusion. Problem definition absorbs approximately 30% of the total time required to complete a project. This includes receiving information from marketing such as desired product specifications, constraints, and criteria. One designer is typically assigned as the primary owner of the project. They may request secondary assistance from others, but responsibility of the final outcome is solely for the primary. The Concept development phase (40% project duration) is used to ideate and verify early-stage proof-of-concept, without moving into prototyping, which is the ensuing phase. Prototyping allows for the designers to develop their concepts and verify if they will be feasible or not. The results of prototyping are presented in a design meeting where those in attendance (generally those from marketing, senior officials, industrial designers, and product engineers) either approve or disapprove of the design. If the attendees disapprove, the product moves into the Refinement phase until approval is granted or the product is determined to be unfeasible. Lastly, a conclusion report is generated and presented to marketing, where they can shelf the idea or push it to industrial designers and/or product engineers.

Meetings are generally not scheduled with the exception of a few formal meetings where external attendees are required for approval and verification of the direction on the project. Informal meetings are sometimes used to generate concepts with the use of a dry-erase board, but without using specific design tools/techniques. Other informal meetings are used for verification of project direction and concepts.
Table 4.9: Interview summary for Isaac.

<table>
<thead>
<tr>
<th>Date</th>
<th>Duration (HH:MM)</th>
<th>Location</th>
<th>Time of Day</th>
<th>Relation</th>
</tr>
</thead>
<tbody>
<tr>
<td>11/04/2015</td>
<td>00:48</td>
<td>Meeting Room</td>
<td>2:00pm</td>
<td>Existing contact through research group</td>
</tr>
</tbody>
</table>

**Major Takeaway**

Isaac is an industrial designer and provides a unique perspective compared to the engineers but still does not use specific tools during design projects.

4.10 C.ME.1 – Jordan

Jordan from Company C was interviewed over the phone on March 10th, 2016. He has a master’s degree in mechanical engineering and has worked in industry for a total of two years. His primary responsibility is to develop a topology optimization code within a given design space. About 95% of his work is behind a desk with minimal contact with others, besides email. He also stated that he has to track the number of hours he works on a project so they can be billed to the appropriate company, which is different from Company’s A and B.

He primarily works on creating an FEA solver to optimize with respect to a given set of requirements. This project has one formal meeting between every two and three months to update a group of five people. This meeting typically involves three others at the same corporate level as him and two managers. Although these meetings are scheduled in advance, Jordan highly stresses the informality of these meetings and their sole purpose is to provide an update to the group within a thirty-minute timeframe.

Regarding informal meetings throughout the development of his project, he will seek guidance from his manager if he is involved with a problem that he has not experienced
before, thus continuing a trend of seeking answers to an area outside of one’s specialty. The complexity and size of the problem will also have an affect on this as justification from another person is sometimes needed before moving on to the next project’s problem.

Table 4.10: Interview summary for Jordan.

<table>
<thead>
<tr>
<th>Date</th>
<th>Duration (HH:MM)</th>
<th>Location</th>
<th>Time of Day</th>
<th>Relation</th>
</tr>
</thead>
<tbody>
<tr>
<td>03/10/2016</td>
<td>00:45</td>
<td>(Over the phone)</td>
<td>7:00pm</td>
<td>Former Co-worker</td>
</tr>
</tbody>
</table>

**Major Takeaway**
The majority of Jordan’s work is contracted to projects with the majority of his time spent behind a desk collaborating via email.
CHAPTER 5: DISCUSSION OF INTERVIEWING RESULTS

Results collected from the summaries are represented and discussed to provide an analysis of how practicing engineers in industry collaborate or work individually.

5.1 Design Process and Tools in Industry

Each interviewee’s responses were analyzed to detect patterns in what they were discussing. Table 5.1 shows if designers use specific processes provided to them, if they use their own process, or if they use a combination of the two.

Table 5.1: Designers’ use of the design process or tools.

<table>
<thead>
<tr>
<th>Row #</th>
<th>Topic</th>
<th>Alex</th>
<th>Brad</th>
<th>Chris</th>
<th>David</th>
<th>Erin</th>
<th>Frank</th>
<th>Grace</th>
<th>Hank</th>
<th>Isaac</th>
<th>Isaac</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Project types</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>Prd</td>
<td>Prd</td>
<td>--</td>
<td>Prd</td>
<td>Prd</td>
<td>Prd</td>
</tr>
<tr>
<td>2</td>
<td>Personally developed</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>(informal) procedure used?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Company provided</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>(formal) procedure used?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Collaborative design</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>tools used? *</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Individual design</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>tools used?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Assigned on project</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>with others of the</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>same specialty</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Except for computer-aided design (CAD)

**Legend:** F – Fixture/Tooling, Prc – Process, Prd - Product

The results from row 1 of Table 5.1 show that the mechanical engineers with Company A all work on fixture design in the factory. This is expected as those that work in manufacturing need to provide resources to the production floor, and mechanical
engineers tend to provide this through new or modified fixtures. The industrial engineer for the group works on improving the process. As Erin stated in her interview, “Most of my projects are on process improvements to improve efficiency ... with work instructions and line changes.” All of those at Company B and C work on product design, with the exception of Hank, who is a vice president that manages engineers and provides administrative support. This provides a further basis of triangulation to understand how those across multiple industries providing their engineering support collaborate.

Regarding the design process itself (rows 2 and 3), all of the engineers use a personally developed design process that typically models that of those presented in textbooks, which likely concludes that their collegiate experiences have an effect on their design process, even if it is not similar to their experiences in college. Also of note is the formal design process. Company C does not have a formal design process, which could potentially be explained by the relative youth of that company. Jordan also stated he, “Want[s] to stress the informality of [Company C],” which could mean the company is relatively relaxed to others and that the company believes the employees they have are independent enough to work on their projects at an appropriate pace without the need to follow a corporate structure. Collaboration is then not enforced at specific stages but is used, as needed.

David, who is an engineering manager, knew of a design process that the company provides and reproduced it in detail, but neither his subordinates or his engineering manager peer (who had the job for about six months when interviewed) could reproduce
this. This shows a lack of communication amongst the various levels regarding the design process, although this could be part of the culture of the department where Brad stated, “A process or tool should not be too restrictive ... to discourage creativity.” Instead of the manager providing the process to designers, he may ‘encourage creativity’ by not providing it and allowing designers to proceed at their own pace, as long as they make sufficient progress on a project.

With the exception of computer-aided design (CAD), established design tools (rows 4 and 5), such as those from the reviewed textbooks from this thesis, were not used by any of those interviewed. CAD would be used on occasion during meetings concurrently and in-person but no other tools were used. Note that the semi-structured interviewing allowed the interview to provide additional clarification about example tools such as brainstorming, QFD, and method 6-3-5. With Isaac, the interview became light-hearted when he was asked if he or if anyone in his group used design tools and his response was, “[Laughter] no, we do not use any tools like [brainstorming] here.” This is especially interesting as reviewed text uses design tools as a primary point of collaboration amongst designers in industry, but this is not the method through which they collaborate. Only Brad ever used a checklist as his individual design tool, although he did not state this by any formal name, only mentioning, “A tool would be useful, such as one that would list out what is generally needed to complete a project” and how he would use it to complete specific projects.
Also in terms of collaboration, none of the engineers or designers stated they would be paired with another of the same specialty (row six). Each would assign a specific project to an individual or be assigned a project. Projects were generally within their realm of specialty, but if it required any additional experience or knowledge from other departments or personnel, the assigned would have the opportunity to retrieve the information needed to successfully complete the project. This provides support to published literature that discusses collaborative specializing in industry projects.

**Takeaways:**

- *All engineers develop their own design process but product designers tend to have a focused process given by the company.*
- *Tools are not typically used for collaboration in industry in the same manner as discussed in textbooks.*

**5.2 Informal Meetings of Collaboration**

To further get to the understanding of the use of meetings in industry, questions were formed around both informal and formal meetings. Informal meetings were described as those being “spur of the moment” or unscheduled where one could walk into another’s office to discuss a project. Formal meetings were scheduled in advance and on a calendar that others could be invited to. A pattern matrix showing informal meetings is shown in Table 5.2.
Table 5.2: Intent and content of informal/unscheduled meetings.

<table>
<thead>
<tr>
<th>Row #</th>
<th>Topic</th>
<th>Alex</th>
<th>Brad</th>
<th>Chris</th>
<th>David</th>
<th>Erin</th>
<th>Frank</th>
<th>Grace</th>
<th>Hank</th>
<th>Isaac</th>
<th>Jordan</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Discussion about understanding problem</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>2</td>
<td>Concept generation performed</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>3</td>
<td>Concept critique</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>4</td>
<td>Used at stage gates?</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>5</td>
<td>Attendees from outside engineering?</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
</tbody>
</table>

Regardless if it was product, process, or fixture design, the purpose of all informal meetings were to discuss the problem at hand and to get design critiques (rows one and three). Only Erin stated that design critiques were not involved at informal meetings, but her definition of a concept as related to fixtures in a manufacturing facility could have influenced this since she does not design fixtures. However, she did have design critiques with those in her group outside of formal meetings to verify the direction of the overall project. Virtually no concept generation was performed in any of these meetings aside from Isaac where his group would occasionally, “Use a whiteboard to generate concepts,” although these were not completed with specific tools.

Those outside of engineering or design specialties would be at these informal meetings, primarily because of the project assignee requesting the assistance of their resource (row five). Questions regarding the overall design of a concept, its machinability, the ergonomics, or the direction are typically asked in these meetings.
Therefore, the primary purpose of informal meetings is to gather information from specialized resources to verify and further an existing understanding of the project. Moreover, these resources can include suppliers or catalogues to assist in data collection.

**Takeaways:**

- *Informal meetings occur frequently throughout the design process and focus on problem understanding and design evaluation.*
- *Expertise is usually sought outside of engineering to generate design critiques and discussion.*

### 5.3 Formal Meetings of Collaboration

A pattern matrix for formal meetings is shown in Table 5.3. From reviewing the interviews of each participant, it is clear that the purpose of formal meetings is not to discuss the problem or to generate concepts, but to critique and provide updates on a project’s current status. The fact that formal meetings and informal meetings overlap in terms of design critiques is due to the different personnel that attend these meetings. While informal meetings typically had direct managers, operators, machinists, engineers of a different specialty, or outside resources to discuss the project with, formal meetings tend to also have engineers of the same specialty (especially for Company A’s manufacturing) and those higher on the corporate ladder (Companies B and C).
Table 5.3: Intent and content of formal/scheduled meetings.

<table>
<thead>
<tr>
<th>Row #</th>
<th>Topic</th>
<th>Alex</th>
<th>Brad</th>
<th>Chris</th>
<th>David</th>
<th>Erin</th>
<th>Frank</th>
<th>Grace</th>
<th>Hank</th>
<th>Isaac</th>
<th>Jordan</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Discussion about understanding problem</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>2</td>
<td>Concept generation performed</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>3</td>
<td>Concept critique</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Project updates</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>5</td>
<td>Used at stage gates?</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>6</td>
<td>Attendees from outside engineering?</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
</tbody>
</table>

Hank specifically stated the differences at each formal meeting within their stage gate design process. Typically, the first stage gate would include vice presidents, industrial designers, and project engineers of various disciplines. The second stage gate would then include those same project engineers, industrial designers, and occasionally a vice president, but would also include members from quality. The third stage gate would not include industrial designers anymore as the concept was ‘frozen,’ but international engineers would become more involved in the detailed design of the product. Those in attendance of the fourth and final gate meeting would be the project engineer in charge, product manager, safety/risk qualifier, regulatory, quality, and vice presidents. Each of these would sign off on the final documentation before production.

This method of collaboration in terms of product updates are expected because this allows for a broad range of disciplines to get involved on a project at a high-level. This
provides the company with the appropriate resources to successfully complete a project while also maintaining a desired level of efficiency required for a company to remain in operation. Also Company B’s level of collaboration within formal meetings were primarily used for updates, to review a project, and to determine if the progress made is of an appropriate level to move into the next gate. Since Company B’s primary consumer market is for the public instead of specifically trained individuals, this could explain why this level of detail in maintaining a process is required. Also, additional regulations may be imposed on the designers or engineers because their product is being sold directly to consumers instead of in manufacturing where fixtures and equipment are designed to construct the final products.

Manufacturing tends not to have outside assistance in their projects, compared to product or process designers. This could be because of the limited number of participants that would be involved with the use of a product generated by the manufacturing engineers. Additionally, although the industrial engineer with Company A works in manufacturing, her process designs are under more scrutiny from other resources because of the more broad effect it has within the entire factory as it not only affects production and quality, but it can also affect suppliers and more directly affect the company’s bottom line.

Moreover, manufacturing does not typically have stage gates used in their projects. Although according to David, they do have a formalized system provided by the company, they do not typically follow the specified process, likely because
manufacturing can become retroactive (fixing a problem that has appeared) instead of proactive (preventing the problem before it occurs).

**Takeaways:**

- *Formal meetings tend to occur weekly or with stage-gates, which is less frequent than informal meetings that typically occur sporadically throughout the day.*
- *Expertise is usually sought outside of engineering to provide targeted feedback from their targeted areas (e.g. regulatory, safety, quality).*
- *Manufacturing does not use as much external expertise in formal meetings, likely since their users are trained, while product developers design for “all” users.*

5.4 **Time Allotted Throughout Design Process**

The time allotted to each phase of the design process was also analyzed to develop an understanding of the overall temporal focus throughout the duration of a project. This was further separated to determine how management perceived time spent vs. their subordinates that would be working on the project. Results were taken from the overall percentage of time each phase required throughout the development of a product (Figure 5.1). Note that this is not the calendar time required to complete each phase of the process but the amount of time the participant directly expended on that phase. An example of this difference is that an engineer may require a part to be machined. They will provide drawings to a machinist but not perform the machining themselves. Thus, they credit
their time expended from the drawings and not from the required time to machine the part.

![Pie charts showing perceived time expended in each phase of the design process according to (a) "non-management" and (b) managers.](image)

**Figure 5.1:** Perceived time expended in each phase of the design process according to (a) "non-management" and (b) managers.

These figures provide an unexpected perspective into how engineers and designers not in management perceive the amount of time they expend in each phase of the process as compared to their managers. Those in entry-level positions tend to spend the majority of their time in the product planning phase with equal time spent in both the conceptual and embodiment design phases. These results are similar as seen in Figure 1.1 where the majority of the discussion was based on all but the detail design phase (which,
coincidentally, both accounted for approximately five percent of the total time in each). Conversely, management believed the majority of the time spent on a project was for embodiment, where the bulk of prototyping, testing, and further developing designs would take place. A manager’s perspective on time spent throughout the design process was similar to that presented in the design textbooks with only about two percentage points differing in each phase.

These results could be explained by management needing to see results of a given project, and embodiment design is typically where results are desired as this is the last proving stage before any major builds occur. Both conceptual design and detail design remained consistent between the two perspectives. Detail design is the closing out of a project and most of the designers did not want to spend much time here to ensure the project’s completion. Conceptual design, where important decisions must be made early for a project to be successful, consumed about 25% of the total time. This was likely enough time for the engineers and designers to develop concepts, quickly verify their applicability through informal meetings, and then discuss these with management in formal meetings to get verification onto embodiment design.

Another note is the almost 25% increase in the amount of time required to understand the problem for those not in a management position. Likely, management has received a problem from another source or has observed a problem that requires fixing. He or she then forwards this to one of their subordinates. Then, those assigned to the project must spend time understanding the problem they were assigned and establish a timeline for
project completion. The level at which the assigned engineer understands the problem is different from the manager that assigned the project, thus the engineer needs to verify all aspects of the project before continuing into further development.

**Takeaways:**

- *Management and the designers/engineers they manage do not spend similar amounts of time on each phase of the design process.*
- *Managers expect most time to be spent in embodiment design while those lower on the corporate ladder spend more time in early phases of problem definition.*
CHAPTER 6: CONCLUSIONS AND FUTURE WORK

The three research questions are restated and conclusions are provided for each. Further, future work and associated research questions for that will also be provided as a potential direction for subsequent research.

6.1 Conclusions for Research Questions

As stated in Chapter 1, the first research question is centered on understanding when in the design process engineers work together. It is repeated here as:

**Research Question 1:** When do practicing engineers in industry work together in design projects?

In answering this question, practicing engineers in industry primarily work together at both informal and formal meetings. Formal meetings tend to occur weekly or monthly and did have correlations with project type. For example, process projects require more formalized meetings but fixture and manufacturing projects tended to revolve around informal meetings. Moreover, Company B’s formal stage-gate structure necessitates a series of signatures at each gate to continue forward in the project. These meetings occur less frequently than informal meetings, which typically occur sporadically throughout the workday or week. The importance to industry in collaboration through informal meetings is by providing project updates and verifying concepts before reaching a formal meeting, which is more important to industry than using design tools.
Research Question 2: Why do practicing engineers in industry work together in design projects?

Practicing engineers typically work together when a specific part of their project requires specialized assistance from another resource. While these engineers do work together in design, they would either be the only one responsible for a project or assigned to a project with an engineer or designer of another background that had a specific specialty to provide. At Company A’s manufacturing department, a manufacturing engineer whose specialty is in mechanical engineering could be partnered with a test engineer that would either be an electrical or computer engineer. Although there are some overlap between these two, this allowed for them to be more efficient in completing the project where one engineer did not have to also specialize in another field. This pattern was similarly found in Company B where a project engineer would be assigned to a project with various mechanical and electrical components. While they could retrieve information on other existing products of the company, specific requirements, such as the power source, would need to be satisfied by requesting the assistance of the power-sourcing department. This also maintains the specialties between each group where individuals can be working on several projects at the same time, rather than working on a single project through to its completion.

Research Question 3: How do practicing engineers in industry work together in design projects?
During the development of a product through the design process, meetings primarily exist informally across all three companies. Informal meetings (ones that were not scheduled in advance) were held to discuss the problem for better understanding and to retrieve feedback on a given design before formally presenting it to a group of engineers. Feedback would typically be asked from operators that would use the product, shop machinists that would have to machine the parts, or other engineers that had more experience on a similar project or different field. Formal meetings are held to receive updates on a project and their duration is usually about five to ten minutes, with some exceptions. No formal meetings were held to collaborate on generation of concepts, which adds credence to the differences of collaboration in industry compared with existing text.

In comparison, every reviewed textbook mentions teams in collaboration but none of the interviewees specifically mentioned a team. Specifically, each interviewee would mention meetings or a group. This shows that the use of collaboration in industry is generally different that what is described in textbooks. Collaboration can be completed in various levels, but as for companies A, B, and C, collaboration is reserved for regular project updates with management and informally with work colleagues to discuss ideas and no formal tools are used for concept generation or evaluation. This appeared to occur across multiple project domains, although more research should be performed to determine how generalized these conclusions can be. It is important to note that these conclusions are for the specific companies interviewed (Table 6.1). Further, while meetings were the primary source of collaboration in industry, none of these involved the
use of tools. Conversely, each textbook discussed tools as an option to bring designers together to collaborate. Therefore, how a practicing engineer in industry works with others is different from what has been published in textbooks (Table 6.2).

Table 6.1: Areas of application for research conclusions based on company type.

<table>
<thead>
<tr>
<th>Company/Department “Function”</th>
<th>Conclusions Apply</th>
<th>Conclusions May Apply</th>
<th>More Research Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturing</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Development</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Research</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Consulting</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Contractors</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Novel Design Development</td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

Table 6.2: Comparisons between what is taught in textbooks with what is practiced in industry.

<table>
<thead>
<tr>
<th>#</th>
<th>Taught</th>
<th>Reality</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tools are used to bring designers together to collaborate</td>
<td>Meetings are used to bring designers together to collaborate</td>
</tr>
<tr>
<td>2</td>
<td>Textbooks discuss collaboration through a team</td>
<td>Interviewees never mentioned collaboration through a team</td>
</tr>
<tr>
<td>3</td>
<td>Teamwork typically discussed as occurring throughout a project</td>
<td>Projects typically are assigned a single engineer or designer</td>
</tr>
</tbody>
</table>

6.2 Potential Future Work

Additional companies should be explored to add to the existing data set presented in this thesis. Companies that perform design of specialty or novel products can be interviewed to understand how they progress through the design process. This will help to
provide additional triangulation from which the methods used in industry for collaboration can be better understood. This will allow academia to potentially provide resources that could better the efficiency of future engineering tasks.

**Future Research Question 1:** What resource can academia provide for individual designers to progress more efficiently through the design process?

**Future Research Question 2:** How do design-oriented companies of novel products collaborate in design?

With a more clear understanding of how industry collaborates in design, this can also provide a basis from which modifications to existing design courses are taught. Some courses are taught in groups of students from a single discipline where they all work on the same project throughout its completion. With the exception of additional experience, which students typically have reasonably similar experiences with one another, multidisciplinary collaboration could become the standard since this provides a more realistic scenario that the students would encounter in industry.

**Future Research Question 3:** How does the impact of students on multidisciplinary collaboration in capstone courses affect industry as compared to those on single-disciplinary collaboration?
CHAPTER 7: REFERENCES


gathering in engineering design research.


261–264.


APPENDICES
APPENDIX A: EVOLUTION OF INTERVIEW QUESTIONS

The development of interview questions from the initial set requesting basic information to the final set that better generates the needed responses for this research is provided. The purpose in providing these is to help generate context from what is required when creating a semi-structured set of interview questions for research credibility and for future researchers to better understand interview question development.

The initial interview questions (Table A.1) were too broad for use in an actual interview. Also note that there is a lack of triangulation between each question, which also are not divided into topics. Definitions were also not complete as question two even included the note to “DEFINE.” Multiple questions included several meanings, thus these questions had to be better specified in further iterations.

<table>
<thead>
<tr>
<th>#</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Briefly describe your previous design experience with the company?</td>
</tr>
<tr>
<td>2</td>
<td>Describe the type of projects you have worked on? (small, medium, large; simple, complex; easy, moderate, hard) DEFINE</td>
</tr>
<tr>
<td>3</td>
<td>How was the project defined?</td>
</tr>
<tr>
<td>4</td>
<td>Why are design reviews typically performed for a project? Safety, cost, complexity, experience, etc.</td>
</tr>
<tr>
<td>5a</td>
<td>Describe your design procedure. What was this based on? Experience, textbook, a class, etc.</td>
</tr>
<tr>
<td>5b</td>
<td>Why did you elect not to use a specified design procedure? What would encourage you to use one?</td>
</tr>
<tr>
<td>6</td>
<td>Is this design still in use? If so, what modifications have been made? If not in use, please explain.</td>
</tr>
<tr>
<td>7</td>
<td>What were the major concerns of your project?</td>
</tr>
</tbody>
</table>
The second set of interview questions introduced topics and immediately began to show a semblance of the current interview questions (Table A.2). Basic background information on the interviewee was asked but no specifics regarding projects that the designer or engineer was assigned. More questions included notes to define more of what they meant. Also, questions were divided into six topics, but more specifics were required.

**Table A.2: Second iteration of interview questions.**

<table>
<thead>
<tr>
<th>Topic</th>
<th>#</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intro.</td>
<td>1</td>
<td>What is your position title and description? How many years have you been in this position?</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Briefly describe your previous design experience with the company?</td>
</tr>
<tr>
<td>Project Description</td>
<td>3</td>
<td>What type of projects have you worked on? Tooling design, fixture design, etc.</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>How many design projects per year are assigned?</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Describe the size of the project you worked on (small, medium, large) DEFINE</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Describe the complexity of the project (simple, complex) DEFINE</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>Describe the difficulty of the project (easy, moderate, hard) DEFINE</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>How were you introduced to the projects? Email, formal documentation, verbal, etc.</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>How was the project defined?</td>
</tr>
<tr>
<td>Design Reviews</td>
<td>10</td>
<td>How many design reviews do you typically have for a project?</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>What type of design reviews were performed and with whom? (e.g. Formal design review with management, informal review with shop personnel, design discussion with engineering colleagues, discussion with operators, etc.)</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>Why are design reviews typically performed for a project? Safety, cost, complexity, experience, etc.</td>
</tr>
<tr>
<td>Design Process</td>
<td>13</td>
<td>Did you follow a structured procedure? (Yes/No)</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>Describe your design procedure. What was this based on? Experience, textbook, a class, etc.</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>Why did you elect not to use a specified design procedure? What would encourage you to use one?</td>
</tr>
<tr>
<td>Final Design</td>
<td>16</td>
<td>Is this design still in use? If so, what modifications have been made? If not in use, please explain.</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>What were the major concerns of your project?</td>
</tr>
<tr>
<td>Misc.</td>
<td>18</td>
<td>How many man-hours are typically required to complete your projects?</td>
</tr>
</tbody>
</table>
The third iteration included additional questions on teaming and collaboration in design. Definitions began to become more developed on resources, scope, scale, and size of projects. Questions were still divided into five topics but this version included the most number of questions for the interview. Questions specifically asking for projects from the interviewee were now included as this was expected to better help focus the interviewee on topics.

### Table A.3: Third iteration of interview questions.

<table>
<thead>
<tr>
<th>Topic</th>
<th>#</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Introduction</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>What is your position title and description? How many years have you been in this position?</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Briefly describe your previous design experience with the company?</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>Describe the most recent project you have completed.</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>Describe a challenging project that you best remember from your past experiences with the company.</td>
</tr>
<tr>
<td><strong>Project Description</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>What type of projects have you worked on? Tooling design, fixture design, etc.</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>How many design projects per year are assigned?</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>What resources did you use throughout your project? (Technical, electronic, software, people, etc.)</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>Did you follow a structured procedure?</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>What software was used?</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>Who all assisted with the project? (Including engineers, machinists, operators, outside sales, managers, etc.)</td>
</tr>
<tr>
<td>10a</td>
<td></td>
<td>What type of feedback did you receive from these co-workers?</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td>How many of these projects were team based? (Number of co-workers directly assigned to the project)</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td>How would you describe the size of the project you worked on? Why did you describe it as that size?</td>
</tr>
<tr>
<td>13</td>
<td></td>
<td>How many man-hours are typically required to complete your projects?</td>
</tr>
<tr>
<td>14</td>
<td></td>
<td>Describe the complexity of the project (simple, complex) DEFINE</td>
</tr>
<tr>
<td>Topic</td>
<td>#</td>
<td>Question</td>
</tr>
<tr>
<td>---------------</td>
<td>--------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>15</td>
<td>From your perspective, what was challenging about this project?</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>How challenging would you say this project was?</td>
<td></td>
</tr>
<tr>
<td>16a</td>
<td>Why do you think this was or was not challenging?</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Project Challenge: Did you have a co-op, intern, or new engineer help with your project?</td>
<td></td>
</tr>
<tr>
<td>17a</td>
<td>Why did you ask this person to help with your project?</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>How were you introduced to the projects? Email, formal documentation, verbal, etc.</td>
<td></td>
</tr>
<tr>
<td>19a</td>
<td>Is this introduction to the project common? Why?</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>How were you introduced to the projects? Email, formal documentation, verbal, etc.</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>How was the project defined in the method of introduction?</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>How many design reviews do you typically have for a project?</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>What type of design reviews were performed and with whom? (e.g. Formal design review with management, informal review with shop personnel, design discussion with engineering colleagues, discussion with operators, etc.)</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Why are design reviews typically performed for a project? Safety, cost, complexity, experience, etc.</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>Did you follow a structured procedure provided by the company? (Yes/No)</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Did you follow a structured procedure based on your personal experience? (Yes/No)</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>Describe your design procedure. What was this based on? Experience, textbook, a class, etc.</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>Why did you elect not to use a specified design procedure? What would encourage you to use one?</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>Is this designed product still in use? If so, what modifications have been made? If not in use, please explain.</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>What were the major concerns of your project?</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>What were your final reflections on the project?</td>
<td></td>
</tr>
</tbody>
</table>

More questions were directed toward triangulation of questions, such as question seventeen-A, which posed a “why” question to the interviewee to add onto who they asked to assist with the project (Table A.4). As these questions continued becoming more specific, the overall benefit of these questions came into question and a fundamental understanding and reasoning for each question was developed to ensure each question was absolutely required for the research being performed.
<table>
<thead>
<tr>
<th>Topic</th>
<th>#</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>1</td>
<td>What is your position title and description? How many years have you been in this position?</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Briefly describe your previous design experience with the company?</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Describe the most recent project you have completed.</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Describe a challenging project that you best remember from your past experiences with the company.</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>What type of projects have you worked on? Tooling design, fixture design, etc.</td>
</tr>
<tr>
<td></td>
<td>5a</td>
<td>How would you classify your most recent project and your challenging project?</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>How many design projects per year are assigned?</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>What resources did you use throughout your project? (Technical, electronic, software, people, etc.)</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>Did you follow a structured procedure?</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>What software was used?</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>Who all assisted with the project? (Including engineers, machinists, operators, outside sales, managers, etc.)</td>
</tr>
<tr>
<td></td>
<td>10a</td>
<td>What type of feedback did you receive from these co-workers?</td>
</tr>
<tr>
<td>Project</td>
<td>11</td>
<td>How many of these projects were team based? (Number of co-workers directly assigned to the project)</td>
</tr>
<tr>
<td>Description</td>
<td>12</td>
<td>How would you describe the size of the project you worked on? Why did you describe it as that size?</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>How many man-hours are typically required to complete your projects?</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>Describe the complexity of the project (simple, complex)?</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>Why, how, etc. was this complex?</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>How challenging would you say this project was?</td>
</tr>
<tr>
<td></td>
<td>16a</td>
<td>From your perspective, what was challenging about this project?</td>
</tr>
<tr>
<td></td>
<td>16b</td>
<td>Why do you think this was or was not challenging?</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>Project Challenge: Did you have a co-op, intern, or new engineer help with your project?</td>
</tr>
<tr>
<td></td>
<td>17a</td>
<td>Why did you ask this person to help with your project?</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>What tools did you use with your resources to communicate your design concepts or ideas?</td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>How were you introduced to the projects? Email, formal documentation, verbal, etc.</td>
</tr>
<tr>
<td></td>
<td>19a</td>
<td>Is this introduction to the project common? Why?</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>How was the project defined in the method of introduction?</td>
</tr>
<tr>
<td></td>
<td>21</td>
<td>How many design reviews do you typically have for a project?</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>What type of design reviews were performed and with whom? (e.g. Formal design review with management, informal review with shop personnel, design discussion with engineering colleagues, discussion with operators, etc.)</td>
</tr>
</tbody>
</table>
Questions were narrowed down from over thirty questions, including the follow-up questions, down to 27 (Table A.5). This helped to ensure the interview was continually focused, questions were appropriately triangulated, and the interview could maintain a maximum length of one hour. This would help ensure the interviewer best maintained the focus of the interviewee while also respecting the time they were spending on the interview itself.

<table>
<thead>
<tr>
<th>Topic</th>
<th>#</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>1</td>
<td>What is your position title and description? How many years have you been in this position?</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Briefly describe your previous design experience with the company?</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Describe the most recent project you have completed.</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Describe a challenging project that you best remember from your past experiences with the company.</td>
</tr>
<tr>
<td>Project Description</td>
<td>5</td>
<td>What type of projects have you worked on? Tooling design, fixture design, etc.</td>
</tr>
<tr>
<td></td>
<td>5a</td>
<td>How would you classify your most recent project and your challenging project?</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>How many design projects per year are assigned?</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>What resources did you use throughout your project? (Technical, electronic,</td>
</tr>
<tr>
<td>Topic</td>
<td>#</td>
<td>Question</td>
</tr>
<tr>
<td>-------</td>
<td>----</td>
<td>----------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>software, people, etc.)</td>
</tr>
<tr>
<td>8</td>
<td>Did you follow a structured procedure?</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>What software was used?</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Who all assisted with the project? (Including engineers, machinists, operators, outside sales, managers, etc.) What type of feedback did you receive from these resources?</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>How many of these projects were team based? (Number of co-workers directly assigned to the project)</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>How would you describe the size of the project you worked on? Why did you describe it as that size? How many man hours were required to complete the project?</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Describe the complexity of the project (simple, complex)? Why? How?</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>How challenging would you say this project was? Why? What was or was not challenging?</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Project Challenge: Could a co-op, intern, or entry-level engineer complete the project on their own? Why or why not?</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>What tools did you use with your resources to communicate your design concepts or ideas?</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>How were you introduced to the projects (Email, formal documentation, verbal, etc.)? Is this common? Why do you think you were introduced in this manner?</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>How was the project defined in the method of introduction?</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>How many meetings do you typically have for a project? What were the purpose of these meetings?</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>What type of meetings were performed and with whom? Do you have design development meetings? (Formal meeting with management, informal meeting with shop personnel, design discussion with engineering colleagues, discussion with operators)</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>If a structured procedure was followed, did you follow a structured procedure provided by the company or your personal experience? (Yes/No)</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>If yes, describe your design procedure. What was this based on? Experience, textbook, a class, etc.</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>If no, why did you elect not to use a specified design procedure? What would encourage you to use one?</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>Is this designed product still in use? If so, what modifications have been made? If not in use, please explain.</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>What were the major concerns of your final designed product?</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>What were your final reflections on the project?</td>
<td></td>
</tr>
</tbody>
</table>

The final set of questions narrowed the topics list down to four topics, eliminating the final product questions, as responses to these questions were consistently met with
similar responses questioning the purpose of these questions and there was minimal value of these to this research (Table A.6). Those questions could potentially be useful on other research that required more information on post-design analysis.

Table A.6: Final iteration of questions used for interviewing.

<table>
<thead>
<tr>
<th>Topic</th>
<th>#</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>1</td>
<td>What is your position title and description? How many years have you been in this position?</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Briefly describe your previous design experience with the company? Describe your education background.</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Describe the most recent project you have completed.</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Describe a challenging project that you best remember from your past experiences with the company.</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>What type of projects have you worked on? Tooling design, fixture design, etc.</td>
</tr>
<tr>
<td></td>
<td>5a</td>
<td>How would you classify your most recent project and your challenging project?</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>How many design projects per year are you assigned?</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>What resources did you use throughout your project? (Technical, electronic, software, people, etc.)</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>Did you follow a structured procedure?</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>What software was used?</td>
</tr>
<tr>
<td>Project Description</td>
<td>10</td>
<td>Who all assisted with the project? (Including engineers, machinists, operators, outside sales, managers, etc.) What type of feedback did you receive from these resources?</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>How many of these projects were team based? (Number of co-workers directly assigned to the project)</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>How would you describe the size of the project you worked on? Why did you describe it as that size? How many man-hours were required to complete the project?</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>Describe the complexity of the project (simple, complex)? Why? How?</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>How challenging would you say this project was? Why? What was or was not challenging?</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>Project Challenge: Could a co-op, intern, or entry-level engineer complete the project on their own? Why or why not?</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>What tools did you use with your resources to communicate your design concepts or ideas?</td>
</tr>
<tr>
<td>Topic</td>
<td>#</td>
<td>Question</td>
</tr>
<tr>
<td>--------------</td>
<td>----</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Design Meetings</td>
<td>17</td>
<td>How were you introduced to the projects (Email, formal documentation, verbal, etc.)? Is this common? Why do you think you were introduced in this manner?</td>
</tr>
<tr>
<td>Design Meetings</td>
<td>18</td>
<td>How was the project defined in the method of introduction?</td>
</tr>
<tr>
<td>Design Meetings</td>
<td>19</td>
<td>How many meetings do you typically have for a project? What were the purposes of these meetings?</td>
</tr>
<tr>
<td>Design Meetings</td>
<td>20</td>
<td>What type of meetings were performed and with whom? (Formal meeting with management, informal meeting with shop personnel, design discussion with engineering colleagues, discussion with operators)</td>
</tr>
<tr>
<td>Design Meetings</td>
<td>20a</td>
<td>Do you have design development meetings?</td>
</tr>
<tr>
<td>Design Process</td>
<td>21</td>
<td>If a structured procedure was followed, did you follow a structured procedure provided by the company or your personal experience?</td>
</tr>
<tr>
<td>Design Process</td>
<td>22</td>
<td>If yes, describe your design procedure. What was this based on? Experience, textbook, a class, etc.</td>
</tr>
<tr>
<td>Design Process</td>
<td>22a</td>
<td>How much time do you tend to spend in each phase of the design process?</td>
</tr>
<tr>
<td>Design Process</td>
<td>22b</td>
<td>What differences in meeting type and duration in various phases of the design process?</td>
</tr>
<tr>
<td>Design Process</td>
<td>23</td>
<td>If no, why did you elect not to use a specified design procedure? What would encourage you to use one?</td>
</tr>
</tbody>
</table>
To ensure full disclosure of all findings for this research, the complete transcripts of each interview are provided in this appendix. For confidentiality, each interviewee maintains their assigned identification code and mentions of each company are abstracted to their assigned company identifier.

B.1 A.ME.1 – Alex

SO: The purpose of this is for my research at Clemson where from my experiences in the capstone program and then senior program we design primarily in teams of 3, 4, or 5 students and we work on a project together as in that team. Well, when coming here, the most interaction in a team that I have received was maybe working on a project with or maybe getting some assistance from one of the test engineers whether it be like mainly it was Brian Williams. Or it would be one of the techs. And that would be it. So I just wanted to come here and get y’all’s experiences since y'all have been working here much longer than me. Y’all have more experience than I do. I just wanted to see if your insight is the same as mine but hopefully what will come out of this is that if most of the work you do is more individual rather directly in teams then there might be some sort of process of some sort of tool or even software that I could potentially develop or recommend and then you could potentially use it here or someone at some other company so the end goal of this is to try to help increase efficiency and quality the overall ability of the
engineer especially if they’re new like I was when I first started. And increasing the ability to hit the ground running might be helpful.

So I have to get these introductory questions first: what is your position title and description, and how many years have you been at this position?

Brad: Lead manufacturing engineer is the title. I’ve been in this particular role since probably 2006/2007 so 8 or 9 years.

And what exactly are your responsibilities in that role?

Well manufacturing engineer, first and foremost, supporting production, supporting departmental initiatives and filtering those down through the group such as PSR's, manufacturing qualifications, 5S initiatives. Right now, I’m leading a Kaizen team so any number of focus factory and departmental goals that need to be filtered down to the group. Maintaining capital budget, mechanical design reviews, things like that. You know, all of the above our part my responsibilities but first and foremost of these would be supporting production, project management, things like that.

Ok. So what was your previous design experience within [Company A]?

I mean…if we’re talking in a current manufacturing engineering role, when I first started back in ’99, it might be designing fixtures, designing tooling in Pro/E for production. As I’ve gone room and, I guess, progressed over time, I still support that, but not to the same degree that some of the other guys in the group do. I've seen my responsibilities shift to more project management as compared to down in the trenches,
nuts and bolts, designing fixtures. I still do that from time to time but that's not one of the things it would be one of my big portion of my plate right now.

**What other companies have you worked for?**

Milliken and Company at their finishing plant in Pendleton. Co-oped at Metler Toledo back in the mid-90s. but I’ve been at [Company A] since ’99.

**What type of work did you do for those other companies?**

Very similar to what, I guess, a typical co-op or intern would do. Some basic CAD work, some basic data collection. A little bit of fixture design. At Milliken I also did some inventory control, did some 5S, stuff like that.

**Have you attended any workshops or taken any specific classes on designing, and more importantly, either design in general or how to design on your own as an individual rather than in teams?**

So let’s clarify, when talking design, you know, you mean with a CAD package designing a specific mechanism or something?

Yeah, whether it be with CAD or whether it be just having to have something sketched out and then potentially presented to someone before actually going to CAD. Any kind of design work whether it be for fixture or tooling.
I mean, above and beyond what I took in school, I don't believe. It’s one of those things where I’ve refined my craft over the years. Learning from mentors, learning from senior engineers, watching the process, learning as I go and perfecting it through time.

**So what kind of stuff would you say you’ve learned throughout your experiences?**

Learning the design process, you know, to identify what are the key parameters before you sit down on the CAD package and start to, start to sketch it out: what are you trying to accomplish? What are your space constraints? What, if any, budgetary constraints do you have which will affect your selection of materials. Are there any safety considerations that have been identified ahead of time? So mainly getting all the prep work done and answered before you sit down in front of the computer to start the design so that you don't find out halfway through it, “Oh I had to make sure this was a nonconductive material,” or “Oh it needs to be mobile. I had this on a table top.” Getting all your ducks in a row before you sit down to do it is the biggest, you know, it sounds trivial but a lot of people even now don't do that correctly, in my opinion, and they have to go back and rev their design 2, 3, 4 times because they didn't have all the information they needed. Now sometimes that information is not easily come by, but you get as much of it as you can. So one thing, if we had a designer’s kit, and this is just thinking matter of fact, a designer’s kit that forces you to answer specific questions up front, as much as possible. For example, “Are there safety considerations?”, “Is this a mobile device?”, “Is this intended to be a standalone machine?”, “Is it tabletop?” Selection of materials,
know, does it need to be ESD? What type of product is going to go into it? Does it need to be guarded? Is it just simple mechanisms or is there going to be kinetic energy devices such as hydraulic schematics, servos that need light curtains. All of these things, if they’re answered up front, you going to design with that in mind. So, if we had a checklist, maybe the standard, you know…

**That almost sets up your design space for you.**

It really forces you down the correct path because if you can answer these questions up front, then when you actually sit down and start putting the mechanism together in your mind on the computer, “Oh yeah, I remember I’ve got to have ESD shelving. Oh, I’m going to have to have light curtains on this because I'm using, you know, half-inch four pneumatic cylinders to do this action or whatever it is. Make sure you know dot your I’s and cross your T’s. So one of those, I mean a lot of times we do it naturally, we go and write stuff down a piece of paper in a notebook but if we had a checklist that formalizes that this is part of the design process, answer these questions as much as possible. And if there's a problem you can always go back to your checklist and say, “why isn't this right?” Well, this is the assumptions I had when I went into it. Maybe the assumptions change. Maybe what was supposed to be a fixed benchtop type of mechanism, well now they want to roll it from cell to cell so it needs to be mobile. Well, if there’s changes that are required later, you can at least go back to say, “Hey, when I started the process, my checklist said this was benchtop and this was a fixed asset. Now somebody has changed into a mobile device down the road. So, if it takes three more
weeks to finish this and another 1000 to 1500 dollars to modify it, you’ve got your documentation that says, “Hey, when I started the project, these were the assumptions.” So it's always good to have that information up front.

So would having some sort of a pre-populated list of topics to go through that forces you to go through a general listing of every subject, whether it be safety, ESD, material selection, would you say that would be helpful?

I think particularly for the guys that are new, for co-ops, for those that aren’t used to the design process that need to perfect their craft. I think having something more formal like that forces them to think about some of the issues that we take for granted as a more senior designer. You know, we go through the checklist in our head and even now, we’ll miss stuff and if we had it on a paper or whatever, in front of us the whole time, you know, even that would help a seasoned engineer to make sure to keep all their information straight. It's just like solving any kind of technical problem. You list your assumptions first before you try to solve the problem. This is no different: you list your assumptions up front, you knowns, and your assumptions and then you start your design. And when you get to the end you ought to be able to look at your designs and say, “Yep, light curtains, check that out for guarding,” “yep, I’ve got ESD and that’s grounded. Check that off for that, you know.” You ought to be able to look at your finished design and look at your list of knowns and assumptions, and every one of those is satisfied in the design. And if they’re not, you’ve missed something. You didn’t pay attention to the information you had.
Now let’s get into some of the projects you’ve worked on. That’s what the remainder of these questions will focus on. So can you describe your most recent design project that you’ve completed?

We had to do a redesign on the power transmission unit for the old coil-forming machine. The rotary transmission unit for the dial table failed. The drive gear basically destructed, self-destructed and it was about a $45,000 replacement and it wasn't a drop in to get the power transmission unit. The way it was set up was not easily to work on. You had to crawl under the machine, pull the motor and the clutch. So we decided to reengineer it in-house and take the components that worked on the rotary transmission and design and install a new power transmission unit to drive the rotary to drive the dial table. So it was really cool. About a $43,000 cost-savings as well. So basically taking known mechanical concepts on power transmission, we got the drive unit from underneath table, mounted it tabletop so it’s easily accessible. Basically, took the equivalent of a blower belt, a big 1.5-inch wide belt that would transmit power from the motor gear reduction unit to the input shaft for the rotary transmission. Getting that all built and designed and operational, we can go look at that anytime you want to go look at that.

Might have to take a look at that, that’s pretty exciting.

It's pretty neat, I’ve got some pictures to show you. Matter of fact, I know I do on my phone. So going through that design process was neat and, you know, again having the checklist available and have it posted out there and make sure we’re meeting all those
requirements would've been an advantage. We miss some stuff, you know. It's one of those particularly, designing mechanisms for a production environment, you’ve got time pressures, you’ve got budgetary considerations, and you miss stuff. And so any information that we can get solidified up front and have it right there in our face the whole time would be a help.

**Now, what about a second challenging project that you best remember. It doesn’t have to be recent.**

Well, I mean, right now so when we talk design, it can be anything from fixtures to workstations. So right now, our Kaizen event for semi-auto, we’re designing new works, basically a new work cell, so the design concepts that we’re talking about are scalable you know, your checklist is still the same, your requirements, your knowns, your unknowns. It’s all of these different things. You just have to break it down into subcomponents so that even though I've got the big picture in mind, I need to apply these concepts to each of the subcomponents that go into that cell. So for all of our flow channels, all of our buggies, all of our carts and workstations, the process remains same even though we’re focusing on one small subcomponent of the larger cell. So right now, we’re designing carts, buggies, and workstations to do specific tasks and assembly steps. So we’re having to consider things like grounding and ESD, mobility, modular design, ergonomics. All of these things, we have to take into account so not to be a broken record but all these things we talked about for the last project and in general, these checklists, these stating your facts and knowns and assumptions, you know. For every one of these
designs that we’re doing, having that information available, it provides continuity of thought on work, how your designing each station and what not. You know, having continuity of the lessons learned. Ok, if you’re going to do something like this: if you have meters on a shelf, it needs to be this type of material. This is the part number and specs for it.

So for the transmission redesign, what type of project would you say that is? The examples I have here are tooling and fixture design, process design. I wouldn’t think that falls under that. Would you say it’s almost the station partial redesign?

Yeah, I mean that not really even tooling. Machinery redesign and upgrade, if you want.

The buggies and the flow process…

I mean, that’s machinery equipment. That’s process as much as it is anything.

In general, how many design projects are you assigned either per year, or if it is easier, per month?

How about per week?

Well we could take an average per week and multiply it by 50, assuming 2 weeks off.
I mean, you know, there's no general blanket answer for that. For me, personally, maybe not as much as the other guys. I might have one or two things going per week that carry-on over multiple weeks.

**Is it really because you’re overseeing projects?**

Yeah, I mean, it’s more project management. A lot of it is for me so I might have one or two or three designs that might go for months because they’re larger or it takes time to get stuff built and different things and you follow through to completion. So maybe a dozen to a dozen and a half over a calendar year but when you talk about but, you know, when you’re talking about buggies and carts and mechanisms and fixtures and tooling. When you talk about true design work for me, that's a good, good number of projects throughout the year when you figure you’re still doing production support, paperwork, and all the different project management that comes along with these things.

**Ok, so how about just projects in general. Not only design but also with other production, other, let’s say your you put on a 6S…**

So a couple of ways to answer that. If we’re talking just like major projects that are tracked with budgets and hours and PSR's and whatnot, probably a dozen in a calendar year is good number. But when you talk about everything else that goes with it, the smaller not as visible projects, the fire fighting, the we need to design something to repair something on the line, I mean, it could be several dozen, you know. It really depends on how granular you want to get but as far as measurable tracked projects that management
is inclined to request updates on what the tracking on and whatnot, maybe a dozen or so in a calendar year.

**Ok, and what resources do you typically use throughout these projects? Whether it be software, hardware, tooling, people.**

Oh gosh, there’s a myriad of resources between CAD packages, any number of Microsoft products like PowerPoint, Excel, Word for communications, any number of homegrown: Dashboard, EIS, RIS, we’ve got a lot of homegrown apps that we use. I guess what I’ll call indigenous software, stuff like Brainson has their own stuff or MiniTab, things like that. Reference books, you know, my mechanics book, I’ll use that quite often during the design process. Any number of webpages where you go out and do a Google search, “Ok, I need to know about pitch angle on this kind of thread,” or what kind of fasteners to use, rules of thumb for whatever it is you’re looking for. I mean, there's any number of resources that you can use. Pick your neighbor’s brain, I mean literally. If you have tooling questions, you ask your tool and die guys. Electrical questions, you’ll hit up your test engineers or whatever. Any number of places to go to get the answers you seek.

**And so, we've been talking about how you go through and look at a project and you try to break it down to what you need for the project. Do you have an overarching specified procedure that you tend to follow? Do you have that documented somewhere or is it just from your experience?**
Experience. That’s why I say when you first come on, you’ve got to refine your craft and you’re going to learn by your mistakes, you’re going to get lessons learned that you apply to subsequent projects and processes so… I don’t know that you need an overarching set of rules and documents because it tends to limit innovation. But what you need is the upfront information to get you from point A to point B. How you get to point B could be any number ways. And there’s where I wouldn’t want to be limited to I have to do this process or I have to follow this.

So that makes a lot of sense. You don't want to go...you want to set someone up help or help set a designer up but not...

A procedure should be to the benefit the designer. So when I say have a checklist of things you need to answer ahead of time, that's helpful, that's not a hindrance. Having a procedure that says okay you’ve got to do this, this, this, and this during your design process. If it's high-level, I see benefit in it. You know, for example, okay you’ve got X number of things you need to do through the whole process. Number one, fill out your free checklist, whatever you want to call it, listing your knowns and assumptions. Before you go to print have a peer review. Before you go tooling, have your designs checked for accuracy in your prints, okay. And then when you go to receive your tooling, your machined components, maybe have some quality checks on them that you have two or three dimensions checked for accuracy before you assemble, okay. And before you release to production your design, do some fit and function to make sure that all of your assumptions at the very beginning are satisfied when you go to do fit and function. I
could see something like that’s just some basic and reasonable deliverables as you go from concept to completion, but anything more rigid than that, to me, becomes a hindrance because now I’m more concerned with the process that I am the design and I don't want to get to that point. I want to stay focused on the design, you know, if it's just meeting some basic deliverables as we go that's reasonable but beyond that, it becomes a little too rigid in my opinion. It becomes more micromanaging.

I feel like that, in general, and I’m making a general assumption here, most people, I don’t think, like to be micromanaged. So by having some sort of, like what you were talking about, this process here would encourage more people to want to use it.

So the software that you used throughout these, like you said, the Microsoft apps, CAD as far as…

Pro/E and Solidworks. Although we have recently broke AutoCAD back out.

Really? A 3-D version or 2-D version?

2-D. Layouts.

So let’s say for your power transmission project, who all assisted with that?

Technicians. Technicians and tooling guys, guys in the shop.

You didn’t have any co-op or any assistance from any of the other engineers?
I don't think I had a co-op during that time. This is when Alex had his electrical engineering co-op. This would have been late last year (2014).

**Now, do you think that a co-op could have been assigned to this project?**

Do I think a co-op could have been assigned to this project? A more senior co-op, yes, with oversight. And here’s why I say this and this is not…I need to be careful how I answer this. The level of experience they might have when taking something like that that’s malfunctioned that has a significant price tag to it and reengineering a power transmission concept for it. I would feel comfortable letting them explore some options and with guidance and oversight, possibly let them manage the project. Certainly they could take part in it. There’s a lot of CAD that had to be done. A lot of inventory that needed to be ordered. You know, things that needed to be machined certainly would be, you know, in favor of things like that but I don't know that I would say, “Hey, I’m going to turn this over to you.” Now, a senior co-op on the third or fourth rotation, possibly. I've always said that I consider 3\(^{rd}\) and 4\(^{th}\) rotation co-ops to be staff engineers by then, they just don’t have the title. But they have a lot of experience and know-how. They know who to talk to and, you know, there's always that intermediate action with engineering, and particularly with myself to maintain that oversight so possibly could I see turning that over to a co-op, you know.

**Was this this project, was it team-based?**

Team in as much as I was the engineer with, I think, at some point all of my technicians were involved with some level project, in addition to shop assistance. So
yeah, there was a team of folks that had deliverables. It wasn't just a solo project but for this case, I would have be the only mechanical engineer working on the project.

So you were the only mechanical engineer working on the job, period?

Yes, yes, I would say so.

And you said all of the technicians, so five of them?

Yeah, at some point they were all involved with some level of working on the project.

Just wanted to make sure it was first shift or third shift.

Everybody had some level of responsibility.

What about with the buggies?

For Kaizen, it is very team based. We have multiple engineers, multiple technicians, and even some operator assistance with that. Certainly when we were in the planning and presentation phase, everybody was heavily involved. Now that we are in implementation phase, it’s primarily technician with engineering oversight. And both our IE and ME co-ops are heavily involved with it.

So why would you say that they are more involved with the kaizen projects?

What was the primary purpose?

The Kaizen project is huge. It’s basically re-envisioning an entire work cell. That's a bit too big for one person to maintain unless, given the timeframe. It’s a very aggressive timeframe, a very aggressive budget and it needs multiple sets of eyes to make sure one
person doesn’t miss something. If you go back to what I said in the beginning about your deliverables, having your knowns and unknowns, it’s one thing to do it for a singular station, a singular process but you’re talking about an entire workcell. And even though we’re methodical and can break it down into sub-components, at some point you’re going to miss something. With multiple sets of eyes, they’re going to look at it from a different slant whether it’s an IE, a EE, a technician. It's critical for something that big to have a team-based process. And so co-ops, where they plug-in, they’re very involved with designing of the workstations, the process. I’m very pleased with their progress, I think they’re doing a great job.

**How would you describe the overall size of the projects? So let’s continue on with the Kaizen project, you’ve been talking that it’s larger in terms of the overall scope, the number of people involved. So how many people would you say were directly involved?**

We had a dozen people involved at the beginning. We probably have half as many, to three quarters made that are actively involved in the implementation. This is the most expensive Kaizen project we’ve done to date in the factory and it has visibility all the way from the top.

**Really?**

Oh absolutely. We just presented a pared down version of this to our CEO. So it has visibility from the top, down. Particularly, I mean, from the factory level, specifically you know, the general manager on down. All major senior managers are well aware of what
we’re doing. It has, in the last couple days, we presented to the CEO what we’re doing so it has visibility for [Company A]. It's one of those…and when we have our senior managers coming in from overseas, this is going to be one of the things they’re going to be looking at. How are we doing on the Kaizen, absolutely.

What about comparing the Kaizen to the transmission problem? You said it was you, five technicians, and…

A couple of guys in the shop. The scope of the problem didn’t require a huge team. You have to be realistic in how you allocate your resources and so resources in this case are people, okay. I don't need more than one engineer for that, you know. I used all five technicians so they all have a hand in it. So they all have some experience in a project like this. Had I had a co-op during that time, I definitely would have had them involved. It would have been a great learning tool, learning experience. For the Kaizen, there’s no question it's team-based. It has to be team-based to handle something that big, that quick.

And the more point of view?

To make sure we don’t miss stuff. But for something like that where it’s more of a mechanical design, what’s funny about that project is it had a coolness factor to it because every ME, at least on the side (the residential department), including ME managers, stopped by to see how it was going and to watch it run.

I can imagine. I want to see it right now.
I’ve got it on my phone I’ll show you. But yeah, there was definitely a coolness factor to it that you don’t get to do that every day. So yeah, I mean, it did necessitate more than one engineer and I was kind of protecting my turf a little bit cause I was having fun with it and I didn’t want some goober like Gibson to come in and ruin it for me. But yeah, that’s kind of how it went.

I can definitely see that. So how many man-hours were required to complete each of these projects?

Well, the one’s (the Kaizen project) is in process. It’s 1500+ man-hours so far in the Kaizen.

How many are I've been allocated to it against a PSR?

Well, that’s what I’m saying. On paper, 1500 hours so far. In actuality, there is just no way to calculate it, there’s no way to track it. It's an estimate based on, you start with your initial guess and at some point, you say, I probably have three times as many people working on it as I originally intended. So you just scale form there. At best, it’s just a guesstimate.

And can you give any kind of guesstimate on the transmission problem?

Couple hundred hours. Couple hundred dollars when you tally up everybody’s time because it's a project that went over about two months time from start to completion. And so you look at all the shop, the technician time, how much time we spent out there. The odds and ends, it was probably a couple hundred hours.
That’s a really good comparison, especially in terms of size. I know these are different because one is more mechanical while the Kaizen is more process but how would you describe the overall complexity of each of these projects? Which one to you is more complex?

Well, certainly the Kaizen is more complex inasmuch as we’re talking about an entire work cell that you are looking at redesigning processes to make it more efficient. There’s just so many more deliverables. As far as the mechanism itself, having to re-envision from a pure engineering standpoint, mechanical engineering standpoint, the power transmission unit was more complex in that you had to re-envision: How do I get this kinetic energy transferred from this motor/gear reduction unit to this rotary transmission to drive this dial table and meet my requirements of getting it on a tabletop, getting it easily accessible. What was literally a bevel gear type set up, now I’m going to a blower belt equivalent, you know. So re-envisioning how to do that effectively was the more difficult engineering challenge. Complexity is strictly a function, in this case, of the Kaizen event being a bigger scale.

Larger in scale.

Not more difficult engineering-wise, but just bigger scale.

Would you also say dealing with more people also affects that complexity too?

It should simplify it because you’ve got more eyes on it.
Even with the interactions with each other, it wouldn’t affect the complexity there?

I mean I wouldn't say it makes it any more difficult. Everybody has their part.

What type of tools or resources did you use to communicate your ideas with others? Whether it being others on the team or others for the tooling and die for the transmission project?

I think I’m missing something here, I’m not following you here.

If we just focus, let’s say, on the transmission project. So focusing on that, what type of resources did you use to communicate your ideas with others? Whether it be your ideas with the technicians or your ideas with the tool and die guys. Did you use a PowerPoint with them, did you print out prints?

I mean, prints, email, vocal. Very basic, you know.

And then for the Kaizen?

I mean, you've got PowerPoint, you’ve got stuff on paper, you know. I hope I’m not simplifying it too much but stuff on the whiteboard. Your basic, you sit around the table and, you know, put stuff on Excel. I don’t know if that makes sense?

Oh no, it does. If you had an idea outside a meeting, would you email it to the group or would you just write it down and save it for later?
It could be either one, it really depends on how crucial it is to disseminate that information quickly. I mean, if you want it documented, obviously email because you can always go back and say, “Hey, I sent you those.”

And these projects, how were you first introduced to them?

Well, I was introduced to the transmission unit when it failed and we couldn’t run the machine. I was introduced to the Kaizen event when the boss comes in and says, “Hey, you’re in charge of this.”

So, it’s primarily verbal communication?

The coil former was quite auditory: crunch, uh oh. Technicians walk in, you might want to come see this.

No good. And the Kaizen one, when you said the boss came.

The boss sat in that very chair and said, you’re in charge of this. Ok, thanks…

With the exception of parts breaking down, would you say someone coming in and telling you, “Hey, I need you to work on this project,” is that most common or is it more common to receive an email?

Both.

Both equally common?

Yeah.
Is there any kind of format to any of this?

This is [Company A] (no).

I have to ask… I’m pretty sure I know the answer.

You know the answer. No, there’s no format to it. I mean, you may get assigned something in one of the weekly (continuous improvement) meetings but in general, he’s going to come in and say, “Hey, I want you on this.” Usually, it’s verbal because he’s got to explain to you what he wants done. There’s going to be a lot of questions and whatnot.

So it’s almost better to have that interview type introduction?

I’d say it’s absolutely required.

How were these projects initially defined? Not the transmission project because you said that was a crunch and you were brought out there by the technicians.

Quite literally.

The Kaizen project, how did your boss initially come in here and be like, “Hey, I need you to work on this.” Did he give you just a general explanation that we need this line redesigned for a Kaizen event or was it just, I need you to do something, get it done, and it’s up to you as to how you get it done.

No, I mean, it was explained that this was the next Kaizen event and it’s kind of understood when you’re going to do a Kaizen event, you know, what’s the goal of a Kaizen event? Now, they had to call me in and break down what were the specific
management driven objectives, budget, things of that nature; give you your goals and constraints. But once you have those, it’s kind of a blank sheet. Assemble the team and, you know, list out the goals and constraints and start going through the process. Now, to me, it’s probably not as documented as it should be but there is a process to going through a Kaizen event. So, as you go through the process, it forces you to answer specific questions that help you to get to your solution, or your proposed solution.

So now while you’re going through these projects, how often do you have design reviews? Well, for the transmission project, how often would you have peer reviews and at least review your design with someone?

I say this half cocked, with that project, it was almost daily review because I always had someone crawling over it looking at it with me and, “Hey man, what’re you doing? How’re you going to solve this? What’s this for? Why are you doing this?”

Because of all the interest in it?

Oh yeah, it was more informal. Like I said, there was a coolness factor to it that we don’t normally get to work on. Usually, it’s very cut and dry, replace this, fix that. This one was like, there was no obvious solution. We had to reengineer it mechanically to see if we could even get it to work. There was a little bit of trepidation once we had it all bolted together to see if we could get it to work. Confidence was high, but until you see it in operation, is it going to go?

The uncertainty there…
Yeah, there was a little bit of uncertainty. The best laid plans are only as good as their execution. That executes well or they execute me.

Well, good thing it executed well… So then, how many formal design reviews did you have for that project?

Maybe one.

Who was involved in that?

Manager and other ME’s. Anyone that could give me constructed feedback.

Was it mainly just the manufacturing group or did you invite anyone from R&D?

No, absolutely not. Just manufacturing guys.

You were talking about having presented the Kaizen stuff to the CEO.

Oh, that was senior management.

You’ve done that with senior management and with local level?

Every senior manager in the factory plus our CEO has been represented to at this point.

That’s incredible now that I think about it that it has the direct attention of the CEO there.
Well, it was one of those where he comes in to visit and you want to show him a lot of the work that has been going on in the factory. This was one of the projects that was selected cause it’s in implementation phase so it was easy to say, “Hey, it’s already been approved, there’s already a presentation. Cut it down to 15 minutes and you’ve got his full attention.”

Ok

One of those deals.

Alrighty, so the transmission, that’s still in use?

Yep.

Have any modifications been made to it since it was first put out there?

Tweaks, tuning.

Ok. Do you think anything could have been prevented with the checklist? Could any of those tweaks have been prevented or is that just one of those things?

No, it’s one of those where when you get to fit and function… CAD’s going to get you so far.

Any major concerns about it? Anticipated lifespan?

No, because of the way it’s designed, all components should be readily accessible, replaceable. Fairly straight forward.
Any final reflections on these projects at all?

Nothing I can think of. They’re all worthy projects, fairly straight forward. Some forced upon you, the nature of the beast. Others planned but they’re cost savings at the end of the day and, I think, worthwhile.

It helps with production.

Absolutely. They both help the factory for sure.

B.2 A.ME.2 – Brad

SO: The purpose of this is for my research at Clemson where from my experiences in the capstone program and then senior program we design primarily in teams of 3, 4, or 5 students and we work on a project together as in that team. Well, when coming here, the most interaction in a team that I have received was maybe working on a project with or maybe getting some assistance from one of the test engineers whether it be like mainly it was Brian Williams. Or it would be one of the techs. And that would be it. So I just wanted to come here and get y’all’s experiences since y'all have been working here much longer than me. Y’all have more experience than I do. I just wanted to see if your insight is the same as mine but hopefully what will come out of this is that if most of the work you do is more individual rather directly in teams then there might be some sort of process of some sort of tool or even software that I could potentially develop or recommend and then you could potentially use it here or someone at some other company so the end goal
of this is to try to help increase efficiency and quality the overall ability of the engineer especially if they’re new like I was when I first started. And increasing the ability to hit the ground running might be helpful.

So I have to get these introductory questions first: what is your position title and description, and how many years have you been at this position?

Brad: Lead manufacturing engineer is the title. I’ve been in this particular role since probably 2006/2007 so 8 or 9 years.

And what exactly are your responsibilities in that role?

Well manufacturing engineer, first and foremost, supporting production, supporting departmental initiatives and filtering those down through the group such as PSR's, manufacturing qualifications, 5S initiatives. Right now, I’m leading a Kaizen team so any number of focus factory and departmental goals that need to be filtered down to the group. Maintaining capital budget, mechanical design reviews, things like that. You know, all of the above our part my responsibilities but first and foremost of these would be supporting production, project management, things like that.

Ok. So what was your previous design experience within [Company A]?

I mean…if we’re talking in a current manufacturing engineering role, when I first started back in ’99, it might be designing fixtures, designing tooling in Pro/E for production. As I’ve gone room and, I guess, progressed over time, I still support that, but not to the same degree that some of the other guys in the group do. I've seen my
responsibilities shift to more project management as compared to down in the trenches, nuts and bolts, designing fixtures. I still do that from time to time but that's not one of the things it would be one of my big portion of my plate right now.

**What other companies have you worked for?**

Milliken and Company at their finishing plant in Pendleton. Co-oped at Metler Toledo back in the mid-90s. but I’ve been at [Company A] since ’99.

**What type of work did you do for those other companies?**

Very similar to what, I guess, a typical co-op or intern would do. Some basic CAD work, some basic data collection. A little bit of fixture design. At Milliken I also did some inventory control, did some 5S, stuff like that.

**Have you attended any workshops or taken any specific classes on designing, and more importantly, either design in general or how to design on your own as an individual rather than in teams?**

So let’s clarify, when talking design, you know, you mean with a CAD package designing a specific mechanism or something?

**Yeah, whether it be with CAD or whether it be just having to have something sketched out and then potentially presented to someone before actually going to CAD. Any kind of design work whether it be for fixture or tooling.**
I mean, above and beyond what I took in school, I don't believe. It’s one of those things where I’ve refined my craft over the years. Learning from mentors, learning from senior engineers, watching the process, learning as I go and perfecting it through time.

So what kind of stuff would you say you’ve learned throughout your experiences?

Learning the design process, you know, to identify what are the key parameters before you sit down on the CAD package and start to, start to sketch it out: what are you trying to accomplish? What are your space constraints? What, if any, budgetary constraints do you have which will affect your selection of materials. Are there any safety considerations that have been identified ahead of time? So mainly getting all the prep work done and answered before you sit down in front of the computer to start the design so that you don't find out halfway through it, “Oh I had to make sure this was a nonconductive material,” or “Oh it needs to be mobile. I had this on a table top.” Getting all your ducks in a row before you sit down to do it is the biggest, you know, it sounds trivial but a lot of people even now don't do that correctly, in my opinion, and they have to go back and rev their design 2, 3, 4 times because they didn't have all the information they needed. Now sometimes that information is not easily come by, but you get as much of it as you can. So one thing, if we had a designer’s kit, and this is just thinking matter of fact, a designer’s kit that forces you to answer specific questions up front, as much as possible. For example, “Are there safety considerations?” , “Is this a mobile device?”, “Is this intended to be a standalone machine?” , “Is it tabletop?” Selection of materials, you
know, does it need to be ESD? What type of product is going to go into it? Does it need to be guarded? Is it just simple mechanisms or is there going to be kinetic energy devices such as hydraulic schematics, servos that need light curtains. All of these things, if they’re answered up front, you going to design with that in mind. So, if we had a checklist, maybe the standard, you know…

That almost sets up your design space for you.

It really forces you down the correct path because if you can answer these questions up front, then when you actually sit down and start putting the mechanism together in your mind on the computer, “Oh yeah, I remember I’ve got to have ESD shelving. Oh, I’m going to have to have light curtains on this because I'm using, you know, half-inch four pneumatic cylinders to do this action or whatever it is. Make sure you know dot your I’s and cross your T’s. So one of those, I mean a lot of times we do it naturally, we go and write stuff down a piece of paper in a notebook but if we had a checklist that formalizes that this is part of the design process, answer these questions as much as possible. And if there's a problem you can always go back to your checklist and say, “why isn't this right?” Well, this is the assumptions I had when I went into it. Maybe the assumptions change. Maybe what was supposed to be a fixed benchtop type of mechanism, well now they want to roll it from cell to cell so it needs to be mobile. Well, if there’s changes that are required later, you can at least go back to say, “Hey, when I started the process, my checklist said this was benchtop and this was a fixed asset. Now somebody has changed into a mobile device down the road. So, if it takes three more
weeks to finish this and another 1000 to 1500 dollars to modify it, you’ve got your documentation that says, “Hey, when I started the project, these were the assumptions.” So it's always good to have that information up front.

So would having some sort of a pre-populated list of topics to go through that forces you to go through a general listing of every subject, whether it be safety, ESD, material selection, would you say that would be helpful?

I think particularly for the guys that are new, for co-ops, for those that aren’t used to the design process that need to perfect their craft. I think having something more formal like that forces them to think about some of the issues that we take for granted as a more senior designer. You know, we go through the checklist in our head and even now, we’ll miss stuff and if we had it on a paper or whatever, in front of us the whole time, you know, even that would help a seasoned engineer to make sure to keep all their information straight. It's just like solving any kind of technical problem. You list your assumptions first before you try to solve the problem. This is no different: you list your assumptions up front, you knowns, and your assumptions and then you start your design. And when you get to the end you ought to be able to look at your designs and say, “Yep, light curtains, check that out for guarding,” “yep, I’ve got ESD and that’s grounded. Check that off for that, you know.” You ought to be able to look at your finished design and look at your list of knowns and assumptions, and every one of those is satisfied in the design. And if they’re not, you’ve missed something. You didn’t pay attention to the information you had.
Now let’s get into some of the projects you’ve worked on. That’s what the remainder of these questions will focus on. So can you describe your most recent design project that you’ve completed?

We had to do a redesign on the power transmission unit for the old coil-forming machine. The rotary transmission unit for the dial table failed. The drive gear basically destructed, self-destructed and it was about a $45,000 replacement and it wasn't a drop in to get the power transmission unit. The way it was set up was not easily to work on. You had to crawl under the machine, pull the motor and the clutch. So we decided to reengineer it in-house and take the components that worked on the rotary transmission and design and install a new power transmission unit to drive the rotary to drive the dial table. So it was really cool. About a $43,000 cost-savings as well. So basically taking known mechanical concepts on power transmission, we got the drive unit from underneath table, mounted it tabletop so it’s easily accessible. Basically, took the equivalent of a blower belt, a big 1.5-inch wide belt that would transmit power from the motor gear reduction unit to the input shaft for the rotary transmission. Getting that all built and designed and operational, we can go look at that anytime you want to go look at that.

Might have to take a look at that, that’s pretty exciting.

It's pretty neat, I’ve got some pictures to show you. Matter of fact, I know I do on my phone. So going through that design process was neat and, you know, again having the checklist available and have it posted out there and make sure we’re meeting all those
requirements would've been an advantage. We miss some stuff, you know. It's one of those particularly, designing mechanisms for a production environment, you’ve got time pressures, you’ve got budgetary considerations, and you miss stuff. And so any information that we can get solidified up front and have it right there in our face the whole time would be a help.

Now, what about a second challenging project that you best remember. It doesn’t have to be recent.

Well, I mean, right now so when we talk design, it can be anything from fixtures to workstations. So right now, our Kaizen event for semi-auto, we’re designing new works, basically a new work cell, so the design concepts that we’re talking about are scalable you know, your checklist is still the same, your requirements, your knowns, your unknowns. It’s all of these different things. You just have to break it down into subcomponents so that even though I've got the big picture in mind, I need to apply these concepts to each of the subcomponents that go into that cell. So for all of our flow channels, all of our buggies, all of our carts and workstations, the process remains same even though we’re focusing on one small subcomponent of the larger cell. So right now, we’re designing carts, buggies, and workstations to do specific tasks and assembly steps. So we’re having to consider things like grounding and ESD, mobility, modular design, ergonomics. All of these things, we have to take into account so not to be a broken record but all these things we talked about for the last project and in general, these checklists, these stating your facts and knowns and assumptions, you know. For every one of these
designs that we’re doing, having that information available, it provides continuity of thought on work, how your designing each station and what not. You know, having continuity of the lessons learned. Ok, if you’re going to do something like this: if you have meters on a shelf, it needs to be this type of material. This is the part number and specs for it.

So for the transmission redesign, what type of project would you say that is? The examples I have here are tooling and fixture design, process design. I wouldn’t think that falls under that. Would you say it’s almost the station partial redesign?

Yeah, I mean that not really even tooling. Machinery redesign and upgrade, if you want.

The buggies and the flow process…

I mean, that’s machinery equipment. That’s process as much as it is anything.

In general, how many design projects are you assigned either per year, or if it is easier, per month?

How about per week?

Well we could take an average per week and multiply it by 50, assuming 2 weeks off.
I mean, you know, there's no general blanket answer for that. For me, personally, maybe not as much as the other guys. I might have one or two things going per week that carry-on over multiple weeks.

Is it really because you’re overseeing projects?

Yeah, I mean, it’s more project management. A lot of it is for me so I might have one or two or three designs that might go for months because they’re larger or it takes time to get stuff built and different things and you follow through to completion. So maybe a dozen to a dozen and a half over a calendar year but when you talk about but, you know, when you’re talking about buggies and carts and mechanisms and fixtures and tooling. When you talk about true design work for me, that's a good, good number of projects throughout the year when you figure you’re still doing production support, paperwork, and all the different project management that comes along with these things.

Ok, so how about just projects in general. Not only design but also with other production, other, let’s say your you put on a 6S…

So a couple of ways to answer that. If we’re talking just like major projects that are tracked with budgets and hours and PSR's and whatnot, probably a dozen in a calendar year is good number. But when you talk about everything else that goes with it, the smaller not as visible projects, the fire fighting, the we need to design something to repair something on the line, I mean, it could be several dozen, you know. It really depends on how granular you want to get but as far as measurable tracked projects that management
is inclined to request updates on what the tracking on and whatnot, maybe a dozen or so in a calendar year.

**Ok, and what resources do you typically use throughout these projects? Whether it be software, hardware, tooling, people.**

Oh gosh, there’s a myriad of resources between CAD packages, any number of Microsoft products like PowerPoint, Excel, Word for communications, any number of homegrown: Dashboard, EIS, RIS, we’ve got a lot of homegrown apps that we use. I guess what I’ll call indigenous software, stuff like Brainson has their own stuff or MiniTab, things like that. Reference books, you know, my mechanics book, I’ll use that quite often during the design process. Any number of webpages where you go out and do a Google search, “Ok, I need to know about pitch angle on this kind of thread,” or what kind of fasteners to use, rules of thumb for whatever it is you’re looking for. I mean, there's any number of resources that you can use. Pick your neighbor’s brain, I mean literally. If you have tooling questions, you ask your tool and die guys. Electrical questions, you’ll hit up your test engineers or whatever. Any number of places to go to get the answers you seek.

**And so, we've been talking about how you go through and look at a project and you try to break it down to what you need for the project. Do you have an overarching specified procedure that you tend to follow? Do you have that documented somewhere or is it just from your experience?**
Experience. That’s why I say when you first come on, you’ve got to refine your craft and you’re going to learn by your mistakes, you’re going to get lessons learned that you apply to subsequent projects and processes so... I don’t know that you need an overarching set of rules and documents because it tends to limit innovation. But what you need is the upfront information to get you from point A to point B. How you get to point B could be any number ways. And there’s where I wouldn’t wouldn't want to be limited to I have to do this process or I have to follow this.

So that makes a lot of sense. You don't want to go...you want to set someone up help or help set a designer up but not...

A procedure should be to the benefit the designer. So when I say have a checklist of things you need to answer ahead of time, that's helpful, that's not a hindrance. Having a procedure that says okay you’ve got to do this, this, this, and this during your design process. If it's high-level, I see benefit in it. You know, for example, okay you’ve got X number of things you need to do through the whole process. Number one, fill out your free checklist, whatever you want to call it, listing your knowns and assumptions. Before you go to print have a peer review. Before you go tooling, have your designs checked for accuracy in your prints, okay. And then when you go to receive your tooling, your machined components, maybe have some quality checks on them that you have two or three dimensions checked for accuracy before you assemble, okay. And before you release to production your design, do some fit and function to make sure that all of your assumptions at the very beginning are satisfied when you go to do fit and function. I
could see something like that’s just some basic and reasonable deliverables as you go from concept to completion, but anything more rigid than that, to me, becomes a hindrance because now I’m more concerned with the process that I am the design and I don’t want to get to that point. I want to stay focused on the design, you know, if it's just meeting some basic deliverables as we go that's reasonable but beyond that, it becomes a little too rigid in my opinion. It becomes more micromanaging.

I feel like that, in general, and I’m making a general assumption here, most people, I don’t think, like to be micromanaged. So by having some sort of, like what you were talking about, this process here would encourage more people to want to use it.

So the software that you used throughout these, like you said, the Microsoft apps, CAD as far as…

Pro/E and Solidworks. Although we have recently broke AutoCAD back out.

Really? A 3-D version or 2-D version?

2-D. Layouts.

So let’s say for your power transmission project, who all assisted with that?

Technicians. Technicians and tooling guys, guys in the shop.

You didn’t have any co-op or any assistance from any of the other engineers?
I don't think I had a co-op during that time. This is when Alex had his electrical engineering co-op. This would have been late last year (2014).

**Now, do you think that a co-op could have been assigned to this project?**

Do I think a co-op could have been assigned to this project? A more senior co-op, yes, with oversight. And here’s why I say this and this is not…I need to be careful how I answer this. The level of experience they might have when taking something like that that’s malfunctioned that has a significant price tag to it and reengineering a power transmission concept for it. I would feel comfortable letting them explore some options and with guidance and oversight, possibly let them manage the project. Certainly they could take part in it. There’s a lot of CAD that had to be done. A lot of inventory that needed to be ordered. You know, things that needed to be machined certainly would be, you know, in favor of things like that but I don't know that I would say, “Hey, I’m going to turn this over to you.” Now, a senior co-op on the third or fourth rotation, possibly. I've always said that I consider 3rd and 4th rotation co-ops to be staff engineers by then, they just don’t have the title. But they have a lot of experience and know-how. They know who to talk to and, you know, there's always that intermediate action with engineering, and particularly with myself to maintain that oversight so possibly could I see turning that over to a co-op, you know.

**Was this this project, was it team-based?**

Team in as much as I was the engineer with, I think, at some point all of my technicians were involved with some level project, in addition to shop assistance. So
yeah, there was a team of folks that had deliverables. It wasn't just a solo project but for this case, I would have be the only mechanical engineer working on the project.

So you were the only mechanical engineer working on the job, period?

Yes, yes, I would say so.

And you said all of the technicians, so five of them?

Yeah, at some point they were all involved with some level of working on the project.

Just wanted to make sure it was first shift or third shift.

Everybody had some level of responsibility.

What about with the buggies?

For Kaizen, it is very team based. We have multiple engineers, multiple technicians, and even some operator assistance with that. Certainly when we were in the planning and presentation phase, everybody was heavily involved. Now that we are in implementation phase, it’s primarily technician with engineering oversight. And both our IE and ME co-ops are heavily involved with it.

So why would you say that they are more involved with the kaizen projects?

What was the primary purpose?

The Kaizen project is huge. It’s basically re-envisioning an entire work cell. That's a bit too big for one person to maintain unless, given the timeframe. It’s a very aggressive timeframe, a very aggressive budget and it needs multiple sets of eyes to make sure one
person doesn’t miss something. If you go back to what I said in the beginning about your deliverables, having your knowns and unknowns, it’s one thing to do it for a singular station, a singular process but you’re talking about an entire workcell. And even though we’re methodical and can break it down into sub-components, at some point you’re going to miss something. With multiple sets of eyes, they’re going to look at it from a different slant whether it’s an IE, a EE, a technician. It's critical for something that big to have a team-based process. And so co-ops, where they plug-in, they’re very involved with designing of the workstations, the process. I’m very pleased with their progress, I think they’re doing a great job.

**How would you describe the overall size of the projects?** So let’s continue on with the Kaizen project, you’ve been talking that it’s larger in terms of the overall scope, the number of people involved. So how many people would you say were directly involved?

We had a dozen people involved at the beginning. We probably have half as many, to three quarters made that are actively involved in the implementation. This is the most expensive Kaizen project we’ve done to date in the factory and it has visibility all the way from the top.

**Really?**

Oh absolutely. We just presented a pared down version of this to our CEO. So it has visibility from the top, down. Particularly, I mean, from the factory level, specifically you know, the general manager on down. All major senior managers are well aware of what
we’re doing. It has, in the last couple days, we presented to the CEO what we’re doing so it has visibility for [Company A]. It's one of those…and when we have our senior managers coming in from overseas, this is going to be one of the things they’re going to be looking at. How are we doing on the Kaizen, absolutely.

**What about comparing the Kaizen to the transmission problem? You said it was you, five technicians, and…**

A couple of guys in the shop. The scope of the problem didn’t require a huge team. You have to be realistic in how you allocate your resources and so resources in this case are people, okay. I don't need more than one engineer for that, you know. I used all five technicians so they all have a hand in it. So they all have some experience in a project like this. Had I had a co-op during that time, I definitely would have had them involved. It would have been a great learning tool, learning experience. For the Kaizen, there’s no question it's team-based. It has to be team-based to handle something that big, that quick.

**And the more point of view?**

To make sure we don’t miss stuff. But for something like that where it’s more of a mechanical design, what’s funny about that project is it had a coolness factor to it because every ME, at least on the side (the residential department), including ME managers, stopped by to see how it was going and to watch it run.

**I can imagine. I want to see it right now.**
I’ve got it on my phone I’ll show you. But yeah, there was definitely a coolness factor to it that you don’t get to do that every day. So yeah, I mean, it did necessitate more than one engineer and I was kind of protecting my turf a little bit cause I was having fun with it and I didn’t want some goober like Gibson to come in and ruin it for me. But yeah, that’s kind of how it went.

I can definitely see that. So how many man-hours were required to complete each of these projects?

Well, the one’s (the Kaizen project) is in process. It’s 1500+ man-hours so far in the Kaizen.

How many are I've been allocated to it against a PSR?

Well, that’s what I’m saying. On paper, 1500 hours so far. In actuality, there is just no way to calculate it, there’s no way to track it. It's an estimate based on, you start with your initial guess and at some point, you say, I probably have three times as many people working on it as I originally intended. So you just scale form there. At best, it’s just a guesstimate.

And can you give any kind of guesstimate on the transmission problem?

Couple hundred hours. Couple hundred dollars when you tally up everybody’s time because it's a project that went over about two months time from start to completion. And so you look at all the shop, the technician time, how much time we spent out there. The odds and ends, it was probably a couple hundred hours.
That’s a really good comparison, especially in terms of size. I know these are different because one is more mechanical while the Kaizen is more process but how would you describe the overall complexity of each of these projects? Which one to you is more complex?

Well, certainly the Kaizen is more complex inasmuch as we’re talking about an entire work cell that you are looking at redesigning processes to make it more efficient. There’s just so many more deliverables. As far as the mechanism itself, having to re-envision from a pure engineering standpoint, mechanical engineering standpoint, the power transmission unit was more complex in that you had to re-envision: How do I get this kinetic energy transferred from this motor/gear reduction unit to this rotary transmission to drive this dial table and meet my requirements of getting it on a tabletop, getting it easily accessible. What was literally a bevel gear type set up, now I’m going to a blower belt equivalent, you know. So re-envisioning how to do that effectively was the more difficult engineering challenge. Complexity is strictly a function, in this case, of the Kaizen event being a bigger scale.

Larger in scale.

Not more difficult engineering-wise, but just bigger scale.

Would you also say dealing with more people also affects that complexity too?

It should simplify it because you’ve got more eyes on it.
Even with the interactions with each other, it wouldn’t affect the complexity there?

I mean I wouldn't say it makes it any more difficult. Everybody has their part.

What type of tools or resources did you use to communicate your ideas with others? Whether it being others on the team or others for the tooling and die for the transmission project?

I think I’m missing something here, I’m not following you here.

If we just focus, let’s say, on the transmission project. So focusing on that, what type of resources did you use to communicate your ideas with others? Whether it be your ideas with the technicians or your ideas with the tool and die guys. Did you use a PowerPoint with them, did you print out prints?

I mean, prints, email, vocal. Very basic, you know.

And then for the Kaizen?

I mean, you've got PowerPoint, you’ve got stuff on paper, you know. I hope I’m not simplifying it too much but stuff on the whiteboard. Your basic, you sit around the table and, you know, put stuff on Excel. I don’t know if that makes sense?

Oh no, it does. If you had an idea outside a meeting, would you email it to the group or would you just write it down and save it for later?
It could be either one, it really depends on how crucial it is to disseminate that information quickly. I mean, if you want it documented, obviously email because you can always go back and say, “Hey, I sent you those.”

**And these projects, how were you first introduced to them?**

Well, I was introduced to the transmission unit when it failed and we couldn’t run the machine. I was introduced to the Kaizen event when the boss comes in and says, “Hey, you’re in charge of this.”

**So, it’s primarily verbal communication?**

The coil former was quite auditory: crunch, uh oh. Technicians walk in, you might want to come see this.

**No good. And the Kaizen one, when you said the boss came.**

The boss sat in that very chair and said, you’re in charge of this. Ok, thanks…

**With the exception of parts breaking down, would you say someone coming in and telling you, “Hey, I need you to work on this project,” is that most common or is it more common to receive an email?**

Both.

**Both equally common?**

Yeah.
Is there any kind of format to any of this?

This is [Company A] (no).

I have to ask… I’m pretty sure I know the answer.

You know the answer. No, there’s no format to it. I mean, you may get assigned something in one of the weekly (continuous improvement) meetings but in general, he’s going to come in and say, “Hey, I want you on this.” Usually, it’s verbal because he’s got to explain to you what he wants done. There’s going to be a lot of questions and whatnot.

So it’s almost better to have that interview type introduction?

I’d say it’s absolutely required.

How were these projects initially defined? Not the transmission project because you said that was a crunch and you were brought out there by the technicians.

Quite literally.

The Kaizen project, how did your boss initially come in here and be like, “Hey, I need you to work on this.” Did he give you just a general explanation that we need this line redesigned for a Kaizen event or was it just, I need you to do something, get it done, and it’s up to you as to how you get it done.

No, I mean, it was explained that this was the next Kaizen event and it’s kind of understood when you’re going to do a Kaizen event, you know, what’s the goal of a Kaizen event? Now, they had to call me in and break down what were the specific
management driven objectives, budget, things of that nature; give you your goals and constraints. But once you have those, it’s kind of a blank sheet. Assemble the team and, you know, list out the goals and constraints and start going through the process. Now, to me, it’s probably not as documented as it should be but there is a process to going through a Kaizen event. So, as you go through the process, it forces you to answer specific questions that help you to get to your solution, or your proposed solution.

So now while you’re going through these projects, how often do you have design reviews? Well, for the transmission project, how often would you have peer reviews and at least review your design with someone?

I say this half cocked, with that project, it was almost daily review because I always had someone crawling over it looking at it with me and, “Hey man, what’re you doing? How’re you going to solve this? What’s this for? Why are you doing this?”

Because of all the interest in it?

Oh yeah, it was more informal. Like I said, there was a coolness factor to it that we don’t normally get to work on. Usually, it’s very cut and dry, replace this, fix that. This one was like, there was no obvious solution. We had to reengineer it mechanically to see if we could even get it to work. There was a little bit of trepidation once we had it all bolted together to see if we could get it to work. Confidence was high, but until you see it in operation, is it going to go?

The uncertainty there…
Yeah, there was a little bit of uncertainty. The best laid plans are only as good as their execution. That executes well or they execute me.

Well, good thing it executed well... So then, how many formal design reviews did you have for that project?

Maybe one.

Who was involved in that?

Manager and other ME’s. Anyone that could give me constructed feedback.

Was it mainly just the manufacturing group or did you invite anyone from R&D?

No, absolutely not. Just manufacturing guys.

You were talking about having presented the Kaizen stuff to the CEO.

Oh, that was senior management.

You’ve done that with senior management and with local level?

Every senior manager in the factory plus our CEO has been represented to at this point.

That’s incredible now that I think about it that it has the direct attention of the CEO there.
Well, it was one of those where he comes in to visit and you want to show him a lot of the work that has been going on in the factory. This was one of the projects that was selected cause it’s in implementation phase so it was easy to say, “Hey, it’s already been approved, there’s already a presentation. Cut it down to 15 minutes and you’ve got his full attention.”

Ok

One of those deals.

Alrighty, so the transmission, that’s still in use?

Yep.

Have any modifications been made to it since it was first put out there?

Tweaks, tuning.

Ok. Do you think anything could have been prevented with the checklist? Could any of those tweaks have been prevented or is that just one of those things?

No, it’s one of those where when you get to fit and function… CAD’s going to get you so far.

Any major concerns about it? Anticipated lifespan?

No, because of the way it’s designed, all components should be readily accessible, replaceable. Fairly straight forward.
Any final reflections on these projects at all?

Nothing I can think of. They’re all worthy projects, fairly straight forward. Some forced upon you, the nature of the beast. Others planned but they’re cost savings at the end of the day and, I think, worthwhile.

It helps with production.

Absolutely. They both help the factory for sure.

B.3 A.ME.3 – Chris

SO: The purpose of this is for my research at Clemson where from my experiences in the capstone program and then senior program we design primarily in teams of 3, 4, or 5 students and we work on a project together as in that team. Well, when coming here, the most interaction in a team that I have received was maybe working on a project with or maybe getting some assistance from one of the test engineers whether it be like mainly it was Brian Williams. Or it would be one of the techs. And that would be it. So I just wanted to come here and get y’all’s experiences since y'all have been working here much longer than me. Y’all have more experience than I do. I just wanted to see if your insight is the same as mine but hopefully what will come out of this is that if most of the work you do is more individual rather directly in teams then there might be some sort of process of some sort of tool or even software that I could potentially develop or recommend and then you could potentially use it here or someone at some other company so the end goal
of this is to try to help increase efficiency and quality the overall ability of the engineer especially if they’re new like I was when I first started. And increasing the ability to hit the ground running might be helpful.

So I have to get these introductory questions first: what is your position title and description, and how many years have you been at this position?

Brad: Lead manufacturing engineer is the title. I’ve been in this particular role since probably 2006/2007 so 8 or 9 years.

And what exactly are your responsibilities in that role?

Well manufacturing engineer, first and foremost, supporting production, supporting departmental initiatives and filtering those down through the group such as PSR’s, manufacturing qualifications, 5S initiatives. Right now, I’m leading a Kaizen team so any number of focus factory and departmental goals that need to be filtered down to the group. Maintaining capital budget, mechanical design reviews, things like that. You know, all of the above our part my responsibilities but first and foremost of these would be supporting production, project management, things like that.

Ok. So what was your previous design experience within [Company A]?

I mean…if we’re talking in a current manufacturing engineering role, when I first started back in ’99, it might be designing fixtures, designing tooling in Pro/E for production. As I’ve gone room and, I guess, progressed over time, I still support that, but not to the same degree that some of the other guys in the group do. I’ve seen my
responsibilities shift to more project management as compared to down in the trenches, nuts and bolts, designing fixtures. I still do that from time to time but that's not one of the things it would be one of my big portion of my plate right now.

**What other companies have you worked for?**

Milliken and Company at their finishing plant in Pendleton. Co-oped at Metler Toledo back in the mid-90s. but I’ve been at [Company A] since ’99.

**What type of work did you do for those other companies?**

Very similar to what, I guess, a typical co-op or intern would do. Some basic CAD work, some basic data collection. A little bit of fixture design. At Milliken I also did some inventory control, did some 5S, stuff like that.

**Have you attended any workshops or taken any specific classes on designing, and more importantly, either design in general or how to design on your own as an individual rather than in teams?**

So let’s clarify, when talking design, you know, you mean with a CAD package designing a specific mechanism or something?

Yeah, whether it be with CAD or whether it be just having to have something sketched out and then potentially presented to someone before actually going to CAD. Any kind of design work whether it be for fixture or tooling.
I mean, above and beyond what I took in school, I don't believe. It’s one of those things where I’ve refined my craft over the years. Learning from mentors, learning from senior engineers, watching the process, learning as I go and perfecting it through time.

So what kind of stuff would you say you’ve learned throughout your experiences?

Learning the design process, you know, to identify what are the key parameters before you sit down on the CAD package and start to, start to sketch it out: what are you trying to accomplish? What are your space constraints? What, if any, budgetary constraints do you have which will affect your selection of materials. Are there any safety considerations that have been identified ahead of time? So mainly getting all the prep work done and answered before you sit down in front of the computer to start the design so that you don't find out halfway through it, “Oh I had to make sure this was a nonconductive material,” or “Oh it needs to be mobile. I had this on a table top.” Getting all your ducks in a row before you sit down to do it is the biggest, you know, it sounds trivial but a lot of people even now don't do that correctly, in my opinion, and they have to go back and rev their design 2, 3, 4 times because they didn't have all the information they needed. Now sometimes that information is not easily come by, but you get as much of it as you can. So one thing, if we had a designer’s kit, and this is just thinking matter of fact, a designer’s kit that forces you to answer specific questions up front, as much as possible. For example, “Are there safety considerations?”, “Is this a mobile device?”, “Is this intended to be a standalone machine?”, “Is it tabletop?” Selection of materials, you
know, does it need to be ESD? What type of product is going to go into it? Does it need to be guarded? Is it just simple mechanisms or is there going to be kinetic energy devices such as hydraulic schematics, servos that need light curtains. All of these things, if they’re answered up front, you going to design with that in mind. So, if we had a checklist, maybe the standard, you know…

That almost sets up your design space for you.

It really forces you down the correct path because if you can answer these questions up front, then when you actually sit down and start putting the mechanism together in your mind on the computer, “Oh yeah, I remember I’ve got to have ESD shelving. Oh, I’m going to have to have light curtains on this because I'm using, you know, half-inch four pneumatic cylinders to do this action or whatever it is. Make sure you know dot your I’s and cross your T’s. So one of those, I mean a lot of times we do it naturally, we go and write stuff down a piece of paper in a notebook but if we had a checklist that formalizes that this is part of the design process, answer these questions as much as possible. And if there's a problem you can always go back to your checklist and say, “why isn't this right?” Well, this is the assumptions I had when I went into it. Maybe the assumptions change. Maybe what was supposed to be a fixed benchtop type of mechanism, well now they want to roll it from cell to cell so it needs to be mobile. Well, if there’s changes that are required later, you can at least go back to say, “Hey, when I started the process, my checklist said this was benchtop and this was a fixed asset. Now somebody has changed into a mobile device down the road. So, if it takes three more
weeks to finish this and another 1000 to 1500 dollars to modify it, you’ve got your documentation that says, “Hey, when I started the project, these were the assumptions.” So it's always good to have that information up front.

**So would having some sort of a pre-populated list of topics to go through that forces you to go through a general listing of every subject, whether it be safety, ESD, material selection, would you say that would be helpful?**

I think particularly for the guys that are new, for co-ops, for those that aren’t used to the design process that need to perfect their craft. I think having something more formal like that forces them to think about some of the issues that we take for granted as a more senior designer. You know, we go through the checklist in our head and even now, we’ll miss stuff and if we had it on a paper or whatever, in front of us the whole time, you know, even that would help a seasoned engineer to make sure to keep all their information straight. It's just like solving any kind of technical problem. You list your assumptions first before you try to solve the problem. This is no different: you list your assumptions up front, you knowns, and your assumptions and then you start your design. And when you get to the end you ought to be able to look at your designs and say, “Yep, light curtains, check that out for guarding,” “yep, I’ve got ESD and that’s grounded. Check that off for that, you know.” You ought to be able to look at your finished design and look at your list of knowns and assumptions, and every one of those is satisfied in the design. And if they’re not, you’ve missed something. You didn’t pay attention to the information you had.
Now let’s get into some of the projects you’ve worked on. That’s what the remainder of these questions will focus on. So can you describe your most recent design project that you’ve completed?

We had to do a redesign on the power transmission unit for the old coil-forming machine. The rotary transmission unit for the dial table failed. The drive gear basically destructed, self-destructed and it was about a $45,000 replacement and it wasn't a drop in to get the power transmission unit. The way it was set up was not easily to work on. You had to crawl under the machine, pull the motor and the clutch. So we decided to reengineer it in-house and take the components that worked on the rotary transmission and design and install a new power transmission unit to drive the rotary to drive the dial table. So it was really cool. About a $43,000 cost-savings as well. So basically taking known mechanical concepts on power transmission, we got the drive unit from underneath table, mounted it tabletop so it’s easily accessible. Basically, took the equivalent of a blower belt, a big 1.5-inch wide belt that would transmit power from the motor gear reduction unit to the input shaft for the rotary transmission. Getting that all built and designed and operational, we can go look at that anytime you want to go look at that.

Might have to take a look at that, that’s pretty exciting.

It's pretty neat, I’ve got some pictures to show you. Matter of fact, I know I do on my phone. So going through that design process was neat and, you know, again having the checklist available and have it posted out there and make sure we’re meeting all those
requirements would've been an advantage. We miss some stuff, you know. It's one of those particularly, designing mechanisms for a production environment, you’ve got time pressures, you’ve got budgetary considerations, and you miss stuff. And so any information that we can get solidified up front and have it right there in our face the whole time would be a help.

Now, what about a second challenging project that you best remember. It doesn’t have to be recent.

Well, I mean, right now so when we talk design, it can be anything from fixtures to workstations. So right now, our Kaizen event for semi-auto, we’re designing new works, basically a new work cell, so the design concepts that we’re talking about are scalable you know, your checklist is still the same, your requirements, your knowns, your unknowns. It’s all of these different things. You just have to break it down into subcomponents so that even though I've got the big picture in mind, I need to apply these concepts to each of the subcomponents that go into that cell. So for all of our flow channels, all of our buggies, all of our carts and workstations, the process remains same even though we’re focusing on one small subcomponent of the larger cell. So right now, we’re designing carts, buggies, and workstations to do specific tasks and assembly steps. So we’re having to consider things like grounding and ESD, mobility, modular design, ergonomics. All of these things, we have to take into account so not to be a broken record but all these things we talked about for the last project and in general, these checklists, these stating your facts and knowns and assumptions, you know. For every one of these
designs that we’re doing, having that information available, it provides continuity of thought on work, how your designing each station and what not. You know, having continuity of the lessons learned. Ok, if you’re going to do something like this: if you have meters on a shelf, it needs to be this type of material. This is the part number and specs for it.

So for the transmission redesign, what type of project would you say that is? The examples I have here are tooling and fixture design, process design. I wouldn’t think that falls under that. Would you say it’s almost the station partial redesign?

Yeah, I mean that not really even tooling. Machinery redesign and upgrade, if you want.

The buggies and the flow process…

I mean, that’s machinery equipment. That’s process as much as it is anything.

In general, how many *design projects* are you assigned either per year, or if it is easier, per month?

How about per week?

Well we could take an average per week and multiply it by 50, assuming 2 weeks off.
I mean, you know, there's no general blanket answer for that. For me, personally, maybe not as much as the other guys. I might have one or two things going per week that carry-on over multiple weeks.

**Is it really because you’re overseeing projects?**

Yeah, I mean, it’s more project management. A lot of it is for me so I might have one or two or three designs that might go for months because they’re larger or it takes time to get stuff built and different things and you follow through to completion. So maybe a dozen to a dozen and a half over a calendar year but when you talk about but, you know, when you’re talking about buggies and carts and mechanisms and fixtures and tooling. When you talk about true design work for me, that's a good, good number of projects throughout the year when you figure you’re still doing production support, paperwork, and all the different project management that comes along with these things.

**Ok, so how about just projects in general. Not only design but also with other production, other, let’s say your you put on a 6S…**

So a couple of ways to answer that. If we’re talking just like major projects that are tracked with budgets and hours and PSR's and whatnot, probably a dozen in a calendar year is good number. But when you talk about everything else that goes with it, the smaller not as visible projects, the fire fighting, the we need to design something to repair something on the line, I mean, it could be several dozen, you know. It really depends on how granular you want to get but as far as measurable tracked projects that management
is inclined to request updates on what the tracking on and whatnot, maybe a dozen or so in a calendar year.

**Ok, and what resources do you typically use throughout these projects? Whether it be software, hardware, tooling, people.**

Oh gosh, there’s a myriad of resources between CAD packages, any number of Microsoft products like PowerPoint, Excel, Word for communications, any number of homegrown: Dashboard, EIS, RIS, we’ve got a lot of homegrown apps that we use. I guess what I’ll call indigenous software, stuff like Brainson has their own stuff or MiniTab, things like that. Reference books, you know, my mechanics book, I’ll use that quite often during the design process. Any number of webpages where you go out and do a Google search, “Ok, I need to know about pitch angle on this kind of thread,” or what kind of fasteners to use, rules of thumb for whatever it is you’re looking for. I mean, there's any number of resources that you can use. Pick your neighbor’s brain, I mean literally. If you have tooling questions, you ask your tool and die guys. Electrical questions, you’ll hit up your test engineers or whatever. Any number of places to go to get the answers you seek.

**And so, we've been talking about how you go through and look at a project and you try to break it down to what you need for the project. Do you have an overarching specified procedure that you tend to follow? Do you have that documented somewhere or is it just from your experience?**
Experience. That’s why I say when you first come on, you’ve got to refine your craft and you’re going to learn by your mistakes, you’re going to get lessons learned that you apply to subsequent projects and processes so… I don’t know that you need an overarching set of rules and documents because it tends to limit innovation. But what you need is the upfront information to get you from point A to point B. How you get to point B could be any number ways. And there’s where I wouldn’t wouldn't want to be limited to I have to do this process or I have to follow this.

So that makes a lot of sense. You don't want to go…you want to set someone up help or help set a designer up but not…

A procedure should be to the benefit the designer. So when I say have a checklist of things you need to answer ahead of time, that's helpful, that's not a hindrance. Having a procedure that says okay you’ve got to do this, this, this, and this during your design process. If it's high-level, I see benefit in it. You know, for example, okay you’ve got X number of things you need to do through the whole process. Number one, fill out your free checklist, whatever you want to call it, listing your knowns and assumptions. Before you go to print have a peer review. Before you go tooling, have your designs checked for accuracy in your prints, okay. And then when you go to receive your tooling, your machined components, maybe have some quality checks on them that you have two or three dimensions checked for accuracy before you assemble, okay. And before you release to production your design, do some fit and function to make sure that all of your assumptions at the very beginning are satisfied when you go to do fit and function. I
could see something like that’s just some basic and reasonable deliverables as you go from concept to completion, but anything more rigid than that, to me, becomes a hindrance because now I’m more concerned with the process that I am the design and I don’t want to get to that point. I want to stay focused on the design, you know, if it's just meeting some basic deliverables as we go that's reasonable but beyond that, it becomes a little too rigid in my opinion. It becomes more micromanaging.

I feel like that, in general, and I’m making a general assumption here, most people, I don’t think, like to be micromanaged. So by having some sort of, like what you were talking about, this process here would encourage more people to want to use it.

So the software that you used throughout these, like you said, the Microsoft apps, CAD as far as…

Pro/E and Solidworks. Although we have recently broke AutoCAD back out.

Really? A 3-D version or 2-D version?

2-D. Layouts.

So let’s say for your power transmission project, who all assisted with that?

Technicians. Technicians and tooling guys, guys in the shop.

You didn’t have any co-op or any assistance from any of the other engineers?
I don't think I had a co-op during that time. This is when Alex had his electrical engineering co-op. This would have been late last year (2014).

**Now, do you think that a co-op could have been assigned to this project?**

Do I think a co-op could have been assigned to this project? A more senior co-op, yes, with oversight. And here’s why I say this and this is not…I need to be careful how I answer this. The level of experience they might have when taking something like that that’s malfunctioned that has a significant price tag to it and reengineering a power transmission concept for it. I would feel comfortable letting them explore some options and with guidance and oversight, possibly let them manage the project. Certainly they could take part in it. There’s a lot of CAD that had to be done. A lot of inventory that needed to be ordered. You know, things that needed to be machined certainly would be, you know, in favor of things like that but I don't know that I would say, “Hey, I’m going to turn this over to you.” Now, a senior co-op on the third or fourth rotation, possibly. I've always said that I consider 3rd and 4th rotation co-ops to be staff engineers by then, they just don’t have the title. But they have a lot of experience and know-how. They know who to talk to and, you know, there's always that intermediate action with engineering, and particularly with myself to maintain that oversight so possibly could I see turning that over to a co-op, you know.

**Was this this project, was it team-based?**

Team in as much as I was the engineer with, I think, at some point all of my technicians were involved with some level project, in addition to shop assistance. So
yeah, there was a team of folks that had deliverables. It wasn't just a solo project but for this case, I would have be the only mechanical engineer working on the project.

**So you were the only mechanical engineer working on the job, period?**

Yes, yes, I would say so.

**And you said all of the technicians, so five of them?**

Yeah, at some point they were all involved with some level of working on the project.

**Just wanted to make sure it was first shift or third shift.**

Everybody had some level of responsibility.

**What about with the buggies?**

For Kaizen, it is very team based. We have multiple engineers, multiple technicians, and even some operator assistance with that. Certainly when we were in the planning and presentation phase, everybody was heavily involved. Now that we are in implementation phase, it’s primarily technician with engineering oversight. And both our IE and ME co-ops are heavily involved with it.

**So why would you say that they are more involved with the kaizen projects?**

**What was the primary purpose?**

The Kaizen project is huge. It’s basically re-envisioning an entire work cell. That's a bit too big for one person to maintain unless, given the timeframe. It’s a very aggressive timeframe, a very aggressive budget and it needs multiple sets of eyes to make sure one
person doesn’t miss something. If you go back to what I said in the beginning about your
deliverables, having your knowns and unknowns, it’s one thing to do it for a singular
station, a singular process but you’re talking about an entire workcell. And even though
we’re methodical and can break it down into sub-components, at some point you’re going
to miss something. With multiple sets of eyes, they’re going to look at it from a different
slant whether it’s an IE, a EE, a technician. It's critical for something that big to have a
team-based process. And so co-ops, where they plug-in, they’re very involved with
designing of the workstations, the process. I’m very pleased with their progress, I think
they’re doing a great job.

How would you describe the overall size of the projects? So let’s continue on
with the Kaizen project, you’ve been talking that it’s larger in terms of the overall
scope, the number of people involved. So how many people would you say were
directly involved?

We had a dozen people involved at the beginning. We probably have half as many, to
three quarters made that are actively involved in the implementation. This is the most
expensive Kaizen project we’ve done to date in the factory and it has visibility all the
way from the top.

Really?

Oh absolutely. We just presented a pared down version of this to our CEO. So it has
visibility from the top, down. Particularly, I mean, from the factory level, specifically you
know, the general manager on down. All major senior managers are well aware of what
we’re doing. It has, in the last couple days, we presented to the CEO what we’re doing so it has visibility for [Company A]. It's one of those…and when we have our senior managers coming in from overseas, this is going to be one of the things they’re going to be looking at. How are we doing on the Kaizen, absolutely.

**What about comparing the Kaizen to the transmission problem? You said it was you, five technicians, and…**

A couple of guys in the shop. The scope of the problem didn’t require a huge team. You have to be realistic in how you allocate your resources and so resources in this case are people, okay. I don't need more than one engineer for that, you know. I used all five technicians so they all have a hand in it. So they all have some experience in a project like this. Had I had a co-op during that time, I definitely would have had them involved. It would have been a great learning tool, learning experience. For the Kaizen, there’s no question it's team-based. It has to be team-based to handle something that big, that quick.

**And the more point of view?**

To make sure we don’t miss stuff. But for something like that where it’s more of a mechanical design, what’s funny about that project is it had a coolness factor to it because every ME, at least on the side (the residential department), including ME managers, stopped by to see how it was going and to watch it run.

**I can imagine. I want to see it right now.**
I’ve got it on my phone I’ll show you. But yeah, there was definitely a coolness factor to it that you don’t get to do that every day. So yeah, I mean, it did necessitate more than one engineer and I was kind of protecting my turf a little bit cause I was having fun with it and I didn’t want some goober like Gibson to come in and ruin it for me. But yeah, that’s kind of how it went.

I can definitely see that. So how many man-hours were required to complete each of these projects?

Well, the one’s (the Kaizen project) is in process. It’s 1500+ man-hours so far in the Kaizen.

How many are I've been allocated to it against a PSR?

Well, that’s what I’m saying. On paper, 1500 hours so far. In actuality, there is just no way to calculate it, there’s no way to track it. It's an estimate based on, you start with your initial guess and at some point, you say, I probably have three times as many people working on it as I originally intended. So you just scale form there. At best, it’s just a guesstimate.

And can you give any kind of guesstimate on the transmission problem?

Couple hundred hours. Couple hundred dollars when you tally up everybody’s time because it's a project that went over about two months time from start to completion. And so you look at all the shop, the technician time, how much time we spent out there. The odds and ends, it was probably a couple hundred hours.
That’s a really good comparison, especially in terms of size. I know these are different because one is more mechanical while the Kaizen is more process but how would you describe the overall complexity of each of these projects? Which one to you is more complex?

Well, certainly the Kaizen is more complex inasmuch as we’re talking about an entire work cell that you are looking at redesigning processes to make it more efficient. There’s just so many more deliverables. As far as the mechanism itself, having to re-envision from a pure engineering standpoint, mechanical engineering standpoint, the power transmission unit was more complex in that you had to re-envision: How do I get this kinetic energy transferred from this motor/gear reduction unit to this rotary transmission to drive this dial table and meet my requirements of getting it on a tabletop, getting it easily accessible. What was literally a bevel gear type set up, now I’m going to a blower belt equivalent, you know. So re-envisioning how to do that effectively was the more difficult engineering challenge. Complexity is strictly a function, in this case, of the Kaizen event being a bigger scale.

Larger in scale.

Not more difficult engineering-wise, but just bigger scale.

Would you also say dealing with more people also affects that complexity too?

It should simplify it because you’ve got more eyes on it.
Even with the interactions with each other, it wouldn’t affect the complexity there?

I mean I wouldn’t say it makes it any more difficult. Everybody has their part.

What type of tools or resources did you use to communicate your ideas with others? Whether it being others on the team or others for the tooling and die for the transmission project?

I think I’m missing something here, I’m not following you here.

If we just focus, let’s say, on the transmission project. So focusing on that, what type of resources did you use to communicate your ideas with others? Whether it be your ideas with the technicians or your ideas with the tool and die guys. Did you use a PowerPoint with them, did you print out prints?

I mean, prints, email, vocal. Very basic, you know.

And then for the Kaizen?

I mean, you’ve got PowerPoint, you’ve got stuff on paper, you know. I hope I’m not simplifying it too much but stuff on the whiteboard. Your basic, you sit around the table and, you know, put stuff on Excel. I don’t know if that makes sense?

Oh no, it does. If you had an idea outside a meeting, would you email it to the group or would you just write it down and save it for later?
It could be either one, it really depends on how crucial it is to disseminate that information quickly. I mean, if you want it documented, obviously email because you can always go back and say, “Hey, I sent you those.”

**And these projects, how were you first introduced to them?**

Well, I was introduced to the transmission unit when it failed and we couldn’t run the machine. I was introduced to the Kaizen event when the boss comes in and says, “Hey, you’re in charge of this.”

**So, it’s primarily verbal communication?**

The coil former was quite auditory: crunch, uh oh. Technicians walk in, you might want to come see this.

**No good. And the Kaizen one, when you said the boss came.**

The boss sat in that very chair and said, you’re in charge of this. Ok, thanks…

**With the exception of parts breaking down, would you say someone coming in and telling you, “Hey, I need you to work on this project,” is that most common or is it more common to receive an email?**

Both.

**Both equally common?**

Yeah.
Is there any kind of format to any of this?

This is [Company A] (no).

I have to ask… I’m pretty sure I know the answer.

You know the answer. No, there’s no format to it. I mean, you may get assigned something in one of the weekly (continuous improvement) meetings but in general, he’s going to come in and say, “Hey, I want you on this.” Usually, it’s verbal because he’s got to explain to you what he wants done. There’s going to be a lot of questions and whatnot.

So it’s almost better to have that interview type introduction?

I’d say it’s absolutely required.

How were these projects initially defined? Not the transmission project because you said that was a crunch and you were brought out there by the technicians.

Quite literally.

The Kaizen project, how did your boss initially come in here and be like, “Hey, I need you to work on this.” Did he give you just a general explanation that we need this line redesigned for a Kaizen event or was it just, I need you to do something, get it done, and it’s up to you as to how you get it done.

No, I mean, it was explained that this was the next Kaizen event and it’s kind of understood when you’re going to do a Kaizen event, you know, what’s the goal of a Kaizen event? Now, they had to call me in and break down what were the specific
management driven objectives, budget, things of that nature; give you your goals and constraints. But once you have those, it’s kind of a blank sheet. Assemble the team and, you know, list out the goals and constraints and start going through the process. Now, to me, it’s probably not as documented as it should be but there is a process to going through a Kaizen event. So, as you go through the process, it forces you to answer specific questions that help you to get to your solution, or your proposed solution.

So now while you’re going through these projects, how often do you have design reviews? Well, for the transmission project, how often would you have peer reviews and at least review your design with someone?

I say this half cocked, with that project, it was almost daily review because I always had someone crawling over it looking at it with me and, “Hey man, what’re you doing? How’re you going to solve this? What’s this for? Why are you doing this?”

Because of all the interest in it?

Oh yeah, it was more informal. Like I said, there was a coolness factor to it that we don’t normally get to work on. Usually, it’s very cut and dry, replace this, fix that. This one was like, there was no obvious solution. We had to reengineer it mechanically to see if we could even get it to work. There was a little bit of trepidation once we had it all bolted together to see if we could get it to work. Confidence was high, but until you see it in operation, is it going to go?

The uncertainty there…
Yeah, there was a little bit of uncertainty. The best laid plans are only as good as their execution. That executes well or they execute me.

Well, good thing it executed well… So then, how many formal design reviews did you have for that project?

Maybe one.

Who was involved in that?

Manager and other ME’s. Anyone that could give me constructed feedback.

Was it mainly just the manufacturing group or did you invite anyone from R&D?

No, absolutely not. Just manufacturing guys.

You were talking about having presented the Kaizen stuff to the CEO.

Oh, that was senior management.

You’ve done that with senior management and with local level?

Every senior manager in the factory plus our CEO has been represented to at this point.

That’s incredible now that I think about it that it has the direct attention of the CEO there.
Well, it was one of those where he comes in to visit and you want to show him a lot of the work that has been going on in the factory. This was one of the projects that was selected cause it’s in implementation phase so it was easy to say, “Hey, it’s already been approved, there’s already a presentation. Cut it down to 15 minutes and you’ve got his full attention.”

Ok

One of those deals.

Alrighty, so the transmission, that’s still in use?

Yep.

Have any modifications been made to it since it was first put out there?

Tweaks, tuning.

Ok. Do you think anything could have been prevented with the checklist? Could any of those tweaks have been prevented or is that just one of those things?

No, it’s one of those where when you get to fit and function… CAD’s going to get you so far.

Any major concerns about it? Anticipated lifespan?

No, because of the way it’s designed, all components should be readily accessible, replaceable. Fairly straight forward.
Any final reflections on these projects at all?

Nothing I can think of. They’re all worthy projects, fairly straight forward. Some forced upon you, the nature of the beast. Others planned but they’re cost savings at the end of the day and, I think, worthwhile.

It helps with production.

Absolutely. They both help the factory for sure.

B.4 A.ME.4 – David

SO: The purpose of this is for my research at Clemson where from my experiences in the capstone program and then senior program we design primarily in teams of 3, 4, or 5 students and we work on a project together as in that team. Well, when coming here, the most interaction in a team that I have received was maybe working on a project with or maybe getting some assistance from one of the test engineers whether it be like mainly it was Brian Williams. Or it would be one of the techs. And that would be it. So I just wanted to come here and get y’all’s experiences since y'all have been working here much longer than me. Y’all have more experience than I do. I just wanted to see if your insight is the same as mine but hopefully what will come out of this is that if most of the work you do is more individual rather directly in teams then there might be some sort of process of some sort of tool or even software that I could potentially develop or recommend and then you could potentially use it here or someone at some other company so the end goal
of this is to try to help increase efficiency and quality the overall ability of the engineer especially if they’re new like I was when I first started. And increasing the ability to hit the ground running might be helpful.

So I have to get these introductory questions first: what is your position title and description, and how many years have you been at this position?

Brad: Lead manufacturing engineer is the title. I’ve been in this particular role since probably 2006/2007 so 8 or 9 years.

And what exactly are your responsibilities in that role?

Well manufacturing engineer, first and foremost, supporting production, supporting departmental initiatives and filtering those down through the group such as PSR's, manufacturing qualifications, 5S initiatives. Right now, I’m leading a Kaizen team so any number of focus factory and departmental goals that need to be filtered down to the group. Maintaining capital budget, mechanical design reviews, things like that. You know, all of the above our part my responsibilities but first and foremost of these would be supporting production, project management, things like that.

Ok. So what was your previous design experience within [Company A]?

I mean…if we’re talking in a current manufacturing engineering role, when I first started back in ’99, it might be designing fixtures, designing tooling in Pro/E for production. As I’ve gone room and, I guess, progressed over time, I still support that, but not to the same degree that some of the other guys in the group do. I've seen my
responsibilities shift to more project management as compared to down in the trenches, nuts and bolts, designing fixtures. I still do that from time to time but that's not one of the things it would be one of my big portion of my plate right now.

**What other companies have you worked for?**

Milliken and Company at their finishing plant in Pendleton. Co-oped at Metler Toledo back in the mid-90s. but I’ve been at [Company A] since ’99.

**What type of work did you do for those other companies?**

Very similar to what, I guess, a typical co-op or intern would do. Some basic CAD work, some basic data collection. A little bit of fixture design. At Milliken I also did some inventory control, did some 5S, stuff like that.

**Have you attended any workshops or taken any specific classes on designing, and more importantly, either design in general or how to design on your own as an individual rather than in teams?**

So let’s clarify, when talking design, you know, you mean with a CAD package designing a specific mechanism or something?

**Yeah, whether it be with CAD or whether it be just having to have something sketched out and then potentially presented to someone before actually going to CAD. Any kind of design work whether it be for fixture or tooling.**
I mean, above and beyond what I took in school, I don't believe. It’s one of those things where I’ve refined my craft over the years. Learning from mentors, learning from senior engineers, watching the process, learning as I go and perfecting it through time.

**So what kind of stuff would you say you’ve learned throughout your experiences?**

Learning the design process, you know, to identify what are the key parameters before you sit down on the CAD package and start to, start to sketch it out: what are you trying to accomplish? What are your space constraints? What, if any, budgetary constraints do you have which will affect your selection of materials. Are there any safety considerations that have been identified ahead of time? So mainly getting all the prep work done and answered before you sit down in front of the computer to start the design so that you don't find out halfway through it, “Oh I had to make sure this was a nonconductive material,” or “Oh it needs to be mobile. I had this on a table top.” Getting all your ducks in a row before you sit down to do it is the biggest, you know, it sounds trivial but a lot of people even now don't do that correctly, in my opinion, and they have to go back and rev their design 2, 3, 4 times because they didn't have all the information they needed. Now sometimes that information is not easily come by, but you get as much of it as you can. So one thing, if we had a designer’s kit, and this is just thinking matter of fact, a designer’s kit that forces you to answer specific questions up front, as much as possible. For example, “Are there safety considerations?”, “Is this a mobile device?”, “Is this intended to be a standalone machine?”, “Is it tabletop?” Selection of materials, you
know, does it need to be ESD? What type of product is going to go into it? Does it need to be guarded? Is it just simple mechanisms or is there going to be kinetic energy devices such as hydraulic schematics, servos that need light curtains. All of these things, if they’re answered up front, you going to design with that in mind. So, if we had a checklist, maybe the standard, you know…

That almost sets up your design space for you.

It really forces you down the correct path because if you can answer these questions up front, then when you actually sit down and start putting the mechanism together in your mind on the computer, “Oh yeah, I remember I’ve got to have ESD shelving. Oh, I’m going to have to have light curtains on this because I'm using, you know, half-inch four pneumatic cylinders to do this action or whatever it is. Make sure you know dot your I’s and cross your T’s. So one of those, I mean a lot of times we do it naturally, we go and write stuff down a piece of paper in a notebook but if we had a checklist that formalizes that this is part of the design process, answer these questions as much as possible. And if there's a problem you can always go back to your checklist and say, “why isn't this right?” Well, this is the assumptions I had when I went into it. Maybe the assumptions change. Maybe what was supposed to be a fixed benchtop type of mechanism, well now they want to roll it from cell to cell so it needs to be mobile. Well, if there’s changes that are required later, you can at least go back to say, “Hey, when I started the process, my checklist said this was benchtop and this was a fixed asset. Now somebody has changed into a mobile device down the road. So, if it takes three more
weeks to finish this and another 1000 to 1500 dollars to modify it, you’ve got your
documentation that says, “Hey, when I started the project, these were the assumptions.”
So it's always good to have that information up front.

**So would having some sort of a pre-populated list of topics to go through that**
**forces you to go through a general listing of every subject, whether it be safety, ESD,**
**material selection, would you say that would be helpful?**

I think particularly for the guys that are new, for co-ops, for those that aren’t used to
the design process that need to perfect their craft. I think having something more formal
like that forces them to think about some of the issues that we take for granted as a more
senior designer. You know, we go through the checklist in our head and even now, we’ll
miss stuff and if we had it on a paper or whatever, in front of us the whole time, you
know, even that would help a seasoned engineer to make sure to keep all their
information straight. It's just like solving any kind of technical problem. You list your
assumptions first before you try to solve the problem. This is no different: you list your
assumptions up front, you knowns, and your assumptions and then you start your design.
And when you get to the end you ought to be able to look at your designs and say, “Yep,
light curtains, check that out for guarding,” “yep, I’ve got ESD and that’s grounded.
Check that off for that, you know.” You ought to be able to look at your finished design
and look at your list of knowns and assumptions, and every one of those is satisfied in the
design. And if they’re not, you’ve missed something. You didn’t pay attention to the
information you had.
Now let’s get into some of the projects you’ve worked on. That’s what the remainder of these questions will focus on. So can you describe your most recent design project that you’ve completed?

We had to do a redesign on the power transmission unit for the old coil-forming machine. The rotary transmission unit for the dial table failed. The drive gear basically destructed, self-destructed and it was about a $45,000 replacement and it wasn't a drop in to get the power transmission unit. The way it was set up was not easily to work on. You had to crawl under the machine, pull the motor and the clutch. So we decided to reengineer it in-house and take the components that worked on the rotary transmission and design and install a new power transmission unit to drive the rotary to drive the dial table. So it was really cool. About a $43,000 cost-savings as well. So basically taking known mechanical concepts on power transmission, we got the drive unit from underneath table, mounted it tabletop so it’s easily accessible. Basically, took the equivalent of a blower belt, a big 1.5-inch wide belt that would transmit power from the motor gear reduction unit to the input shaft for the rotary transmission. Getting that all built and designed and operational, we can go look at that anytime you want to go look at that.

Might have to take a look at that, that’s pretty exciting.

It's pretty neat, I’ve got some pictures to show you. Matter of fact, I know I do on my phone. So going through that design process was neat and, you know, again having the checklist available and have it posted out there and make sure we’re meeting all those
requirements would've been an advantage. We miss some stuff, you know. It's one of those particularly, designing mechanisms for a production environment, you’ve got time pressures, you’ve got budgetary considerations, and you miss stuff. And so any information that we can get solidified up front and have it right there in our face the whole time would be a help.

Now, what about a second challenging project that you best remember. It doesn’t have to be recent.

Well, I mean, right now so when we talk design, it can be anything from fixtures to workstations. So right now, our Kaizen event for semi-auto, we’re designing new works, basically a new work cell, so the design concepts that we’re talking about are scalable you know, your checklist is still the same, your requirements, your knowns, your unknowns. It’s all of these different things. You just have to break it down into subcomponents so that even though I've got the big picture in mind, I need to apply these concepts to each of the subcomponents that go into that cell. So for all of our flow channels, all of our buggies, all of our carts and workstations, the process remains same even though we’re focusing on one small subcomponent of the larger cell. So right now, we’re designing carts, buggies, and workstations to do specific tasks and assembly steps. So we’re having to consider things like grounding and ESD, mobility, modular design, ergonomics. All of these things, we have to take into account so not to be a broken record but all these things we talked about for the last project and in general, these checklists, these stating your facts and knowns and assumptions, you know. For every one of these
designs that we’re doing, having that information available, it provides continuity of thought on work, how your designing each station and what not. You know, having continuity of the lessons learned. Ok, if you’re going to do something like this: if you have meters on a shelf, it needs to be this type of material. This is the part number and specs for it.

So for the transmission redesign, what type of project would you say that is? The examples I have here are tooling and fixture design, process design. I wouldn’t think that falls under that. Would you say it’s almost the station partial redesign?

Yeah, I mean that not really even tooling. Machinery redesign and upgrade, if you want.

The buggies and the flow process…

I mean, that’s machinery equipment. That’s process as much as it is anything.

In general, how many design projects are you assigned either per year, or if it is easier, per month?

How about per week?

Well we could take an average per week and multiply it by 50, assuming 2 weeks off.
I mean, you know, there's no general blanket answer for that. For me, personally, maybe not as much as the other guys. I might have one or two things going per week that carry-on over multiple weeks.

**Is it really because you’re overseeing projects?**

Yeah, I mean, it’s more project management. A lot of it is for me so I might have one or two or three designs that might go for months because they’re larger or it takes time to get stuff built and different things and you follow through to completion. So maybe a dozen to a dozen and a half over a calendar year but when you talk about but, you know, when you’re talking about buggies and carts and mechanisms and fixtures and tooling. When you talk about true design work for me, that's a good, good number of projects throughout the year when you figure you’re still doing production support, paperwork, and all the different project management that comes along with these things.

**Ok, so how about just projects in general. Not only design but also with other production, other, let’s say your you put on a 6S...**

So a couple of ways to answer that. If we’re talking just like major projects that are tracked with budgets and hours and PSR's and whatnot, probably a dozen in a calendar year is good number. But when you talk about everything else that goes with it, the smaller not as visible projects, the fire fighting, the we need to design something to repair something on the line, I mean, it could be several dozen, you know. It really depends on how granular you want to get but as far as measurable tracked projects that management
is inclined to request updates on what the tracking on and whatnot, maybe a dozen or so in a calendar year.

**Ok, and what resources do you typically use throughout these projects? Whether it be software, hardware, tooling, people.**

Oh gosh, there’s a myriad of resources between CAD packages, any number of Microsoft products like PowerPoint, Excel, Word for communications, any number of homegrown: Dashboard, EIS, RIS, we’ve got a lot of homegrown apps that we use. I guess what I’ll call indigenous software, stuff like Brainson has their own stuff or MiniTab, things like that. Reference books, you know, my mechanics book, I’ll use that quite often during the design process. Any number of webpages where you go out and do a Google search, “Ok, I need to know about pitch angle on this kind of thread,” or what kind of fasteners to use, rules of thumb for whatever it is you’re looking for. I mean, there's any number of resources that you can use. Pick your neighbor’s brain, I mean literally. If you have tooling questions, you ask your tool and die guys. Electrical questions, you’ll hit up your test engineers or whatever. Any number of places to go to get the answers you seek.

**And so, we've been talking about how you go through and look at a project and you try to break it down to what you need for the project. Do you have an overarching specified procedure that you tend to follow? Do you have that documented somewhere or is it just from your experience?**
Experience. That’s why I say when you first come on, you’ve got to refine your craft and you’re going to learn by your mistakes, you’re going to get lessons learned that you apply to subsequent projects and processes so… I don’t know that you need an overarching set of rules and documents because it tends to limit innovation. But what you need is the upfront information to get you from point A to point B. How you get to point B could be any number ways. And there’s where I wouldn’t want to be limited to I have to do this process or I have to follow this.

So that makes a lot of sense. You don't want to go...you want to set someone up help or help set a designer up but not…

A procedure should be to the benefit the designer. So when I say have a checklist of things you need to answer ahead of time, that's helpful, that's not a hindrance. Having a procedure that says okay you’ve got to do this, this, this, and this during your design process. If it's high-level, I see benefit in it. You know, for example, okay you’ve got X number of things you need to do through the whole process. Number one, fill out your free checklist, whatever you want to call it, listing your knowns and assumptions. Before you go to print have a peer review. Before you go tooling, have your designs checked for accuracy in your prints, okay. And then when you go to receive your tooling, your machined components, maybe have some quality checks on them that you have two or three dimensions checked for accuracy before you assemble, okay. And before you release to production your design, do some fit and function to make sure that all of your assumptions at the very beginning are satisfied when you go to do fit and function. I
could see something like that’s just some basic and reasonable deliverables as you go from concept to completion, but anything more rigid than that, to me, becomes a hindrance because now I’m more concerned with the process that I am the design and I don't want to get to that point. I want to stay focused on the design, you know, if it's just meeting some basic deliverables as we go that's reasonable but beyond that, it becomes a little too rigid in my opinion. It becomes more micromanaging.

I feel like that, in general, and I’m making a general assumption here, most people, I don’t think, like to be micromanaged. So by having some sort of, like what you were talking about, this process here would encourage more people to want to use it.

So the software that you used throughout these, like you said, the Microsoft apps, CAD as far as…

Pro/E and Solidworks. Although we have recently broke AutoCAD back out.

Really? A 3-D version or 2-D version?

2-D. Layouts.

So let’s say for your power transmission project, who all assisted with that?

Technicians. Technicians and tooling guys, guys in the shop.

You didn’t have any co-op or any assistance from any of the other engineers?
I don't think I had a co-op during that time. This is when Alex had his electrical engineering co-op. This would have been late last year (2014).

**Now, do you think that a co-op could have been assigned to this project?**

Do I think a co-op could have been assigned to this project? A more senior co-op, yes, with oversight. And here’s why I say this and this is not…I need to be careful how I answer this. The level of experience they might have when taking something like that that’s malfunctioned that has a significant price tag to it and reengineering a power transmission concept for it. I would feel comfortable letting them explore some options and with guidance and oversight, possibly let them manage the project. Certainly they could take part in it. There’s a lot of CAD that had to be done. A lot of inventory that needed to be ordered. You know, things that needed to be machined certainly would be, you know, in favor of things like that but I don't know that I would say, “Hey, I’m going to turn this over to you.” Now, a senior co-op on the third or fourth rotation, possibly. I've always said that I consider 3rd and 4th rotation co-ops to be staff engineers by then, they just don’t have the title. But they have a lot of experience and know-how. They know who to talk to and, you know, there's always that intermediate action with engineering, and particularly with myself to maintain that oversight so possibly could I see turning that over to a co-op, you know.

**Was this this project, was it team-based?**

Team in as much as I was the engineer with, I think, at some point all of my technicians were involved with some level project, in addition to shop assistance. So
yeah, there was a team of folks that had deliverables. It wasn't just a solo project but for this case, I would have be the only mechanical engineer working on the project.

So you were the only mechanical engineer working on the job, period?

Yes, yes, I would say so.

And you said all of the technicians, so five of them?

Yeah, at some point they were all involved with some level of working on the project.

Just wanted to make sure it was first shift or third shift.

Everybody had some level of responsibility.

What about with the buggies?

For Kaizen, it is very team based. We have multiple engineers, multiple technicians, and even some operator assistance with that. Certainly when we were in the planning and presentation phase, everybody was heavily involved. Now that we are in implementation phase, it's primarily technician with engineering oversight. And both our IE and ME co-ops are heavily involved with it.

So why would you say that they are more involved with the kaizen projects?

What was the primary purpose?

The Kaizen project is huge. It's basically re-envisioning an entire work cell. That's a bit too big for one person to maintain unless, given the timeframe. It’s a very aggressive timeframe, a very aggressive budget and it needs multiple sets of eyes to make sure one
person doesn’t miss something. If you go back to what I said in the beginning about your deliverables, having your knowns and unknowns, it’s one thing to do it for a singular station, a singular process but you’re talking about an entire workcell. And even though we’re methodical and can break it down into sub-components, at some point you’re going to miss something. With multiple sets of eyes, they’re going to look at it from a different slant whether it’s an IE, a EE, a technician. It's critical for something that big to have a team-based process. And so co-ops, where they plug-in, they’re very involved with designing of the workstations, the process. I’m very pleased with their progress, I think they’re doing a great job.

How would you describe the overall size of the projects? So let’s continue on with the Kaizen project, you’ve been talking that it’s larger in terms of the overall scope, the number of people involved. So how many people would you say were directly involved?

We had a dozen people involved at the beginning. We probably have half as many, to three quarters made that are actively involved in the implementation. This is the most expensive Kaizen project we’ve done to date in the factory and it has visibility all the way from the top.

Really?

Oh absolutely. We just presented a pared down version of this to our CEO. So it has visibility from the top, down. Particularly, I mean, from the factory level, specifically you know, the general manager on down. All major senior managers are well aware of what
we’re doing. It has, in the last couple days, we presented to the CEO what we’re doing so it has visibility for [Company A]. It's one of those…and when we have our senior managers coming in from overseas, this is going to be one of the things they’re going to be looking at. How are we doing on the Kaizen, absolutely.

What about comparing the Kaizen to the transmission problem? You said it was you, five technicians, and…

A couple of guys in the shop. The scope of the problem didn’t require a huge team. You have to be realistic in how you allocate your resources and so resources in this case are people, okay. I don't need more than one engineer for that, you know. I used all five technicians so they all have a hand in it. So they all have some experience in a project like this. Had I had a co-op during that time, I definitely would have had them involved. It would have been a great learning tool, learning experience. For the Kaizen, there’s no question it's team-based. It has to be team-based to handle something that big, that quick.

And the more point of view?

To make sure we don’t miss stuff. But for something like that where it’s more of a mechanical design, what’s funny about that project is it had a coolness factor to it because every ME, at least on the side (the residential department), including ME managers, stopped by to see how it was going and to watch it run.

I can imagine. I want to see it right now.
I’ve got it on my phone I’ll show you. But yeah, there was definitely a coolness factor to it that you don’t get to do that every day. So yeah, I mean, it did necessitate more than one engineer and I was kind of protecting my turf a little bit cause I was having fun with it and I didn’t want some goober like Gibson to come in and ruin it for me. But yeah, that’s kind of how it went.

I can definitely see that. So how many man-hours were required to complete each of these projects?

Well, the one’s (the Kaizen project) is in process. It’s 1500+ man-hours so far in the Kaizen.

How many are I've been allocated to it against a PSR?

Well, that’s what I’m saying. On paper, 1500 hours so far. In actuality, there is just no way to calculate it, there’s no way to track it. It's an estimate based on, you start with your initial guess and at some point, you say, I probably have three times as many people working on it as I originally intended. So you just scale form there. At best, it’s just a guesstimate.

And can you give any kind of guesstimate on the transmission problem?

Couple hundred hours. Couple hundred dollars when you tally up everybody’s time because it's a project that went over about two months time from start to completion. And so you look at all the shop, the technician time, how much time we spent out there. The odds and ends, it was probably a couple hundred hours.
That’s a really good comparison, especially in terms of size. I know these are different because one is more mechanical while the Kaizen is more process but how would you describe the overall complexity of each of these projects? Which one to you is more complex?

Well, certainly the Kaizen is more complex inasmuch as we’re talking about an entire work cell that you are looking at redesigning processes to make it more efficient. There’s just so many more deliverables. As far as the mechanism itself, having to re-envision from a pure engineering standpoint, mechanical engineering standpoint, the power transmission unit was more complex in that you had to re-envision: How do I get this kinetic energy transferred from this motor/gear reduction unit to this rotary transmission to drive this dial table and meet my requirements of getting it on a tabletop, getting it easily accessible. What was literally a bevel gear type set up, now I’m going to a blower belt equivalent, you know. So re-envisioning how to do that effectively was the more difficult engineering challenge. Complexity is strictly a function, in this case, of the Kaizen event being a bigger scale.

Larger in scale.

Not more difficult engineering-wise, but just bigger scale.

Would you also say dealing with more people also affects that complexity too?

It should simplify it because you’ve got more eyes on it.
Even with the interactions with each other, it wouldn’t affect the complexity there?

I mean I wouldn’t say it makes it any more difficult. Everybody has their part.

What type of tools or resources did you use to communicate your ideas with others? Whether it being others on the team or others for the tooling and die for the transmission project?

I think I’m missing something here, I’m not following you here.

If we just focus, let’s say, on the transmission project. So focusing on that, what type of resources did you use to communicate your ideas with others? Whether it be your ideas with the technicians or your ideas with the tool and die guys. Did you use a PowerPoint with them, did you print out prints?

I mean, prints, email, vocal. Very basic, you know.

And then for the Kaizen?

I mean, you’ve got PowerPoint, you’ve got stuff on paper, you know. I hope I’m not simplifying it too much but stuff on the whiteboard. Your basic, you sit around the table and, you know, put stuff on Excel. I don’t know if that makes sense?

Oh no, it does. If you had an idea outside a meeting, would you email it to the group or would you just write it down and save it for later?
It could be either one, it really depends on how crucial it is to disseminate that information quickly. I mean, if you want it documented, obviously email because you can always go back and say, “Hey, I sent you those.”

And these projects, how were you first introduced to them?

Well, I was introduced to the transmission unit when it failed and we couldn’t run the machine. I was introduced to the Kaizen event when the boss comes in and says, “Hey, you’re in charge of this.”

So, it’s primarily verbal communication?

The coil former was quite auditory: crunch, uh oh. Technicians walk in, you might want to come see this.

No good. And the Kaizen one, when you said the boss came.

The boss sat in that very chair and said, you’re in charge of this. Ok, thanks…

With the exception of parts breaking down, would you say someone coming in and telling you, “Hey, I need you to work on this project,” is that most common or is it more common to receive an email?

Both.

Both equally common?

Yeah.
Is there any kind of format to any of this?

This is [Company A] (no).

I have to ask… I’m pretty sure I know the answer.

You know the answer. No, there’s no format to it. I mean, you may get assigned something in one of the weekly (continuous improvement) meetings but in general, he’s going to come in and say, “Hey, I want you on this.” Usually, it’s verbal because he’s got to explain to you what he wants done. There’s going to be a lot of questions and whatnot.

So it’s almost better to have that interview type introduction?

I’d say it’s absolutely required.

How were these projects initially defined? Not the transmission project because you said that was a crunch and you were brought out there by the technicians.

Quite literally.

The Kaizen project, how did your boss initially come in here and be like, “Hey, I need you to work on this.” Did he give you just a general explanation that we need this line redesigned for a Kaizen event or was it just, I need you to do something, get it done, and it’s up to you as to how you get it done.

No, I mean, it was explained that this was the next Kaizen event and it’s kind of understood when you’re going to do a Kaizen event, you know, what’s the goal of a Kaizen event? Now, they had to call me in and break down what were the specific
management driven objectives, budget, things of that nature; give you your goals and constraints. But once you have those, it’s kind of a blank sheet. Assemble the team and, you know, list out the goals and constraints and start going through the process. Now, to me, it’s probably not as documented as it should be but there is a process to going through a Kaizen event. So, as you go through the process, it forces you to answer specific questions that help you to get to your solution, or your proposed solution.

**So now while you’re going through these projects, how often do you have design reviews?** Well, for the transmission project, how often would you have peer reviews and at least review your design with someone?

I say this half cocked, with that project, it was almost daily review because I always had someone crawling over it looking at it with me and, “Hey man, what’re you doing? How’re you going to solve this? What’s this for? Why are you doing this?”

**Because of all the interest in it?**

Oh yeah, it was more informal. Like I said, there was a coolness factor to it that we don’t normally get to work on. Usually, it’s very cut and dry, replace this, fix that. This one was like, there was no obvious solution. We had to reengineer it mechanically to see if we could even get it to work. There was a little bit of trepidation once we had it all bolted together to see if we could get it to work. Confidence was high, but until you see it in operation, is it going to go?

**The uncertainty there…**
Yeah, there was a little bit of uncertainty. The best laid plans are only as good as their execution. That executes well or they execute me.

Well, good thing it executed well... So then, how many formal design reviews did you have for that project?

Maybe one.

Who was involved in that?

Manager and other ME’s. Anyone that could give me constructed feedback.

Was it mainly just the manufacturing group or did you invite anyone from R&D?

No, absolutely not. Just manufacturing guys.

You were talking about having presented the Kaizen stuff to the CEO.

Oh, that was senior management.

You’ve done that with senior management and with local level?

Every senior manager in the factory plus our CEO has been represented to at this point.

That’s incredible now that I think about it that it has the direct attention of the CEO there.
Well, it was one of those where he comes in to visit and you want to show him a lot of the work that has been going on in the factory. This was one of the projects that was selected cause it’s in implementation phase so it was easy to say, “Hey, it’s already been approved, there’s already a presentation. Cut it down to 15 minutes and you’ve got his full attention.”

Ok

One of those deals.

Alrighty, so the transmission, that’s still in use?

Yep.

Have any modifications been made to it since it was first put out there?

Tweaks, tuning.

Ok. Do you think anything could have been prevented with the checklist? Could any of those tweaks have been prevented or is that just one of those things?

No, it’s one of those where when you get to fit and function… CAD’s going to get you so far.

Any major concerns about it? Anticipated lifespan?

No, because of the way it’s designed, all components should be readily accessible, replaceable. Fairly straight forward.
Any final reflections on these projects at all?

Nothing I can think of. They’re all worthy projects, fairly straight forward. Some forced upon you, the nature of the beast. Others planned but they’re cost savings at the end of the day and, I think, worthwhile.

It helps with production.

Absolutely. They both help the factory for sure.

B.5 A_IE.1 – Erin

SO: The purpose of this is for my research at Clemson where from my experiences in the capstone program and then senior program we design primarily in teams of 3, 4, or 5 students and we work on a project together as in that team. Well, when coming here, the most interaction in a team that I have received was maybe working on a project with or maybe getting some assistance from one of the test engineers whether it be like mainly it was Brian Williams. Or it would be one of the techs. And that would be it. So I just wanted to come here and get y’all’s experiences since y'all have been working here much longer than me. Y’all have more experience than I do. I just wanted to see if your insight is the same as mine but hopefully what will come out of this is that if most of the work you do is more individual rather directly in teams then there might be some sort of process of some sort of tool or even software that I could potentially develop or recommend and then you could potentially use it here or someone at some other company so the end goal
of this is to try to help increase efficiency and quality the overall ability of the engineer especially if they’re new like I was when I first started. And increasing the ability to hit the ground running might be helpful.

So I have to get these introductory questions first: what is your position title and description, and how many years have you been at this position?

Brad: Lead manufacturing engineer is the title. I’ve been in this particular role since probably 2006/2007 so 8 or 9 years.

And what exactly are your responsibilities in that role?

Well manufacturing engineer, first and foremost, supporting production, supporting departmental initiatives and filtering those down through the group such as PSR's, manufacturing qualifications, 5S initiatives. Right now, I’m leading a Kaizen team so any number of focus factory and departmental goals that need to be filtered down to the group. Maintaining capital budget, mechanical design reviews, things like that. You know, all of the above our part my responsibilities but first and foremost of these would be supporting production, project management, things like that.

Ok. So what was your previous design experience within [Company A]?

I mean…if we’re talking in a current manufacturing engineering role, when I first started back in ’99, it might be designing fixtures, designing tooling in Pro/E for production. As I've gone room and, I guess, progressed over time, I still support that, but not to the same degree that some of the other guys in the group do. I've seen my
responsibilities shift to more project management as compared to down in the trenches, nuts and bolts, designing fixtures. I still do that from time to time but that's not one of the things it would be one of my big portion of my plate right now.

**What other companies have you worked for?**

Milliken and Company at their finishing plant in Pendleton. Co-oped at Metler Toledo back in the mid-90s. but I’ve been at [Company A] since ’99.

**What type of work did you do for those other companies?**

Very similar to what, I guess, a typical co-op or intern would do. Some basic CAD work, some basic data collection. A little bit of fixture design. At Milliken I also did some inventory control, did some 5S, stuff like that.

**Have you attended any workshops or taken any specific classes on designing, and more importantly, either design in general or how to design on your own as an individual rather than in teams?**

So let’s clarify, when talking design, you know, you mean with a CAD package designing a specific mechanism or something?

Yeah, whether it be with CAD or whether it be just having to have something sketched out and then potentially presented to someone before actually going to CAD. Any kind of design work whether it be for fixture or tooling.
I mean, above and beyond what I took in school, I don't believe. It’s one of those things where I’ve refined my craft over the years. Learning from mentors, learning from senior engineers, watching the process, learning as I go and perfecting it through time.

**So what kind of stuff would you say you’ve learned throughout your experiences?**

Learning the design process, you know, to identify what are the key parameters before you sit down on the CAD package and start to, start to sketch it out: what are you trying to accomplish? What are your space constraints? What, if any, budgetary constraints do you have which will affect your selection of materials. Are there any safety considerations that have been identified ahead of time? So mainly getting all the prep work done and answered before you sit down in front of the computer to start the design so that you don't find out halfway through it, “Oh I had to make sure this was a nonconductive material,” or “Oh it needs to be mobile. I had this on a table top.” Getting all your ducks in a row before you sit down to do it is the biggest, you know, it sounds trivial but a lot of people even now don't do that correctly, in my opinion, and they have to go back and rev their design 2, 3, 4 times because they didn't have all the information they needed. Now sometimes that information is not easily come by, but you get as much of it as you can. So one thing, if we had a designer’s kit, and this is just thinking matter of fact, a designer’s kit that forces you to answer specific questions up front, as much as possible. For example, “Are there safety considerations?”, “Is this a mobile device?”, “Is this intended to be a standalone machine?”, “Is it tabletop?” Selection of materials, you
know, does it need to be ESD? What type of product is going to go into it? Does it need
to be guarded? Is it just simple mechanisms or is there going to be kinetic energy devices
such as hydraulic schematics, servos that need light curtains. All of these things, if
they’re answered up front, you going to design with that in mind. So, if we had a
checklist, maybe the standard, you know…

That almost sets up your design space for you.

It really forces you down the correct path because if you can answer these questions
up front, then when you actually sit down and start putting the mechanism together in
your mind on the computer, “Oh yeah, I remember I’ve got to have ESD shelving. Oh,
I’m going to have to have light curtains on this because I'm using, you know, half-inch
four pneumatic cylinders to do this action or whatever it is. Make sure you know dot your
I’s and cross your T’s. So one of those, I mean a lot of times we do it naturally, we go
and write stuff down a piece of paper in a notebook but if we had a checklist that
formalizes that this is part of the design process, answer these questions as much as
possible. And if there's a problem you can always go back to your checklist and say,
“why isn't this right?” Well, this is the assumptions I had when I went into it. Maybe the
assumptions change. Maybe what was supposed to be a fixed benchtop type of
mechanism, well now they want to roll it from cell to cell so it needs to be mobile. Well,
if there’s changes that are required later, you can at least go back to say, “Hey, when I
started the process, my checklist said this was benchtop and this was a fixed asset. Now
somebody has changed into a mobile device down the road. So, if it takes three more
weeks to finish this and another 1000 to 1500 dollars to modify it, you’ve got your documentation that says, “Hey, when I started the project, these were the assumptions.” So it's always good to have that information up front.

So would having some sort of a pre-populated list of topics to go through that forces you to go through a general listing of every subject, whether it be safety, ESD, material selection, would you say that would be helpful?

I think particularly for the guys that are new, for co-ops, for those that aren’t used to the design process that need to perfect their craft. I think having something more formal like that forces them to think about some of the issues that we take for granted as a more senior designer. You know, we go through the checklist in our head and even now, we’ll miss stuff and if we had it on a paper or whatever, in front of us the whole time, you know, even that would help a seasoned engineer to make sure to keep all their information straight. It's just like solving any kind of technical problem. You list your assumptions first before you try to solve the problem. This is no different: you list your assumptions up front, you knowns, and your assumptions and then you start your design. And when you get to the end you ought to be able to look at your designs and say, “Yep, light curtains, check that out for guarding,” “yep, I’ve got ESD and that’s grounded. Check that off for that, you know.” You ought to be able to look at your finished design and look at your list of knowns and assumptions, and every one of those is satisfied in the design. And if they’re not, you’ve missed something. You didn’t pay attention to the information you had.
Now let’s get into some of the projects you’ve worked on. That’s what the remainder of these questions will focus on. So can you describe your most recent design project that you’ve completed?

We had to do a redesign on the power transmission unit for the old coil-forming machine. The rotary transmission unit for the dial table failed. The drive gear basically destructed, self-destructed and it was about a $45,000 replacement and it wasn't a drop in to get the power transmission unit. The way it was set up was not easily to work on. You had to crawl under the machine, pull the motor and the clutch. So we decided to reengineer it in-house and take the components that worked on the rotary transmission and design and install a new power transmission unit to drive the rotary to drive the dial table. So it was really cool. About a $43,000 cost-savings as well. So basically taking known mechanical concepts on power transmission, we got the drive unit from underneath table, mounted it tabletop so it’s easily accessible. Basically, took the equivalent of a blower belt, a big 1.5-inch wide belt that would transmit power from the motor gear reduction unit to the input shaft for the rotary transmission. Getting that all built and designed and operational, we can go look at that anytime you want to go look at that.

**Might have to take a look at that, that’s pretty exciting.**

It's pretty neat, I’ve got some pictures to show you. Matter of fact, I know I do on my phone. So going through that design process was neat and, you know, again having the checklist available and have it posted out there and make sure we’re meeting all those
requirements would've been an advantage. We miss some stuff, you know. It's one of those particularly, designing mechanisms for a production environment, you’ve got time pressures, you’ve got budgetary considerations, and you miss stuff. And so any information that we can get solidified up front and have it right there in our face the whole time would be a help.

**Now, what about a second challenging project that you best remember. It doesn’t have to be recent.**

Well, I mean, right now so when we talk design, it can be anything from fixtures to workstations. So right now, our Kaizen event for semi-auto, we’re designing new works, basically a new work cell, so the design concepts that we’re talking about are scalable you know, your checklist is still the same, your requirements, your knowns, your unknowns. It’s all of these different things. You just have to break it down into subcomponents so that even though I've got the big picture in mind, I need to apply these concepts to each of the subcomponents that go into that cell. So for all of our flow channels, all of our buggies, all of our carts and workstations, the process remains same even though we’re focusing on one small subcomponent of the larger cell. So right now, we’re designing carts, buggies, and workstations to do specific tasks and assembly steps. So we’re having to consider things like grounding and ESD, mobility, modular design, ergonomics. All of these things, we have to take into account so not to be a broken record but all these things we talked about for the last project and in general, these checklists, these stating your facts and knowns and assumptions, you know. For every one of these
designs that we’re doing, having that information available, it provides continuity of thought on work, how your designing each station and what not. You know, having continuity of the lessons learned. Ok, if you’re going to do something like this: if you have meters on a shelf, it needs to be this type of material. This is the part number and specs for it.

So for the transmission redesign, what type of project would you say that is? The examples I have here are tooling and fixture design, process design. I wouldn’t think that falls under that. Would you say it’s almost the station partial redesign?

Yeah, I mean that not really even tooling. Machinery redesign and upgrade, if you want.

The buggies and the flow process…

I mean, that’s machinery equipment. That’s process as much as it is anything.

In general, how many design projects are you assigned either per year, or if it is easier, per month?

How about per week?

Well we could take an average per week and multiply it by 50, assuming 2 weeks off.
I mean, you know, there's no general blanket answer for that. For me, personally, maybe not as much as the other guys. I might have one or two things going per week that carry-on over multiple weeks.

**Is it really because you’re overseeing projects?**

Yeah, I mean, it’s more project management. A lot of it is for me so I might have one or two or three designs that might go for months because they’re larger or it takes time to get stuff built and different things and you follow through to completion. So maybe a dozen to a dozen and a half over a calendar year but when you talk about but, you know, when you’re talking about buggies and carts and mechanisms and fixtures and tooling. When you talk about true design work for me, that's a good, good number of projects throughout the year when you figure you’re still doing production support, paperwork, and all the different project management that comes along with these things.

**Ok, so how about just projects in general. Not only design but also with other production, other, let’s say your you put on a 6S…**

So a couple of ways to answer that. If we’re talking just like major projects that are tracked with budgets and hours and PSR's and whatnot, probably a dozen in a calendar year is good number. But when you talk about everything else that goes with it, the smaller not as visible projects, the fire fighting, the we need to design something to repair something on the line, I mean, it could be several dozen, you know. It really depends on how granular you want to get but as far as measurable tracked projects that management
is inclined to request updates on what the tracking on and whatnot, maybe a dozen or so in a calendar year.

**Ok, and what resources do you typically use throughout these projects? Whether it be software, hardware, tooling, people.**

Oh gosh, there’s a myriad of resources between CAD packages, any number of Microsoft products like PowerPoint, Excel, Word for communications, any number of homegrown: Dashboard, EIS, RIS, we’ve got a lot of homegrown apps that we use. I guess what I’ll call indigenous software, stuff like Brainson has their own stuff or MiniTab, things like that. Reference books, you know, my mechanics book, I’ll use that quite often during the design process. Any number of webpages where you go out and do a Google search, “Ok, I need to know about pitch angle on this kind of thread,” or what kind of fasteners to use, rules of thumb for whatever it is you’re looking for. I mean, there's any number of resources that you can use. Pick your neighbor’s brain, I mean literally. If you have tooling questions, you ask your tool and die guys. Electrical questions, you’ll hit up your test engineers or whatever. Any number of places to go to get the answers you seek.

**And so, we've been talking about how you go through and look at a project and you try to break it down to what you need for the project. Do you have an overarching specified procedure that you tend to follow? Do you have that documented somewhere or is it just from your experience?**
Experience. That’s why I say when you first come on, you’ve got to refine your craft and you’re going to learn by your mistakes, you’re going to get lessons learned that you apply to subsequent projects and processes so… I don’t know that you need an overarching set of rules and documents because it tends to limit innovation. But what you need is the upfront information to get you from point A to point B. How you get to point B could be any number ways. And there’s where I wouldn’t wouldn't want to be limited to I have to do this process or I have to follow this.

So that makes a lot of sense. You don't want to go...you want to set someone up help or help set a designer up but not...

A procedure should be to the benefit the designer. So when I say have a checklist of things you need to answer ahead of time, that's helpful, that's not a hindrance. Having a procedure that says okay you’ve got to do this, this, this, and this during your design process. If it's high-level, I see benefit in it. You know, for example, okay you’ve got X number of things you need to do through the whole process. Number one, fill out your free checklist, whatever you want to call it, listing your knowns and assumptions. Before you go to print have a peer review. Before you go tooling, have your designs checked for accuracy in your prints, okay. And then when you go to receive your tooling, your machined components, maybe have some quality checks on them that you have two or three dimensions checked for accuracy before you assemble, okay. And before you release to production your design, do some fit and function to make sure that all of your assumptions at the very beginning are satisfied when you go to do fit and function. I
could see something like that’s just some basic and reasonable deliverables as you go from concept to completion, but anything more rigid than that, to me, becomes a hindrance because now I’m more concerned with the process that I am the design and I don't want to get to that point. I want to stay focused on the design, you know, if it's just meeting some basic deliverables as we go that's reasonable but beyond that, it becomes a little too rigid in my opinion. It becomes more micromanaging.

    I feel like that, in general, and I’m making a general assumption here, most people, I don’t think, like to be micromanaged. So by having some sort of, like what you were talking about, this process here would encourage more people to want to use it.

    So the software that you used throughout these, like you said, the Microsoft apps, CAD as far as…

    Pro/E and Solidworks. Although we have recently broke AutoCAD back out.

    Really? A 3-D version or 2-D version?

    2-D. Layouts.

    So let’s say for your power transmission project, who all assisted with that?

    Technicians. Technicians and tooling guys, guys in the shop.

    You didn’t have any co-op or any assistance from any of the other engineers?
I don't think I had a co-op during that time. This is when Alex had his electrical engineering co-op. This would have been late last year (2014).

**Now, do you think that a co-op could have been assigned to this project?**

Do I think a co-op could have been assigned to this project? A more senior co-op, yes, with oversight. And here’s why I say this and this is not…I need to be careful how I answer this. The level of experience they might have when taking something like that that’s malfunctioned that has a significant price tag to it and reengineering a power transmission concept for it. I would feel comfortable letting them explore some options and with guidance and oversight, possibly let them manage the project. Certainly they could take part in it. There’s a lot of CAD that had to be done. A lot of inventory that needed to be ordered. You know, things that needed to be machined certainly would be, you know, in favor of things like that but I don't know that I would say, “Hey, I’m going to turn this over to you.” Now, a senior co-op on the third or fourth rotation, possibly. I've always said that I consider 3rd and 4th rotation co-ops to be staff engineers by then, they just don’t have the title. But they have a lot of experience and know-how. They know who to talk to and, you know, there's always that intermediate action with engineering, and particularly with myself to maintain that oversight so possibly could I see turning that over to a co-op, you know.

**Was this this project, was it team-based?**

Team in as much as I was the engineer with, I think, at some point all of my technicians were involved with some level project, in addition to shop assistance. So
yeah, there was a team of folks that had deliverables. It wasn't just a solo project but for this case, I would have be the only mechanical engineer working on the project.

    So you were the only mechanical engineer working on the job, period?

    Yes, yes, I would say so.

    And you said all of the technicians, so five of them?

    Yeah, at some point they were all involved with some level of working on the project.

    Just wanted to make sure it was first shift or third shift.

    Everybody had some level of responsibility.

    What about with the buggies?

    For Kaizen, it is very team based. We have multiple engineers, multiple technicians, and even some operator assistance with that. Certainly when we were in the planning and presentation phase, everybody was heavily involved. Now that we are in implementation phase, it’s primarily technician with engineering oversight. And both our IE and ME co-ops are heavily involved with it.

    So why would you say that they are more involved with the kaizen projects? What was the primary purpose?

    The Kaizen project is huge. It’s basically re-envisioning an entire work cell. That's a bit too big for one person to maintain unless, given the timeframe. It’s a very aggressive timeframe, a very aggressive budget and it needs multiple sets of eyes to make sure one
person doesn’t miss something. If you go back to what I said in the beginning about your deliverables, having your knowns and unknowns, it’s one thing to do it for a singular station, a singular process but you’re talking about an entire workcell. And even though we’re methodical and can break it down into sub-components, at some point you’re going to miss something. With multiple sets of eyes, they’re going to look at it from a different slant whether it’s an IE, a EE, a technician. It's critical for something that big to have a team-based process. And so co-ops, where they plug-in, they’re very involved with designing of the workstations, the process. I’m very pleased with their progress, I think they’re doing a great job.

**How would you describe the overall size of the projects? So let’s continue on with the Kaizen project, you’ve been talking that it’s larger in terms of the overall scope, the number of people involved. So how many people would you say were directly involved?**

We had a dozen people involved at the beginning. We probably have half as many, to three quarters made that are actively involved in the implementation. This is the most expensive Kaizen project we’ve done to date in the factory and it has visibility all the way from the top.

**Really?**

Oh absolutely. We just presented a pared down version of this to our CEO. So it has visibility from the top, down. Particularly, I mean, from the factory level, specifically you know, the general manager on down. All major senior managers are well aware of what
we’re doing. It has, in the last couple days, we presented to the CEO what we’re doing so it has visibility for [Company A]. It's one of those…and when we have our senior managers coming in from overseas, this is going to be one of the things they’re going to be looking at. How are we doing on the Kaizen, absolutely.

**What about comparing the Kaizen to the transmission problem? You said it was you, five technicians, and…**

A couple of guys in the shop. The scope of the problem didn’t require a huge team. You have to be realistic in how you allocate your resources and so resources in this case are people, okay. I don't need more than one engineer for that, you know. I used all five technicians so they all have a hand in it. So they all have some experience in a project like this. Had I had a co-op during that time, I definitely would have had them involved. It would have been a great learning tool, learning experience. For the Kaizen, there’s no question it's team-based. It has to be team-based to handle something that big, that quick.

**And the more point of view?**

To make sure we don’t miss stuff. But for something like that where it’s more of a mechanical design, what’s funny about that project is it had a coolness factor to it because every ME, at least on the side (the residential department), including ME managers, stopped by to see how it was going and to watch it run.

**I can imagine. I want to see it right now.**
I’ve got it on my phone I’ll show you. But yeah, there was definitely a coolness factor to it that you don’t get to do that every day. So yeah, I mean, it did necessitate more than one engineer and I was kind of protecting my turf a little bit cause I was having fun with it and I didn’t want some goober like Gibson to come in and ruin it for me. But yeah, that’s kind of how it went.

I can definitely see that. So how many man-hours were required to complete each of these projects?

Well, the one’s (the Kaizen project) is in process. It’s 1500+ man-hours so far in the Kaizen.

How many are I've been allocated to it against a PSR?

Well, that’s what I’m saying. On paper, 1500 hours so far. In actuality, there is just no way to calculate it, there’s no way to track it. It's an estimate based on, you start with your initial guess and at some point, you say, I probably have three times as many people working on it as I originally intended. So you just scale form there. At best, it’s just a guesstimate.

And can you give any kind of guesstimate on the transmission problem?

Couple hundred hours. Couple hundred dollars when you tally up everybody’s time because it's a project that went over about two months time from start to completion. And so you look at all the shop, the technician time, how much time we spent out there. The odds and ends, it was probably a couple hundred hours.
That’s a really good comparison, especially in terms of size. I know these are different because one is more mechanical while the Kaizen is more process but how would you describe the overall complexity of each of these projects? Which one to you is more complex?

Well, certainly the Kaizen is more complex inasmuch as we’re talking about an entire work cell that you are looking at redesigning processes to make it more efficient. There’s just so many more deliverables. As far as the mechanism itself, having to re-envision from a pure engineering standpoint, mechanical engineering standpoint, the power transmission unit was more complex in that you had to re-envision: How do I get this kinetic energy transferred from this motor/gear reduction unit to this rotary transmission to drive this dial table and meet my requirements of getting it on a tabletop, getting it easily accessible. What was literally a bevel gear type set up, now I’m going to a blower belt equivalent, you know. So re-envisioning how to do that effectively was the more difficult engineering challenge. Complexity is strictly a function, in this case, of the Kaizen event being a bigger scale.

Larger in scale.

Not more difficult engineering-wise, but just bigger scale.

Would you also say dealing with more people also affects that complexity too?

It should simplify it because you’ve got more eyes on it.
Even with the interactions with each other, it wouldn’t affect the complexity there?

I mean I wouldn't say it makes it any more difficult. Everybody has their part.

What type of tools or resources did you use to communicate your ideas with others? Whether it being others on the team or others for the tooling and die for the transmission project?

I think I’m missing something here, I’m not following you here.

If we just focus, let’s say, on the transmission project. So focusing on that, what type of resources did you use to communicate your ideas with others? Whether it be your ideas with the technicians or your ideas with the tool and die guys. Did you use a PowerPoint with them, did you print out prints?

I mean, prints, email, vocal. Very basic, you know.

And then for the Kaizen?

I mean, you've got PowerPoint, you’ve got stuff on paper, you know. I hope I’m not simplifying it too much but stuff on the whiteboard. Your basic, you sit around the table and, you know, put stuff on Excel. I don’t know if that makes sense?

Oh no, it does. If you had an idea outside a meeting, would you email it to the group or would you just write it down and save it for later?
It could be either one, it really depends on how crucial it is to disseminate that information quickly. I mean, if you want it documented, obviously email because you can always go back and say, “Hey, I sent you those.”

And these projects, how were you first introduced to them?

Well, I was introduced to the transmission unit when it failed and we couldn’t run the machine. I was introduced to the Kaizen event when the boss comes in and says, “Hey, you’re in charge of this.”

So, it’s primarily verbal communication?

The coil former was quite auditory: crunch, uh oh. Technicians walk in, you might want to come see this.

No good. And the Kaizen one, when you said the boss came.

The boss sat in that very chair and said, you’re in charge of this. Ok, thanks…

With the exception of parts breaking down, would you say someone coming in and telling you, “Hey, I need you to work on this project,” is that most common or is it more common to receive an email?

Both.

Both equally common?

Yeah.
Is there any kind of format to any of this?

This is [Company A] (no).

I have to ask… I’m pretty sure I know the answer.

You know the answer. No, there’s no format to it. I mean, you may get assigned something in one of the weekly (continuous improvement) meetings but in general, he’s going to come in and say, “Hey, I want you on this.” Usually, it’s verbal because he’s got to explain to you what he wants done. There’s going to be a lot of questions and whatnot.

So it’s almost better to have that interview type introduction?

I’d say it’s absolutely required.

How were these projects initially defined? Not the transmission project because you said that was a crunch and you were brought out there by the technicians.

Quite literally.

The Kaizen project, how did your boss initially come in here and be like, “Hey, I need you to work on this.” Did he give you just a general explanation that we need this line redesigned for a Kaizen event or was it just, I need you to do something, get it done, and it’s up to you as to how you get it done.

No, I mean, it was explained that this was the next Kaizen event and it’s kind of understood when you’re going to do a Kaizen event, you know, what’s the goal of a Kaizen event? Now, they had to call me in and break down what were the specific
management driven objectives, budget, things of that nature; give you your goals and constraints. But once you have those, it’s kind of a blank sheet. Assemble the team and, you know, list out the goals and constraints and start going through the process. Now, to me, it’s probably not as documented as it should be but there is a process to going through a Kaizen event. So, as you go through the process, it forces you to answer specific questions that help you to get to your solution, or your proposed solution.

So now while you’re going through these projects, how often do you have design reviews? Well, for the transmission project, how often would you have peer reviews and at least review your design with someone?

I say this half cocked, with that project, it was almost daily review because I always had someone crawling over it looking at it with me and, “Hey man, what’re you doing? How’re you going to solve this? What’s this for? Why are you doing this?”

Because of all the interest in it?

Oh yeah, it was more informal. Like I said, there was a coolness factor to it that we don’t normally get to work on. Usually, it’s very cut and dry, replace this, fix that. This one was like, there was no obvious solution. We had to reengineer it mechanically to see if we could even get it to work. There was a little bit of trepidation once we had it all bolted together to see if we could get it to work. Confidence was high, but until you see it in operation, is it going to go?

The uncertainty there…
Yeah, there was a little bit of uncertainty. The best laid plans are only as good as their execution. That executes well or they execute me.

Well, good thing it executed well… So then, how many formal design reviews did you have for that project?

Maybe one.

Who was involved in that?

Manager and other ME’s. Anyone that could give me constructed feedback.

Was it mainly just the manufacturing group or did you invite anyone from R&D?

No, absolutely not. Just manufacturing guys.

You were talking about having presented the Kaizen stuff to the CEO.

Oh, that was senior management.

You’ve done that with senior management and with local level?

Every senior manager in the factory plus our CEO has been represented to at this point.

That’s incredible now that I think about it that it has the direct attention of the CEO there.
Well, it was one of those where he comes in to visit and you want to show him a lot of the work that has been going on in the factory. This was one of the projects that was selected cause it’s in implementation phase so it was easy to say, “Hey, it’s already been approved, there’s already a presentation. Cut it down to 15 minutes and you’ve got his full attention.”

Ok

One of those deals.

Alrighty, so the transmission, that’s still in use?

Yep.

Have any modifications been made to it since it was first put out there?

Tweaks, tuning.

Ok. Do you think anything could have been prevented with the checklist? Could any of those tweaks have been prevented or is that just one of those things?

No, it’s one of those where when you get to fit and function… CAD’s going to get you so far.

Any major concerns about it? Anticipated lifespan?

No, because of the way it’s designed, all components should be readily accessible, replaceable. Fairly straight forward.
Any final reflections on these projects at all?

Nothing I can think of. They’re all worthy projects, fairly straightforward. Some forced upon you, the nature of the beast. Others planned but they’re cost savings at the end of the day and, I think, worthwhile.

It helps with production.

Absolutely. They both help the factory for sure.

B.6 B.ME.1 – Frank

SO: The purpose of this is for my research at Clemson where from my experiences in the capstone program and then senior program we design primarily in teams of 3, 4, or 5 students and we work on a project together as in that team. Well, when coming here, the most interaction in a team that I have received was maybe working on a project with or maybe getting some assistance from one of the test engineers whether it be like mainly it was Brian Williams. Or it would be one of the techs. And that would be it. So I just wanted to come here and get y’all’s experiences since y'all have been working here much longer than me. Y’all have more experience than I do. I just wanted to see if your insight is the same as mine but hopefully what will come out of this is that if most of the work you do is more individual rather directly in teams then there might be some sort of process of some sort of tool or even software that I could potentially develop or recommend and then you could potentially use it here or someone at some other company so the end goal
of this is to try to help increase efficiency and quality the overall ability of the engineer especially if they’re new like I was when I first started. And increasing the ability to hit the ground running might be helpful.

So I have to get these introductory questions first: what is your position title and description, and how many years have you been at this position?

Brad: Lead manufacturing engineer is the title. I’ve been in this particular role since probably 2006/2007 so 8 or 9 years.

And what exactly are your responsibilities in that role?

Well manufacturing engineer, first and foremost, supporting production, supporting departmental initiatives and filtering those down through the group such as PSR's, manufacturing qualifications, 5S initiatives. Right now, I’m leading a Kaizen team so any number of focus factory and departmental goals that need to be filtered down to the group. Maintaining capital budget, mechanical design reviews, things like that. You know, all of the above our part my responsibilities but first and foremost of these would be supporting production, project management, things like that.

Ok. So what was your previous design experience within [Company A]?

I mean…if we’re talking in a current manufacturing engineering role, when I first started back in ’99, it might be designing fixtures, designing tooling in Pro/E for production. As I’ve gone room and, I guess, progressed over time, I still support that, but not to the same degree that some of the other guys in the group do. I've seen my
responsibilities shift to more project management as compared to down in the trenches, nuts and bolts, designing fixtures. I still do that from time to time but that's not one of the things it would be one of my big portion of my plate right now.

**What other companies have you worked for?**

Milliken and Company at their finishing plant in Pendleton. Co-oped at Metler Toledo back in the mid-90s. but I’ve been at [Company A] since ’99.

**What type of work did you do for those other companies?**

Very similar to what, I guess, a typical co-op or intern would do. Some basic CAD work, some basic data collection. A little bit of fixture design. At Milliken I also did some inventory control, did some 5S, stuff like that.

**Have you attended any workshops or taken any specific classes on designing, and more importantly, either design in general or how to design on your own as an individual rather than in teams?**

So let’s clarify, when talking design, you know, you mean with a CAD package designing a specific mechanism or something?

Yeah, whether it be with CAD or whether it be just having to have something sketched out and then potentially presented to someone before actually going to CAD. Any kind of design work whether it be for fixture or tooling.
I mean, above and beyond what I took in school, I don't believe. It’s one of those things where I’ve refined my craft over the years. Learning from mentors, learning from senior engineers, watching the process, learning as I go and perfecting it through time.

So what kind of stuff would you say you’ve learned throughout your experiences?

Learning the design process, you know, to identify what are the key parameters before you sit down on the CAD package and start to, start to sketch it out: what are you trying to accomplish? What are your space constraints? What, if any, budgetary constraints do you have which will affect your selection of materials. Are there any safety considerations that have been identified ahead of time? So mainly getting all the prep work done and answered before you sit down in front of the computer to start the design so that you don't find out halfway through it, “Oh I had to make sure this was a nonconductive material,” or “Oh it needs to be mobile. I had this on a table top.” Getting all your ducks in a row before you sit down to do it is the biggest, you know, it sounds trivial but a lot of people even now don't do that correctly, in my opinion, and they have to go back and rev their design 2, 3, 4 times because they didn't have all the information they needed. Now sometimes that information is not easily come by, but you get as much of it as you can. So one thing, if we had a designer’s kit, and this is just thinking matter of fact, a designer’s kit that forces you to answer specific questions up front, as much as possible. For example, “Are there safety considerations?”, “Is this a mobile device?”, “Is this intended to be a standalone machine?” , “Is it tabletop?” Selection of materials, you
know, does it need to be ESD? What type of product is going to go into it? Does it need to be guarded? Is it just simple mechanisms or is there going to be kinetic energy devices such as hydraulic schematics, servos that need light curtains. All of these things, if they’re answered up front, you going to design with that in mind. So, if we had a checklist, maybe the standard, you know…

**That almost sets up your design space for you.**

It really forces you down the correct path because if you can answer these questions up front, then when you actually sit down and start putting the mechanism together in your mind on the computer, “Oh yeah, I remember I’ve got to have ESD shelving. Oh, I’m going to have to have light curtains on this because I'm using, you know, half-inch four pneumatic cylinders to do this action or whatever it is. Make sure you know dot your I’s and cross your T’s. So one of those, I mean a lot of times we do it naturally, we go and write stuff down a piece of paper in a notebook but if we had a checklist that formalizes that this is part of the design process, answer these questions as much as possible. And if there's a problem you can always go back to your checklist and say, “why isn't this right?” Well, this is the assumptions I had when I went into it. Maybe the assumptions change. Maybe what was supposed to be a fixed benchtop type of mechanism, well now they want to roll it from cell to cell so it needs to be mobile. Well, if there’s changes that are required later, you can at least go back to say, “Hey, when I started the process, my checklist said this was benchtop and this was a fixed asset. Now somebody has changed into a mobile device down the road. So, if it takes three more
weeks to finish this and another 1000 to 1500 dollars to modify it, you’ve got your documentation that says, “Hey, when I started the project, these were the assumptions.” So it's always good to have that information up front.

**So would having some sort of a pre-populated list of topics to go through that forces you to go through a general listing of every subject, whether it be safety, ESD, material selection, would you say that would be helpful?**

I think particularly for the guys that are new, for co-ops, for those that aren’t used to the design process that need to perfect their craft. I think having something more formal like that forces them to think about some of the issues that we take for granted as a more senior designer. You know, we go through the checklist in our head and even now, we’ll miss stuff and if we had it on a paper or whatever, in front of us the whole time, you know, even that would help a seasoned engineer to make sure to keep all their information straight. It's just like solving any kind of technical problem. You list your assumptions first before you try to solve the problem. This is no different: you list your assumptions up front, you knowns, and your assumptions and then you start your design. And when you get to the end you ought to be able to look at your designs and say, “Yep, light curtains, check that out for guarding,” “yep, I’ve got ESD and that’s grounded. Check that off for that, you know.” You ought to be able to look at your finished design and look at your list of knowns and assumptions, and every one of those is satisfied in the design. And if they’re not, you’ve missed something. You didn’t pay attention to the information you had.
Now let’s get into some of the projects you’ve worked on. That’s what the remainder of these questions will focus on. So can you describe your most recent design project that you’ve completed?

We had to do a redesign on the power transmission unit for the old coil-forming machine. The rotary transmission unit for the dial table failed. The drive gear basically destructed, self-destructed and it was about a $45,000 replacement and it wasn't a drop in to get the power transmission unit. The way it was set up was not easily to work on. You had to crawl under the machine, pull the motor and the clutch. So we decided to reengineer it in-house and take the components that worked on the rotary transmission and design and install a new power transmission unit to drive the rotary to drive the dial table. So it was really cool. About a $43,000 cost-savings as well. So basically taking known mechanical concepts on power transmission, we got the drive unit from underneath table, mounted it tabletop so it’s easily accessible. Basically, took the equivalent of a blower belt, a big 1.5-inch wide belt that would transmit power from the motor gear reduction unit to the input shaft for the rotary transmission. Getting that all built and designed and operational, we can go look at that anytime you want to go look at that.

Might have to take a look at that, that’s pretty exciting.

It's pretty neat, I’ve got some pictures to show you. Matter of fact, I know I do on my phone. So going through that design process was neat and, you know, again having the checklist available and have it posted out there and make sure we’re meeting all those
requirements would've been an advantage. We miss some stuff, you know. It's one of those particularly, designing mechanisms for a production environment, you’ve got time pressures, you’ve got budgetary considerations, and you miss stuff. And so any information that we can get solidified up front and have it right there in our face the whole time would be a help.

**Now, what about a second challenging project that you best remember. It doesn’t have to be recent.**

Well, I mean, right now so when we talk design, it can be anything from fixtures to workstations. So right now, our Kaizen event for semi-auto, we’re designing new works, basically a new work cell, so the design concepts that we’re talking about are scalable you know, your checklist is still the same, your requirements, your knowns, your unknowns. It’s all of these different things. You just have to break it down into subcomponents so that even though I've got the big picture in mind, I need to apply these concepts to each of the subcomponents that go into that cell. So for all of our flow channels, all of our buggies, all of our carts and workstations, the process remains same even though we’re focusing on one small subcomponent of the larger cell. So right now, we’re designing carts, buggies, and workstations to do specific tasks and assembly steps. So we’re having to consider things like grounding and ESD, mobility, modular design, ergonomics. All of these things, we have to take into account so not to be a broken record but all these things we talked about for the last project and in general, these checklists, these stating your facts and knowns and assumptions, you know. For every one of these
designs that we’re doing, having that information available, it provides continuity of thought on work, how your designing each station and what not. You know, having continuity of the lessons learned. Ok, if you’re going to do something like this: if you have meters on a shelf, it needs to be this type of material. This is the part number and specs for it.

So for the transmission redesign, what type of project would you say that is? The examples I have here are tooling and fixture design, process design. I wouldn’t think that falls under that. Would you say it’s almost the station partial redesign?

Yeah, I mean that not really even tooling. Machinery redesign and upgrade, if you want.

The buggies and the flow process…

I mean, that’s machinery equipment. That’s process as much as it is anything.

In general, how many design projects are you assigned either per year, or if it is easier, per month?

How about per week?

Well we could take an average per week and multiply it by 50, assuming 2 weeks off.
I mean, you know, there's no general blanket answer for that. For me, personally, maybe not as much as the other guys. I might have one or two things going per week that carry-on over multiple weeks.

**Is it really because you’re overseeing projects?**

Yeah, I mean, it’s more project management. A lot of it is for me so I might have one or two or three designs that might go for months because they’re larger or it takes time to get stuff built and different things and you follow through to completion. So maybe a dozen to a dozen and a half over a calendar year but when you talk about but, you know, when you’re talking about buggies and carts and mechanisms and fixtures and tooling. When you talk about true design work for me, that's a good, good number of projects throughout the year when you figure you’re still doing production support, paperwork, and all the different project management that comes along with these things.

**Ok, so how about just projects in general. Not only design but also with other production, other, let’s say your you put on a 6S…**

So a couple of ways to answer that. If we’re talking just like major projects that are tracked with budgets and hours and PSR's and whatnot, probably a dozen in a calendar year is good number. But when you talk about everything else that goes with it, the smaller not as visible projects, the fire fighting, the we need to design something to repair something on the line, I mean, it could be several dozen, you know. It really depends on how granular you want to get but as far as measurable tracked projects that management
is inclined to request updates on what the tracking on and whatnot, maybe a dozen or so in a calendar year.

**Ok, and what resources do you typically use throughout these projects? Whether it be software, hardware, tooling, people.**

Oh gosh, there’s a myriad of resources between CAD packages, any number of Microsoft products like PowerPoint, Excel, Word for communications, any number of homegrown: Dashboard, EIS, RIS, we’ve got a lot of homegrown apps that we use. I guess what I’ll call indigenous software, stuff like Brainson has their own stuff or MiniTab, things like that. Reference books, you know, my mechanics book, I’ll use that quite often during the design process. Any number of webpages where you go out and do a Google search, “Ok, I need to know about pitch angle on this kind of thread,” or what kind of fasteners to use, rules of thumb for whatever it is you’re looking for. I mean, there's any number of resources that you can use. Pick your neighbor’s brain, I mean literally. If you have tooling questions, you ask your tool and die guys. Electrical questions, you’ll hit up your test engineers or whatever. Any number of places to go to get the answers you seek.

**And so, we've been talking about how you go through and look at a project and you try to break it down to what you need for the project. Do you have an overarching specified procedure that you tend to follow? Do you have that documented somewhere or is it just from your experience?**
Experience. That’s why I say when you first come on, you’ve got to refine your craft and you’re going to learn by your mistakes, you’re going to get lessons learned that you apply to subsequent projects and processes so… I don’t know that you need an overarching set of rules and documents because it tends to limit innovation. But what you need is the upfront information to get you from point A to point B. How you get to point B could be any number ways. And there’s where I wouldn’t want to be limited to I have to do this process or I have to follow this.

So that makes a lot of sense. You don't want to go...you want to set someone up help or help set a designer up but not…

A procedure should be to the benefit the designer. So when I say have a checklist of things you need to answer ahead of time, that's helpful, that's not a hindrance. Having a procedure that says okay you’ve got to do this, this, this, and this during your design process. If it's high-level, I see benefit in it. You know, for example, okay you’ve got X number of things you need to do through the whole process. Number one, fill out your free checklist, whatever you want to call it, listing your knowns and assumptions. Before you go to print have a peer review. Before you go tooling, have your designs checked for accuracy in your prints, okay. And then when you go to receive your tooling, your machined components, maybe have some quality checks on them that you have two or three dimensions checked for accuracy before you assemble, okay. And before you release to production your design, do some fit and function to make sure that all of your assumptions at the very beginning are satisfied when you go to do fit and function. I
could see something like that’s just some basic and reasonable deliverables as you go from concept to completion, but anything more rigid than that, to me, becomes a hindrance because now I’m more concerned with the process that I am the design and I don't want to get to that point. I want to stay focused on the design, you know, if it's just meeting some basic deliverables as we go that's reasonable but beyond that, it becomes a little too rigid in my opinion. It becomes more micromanaging.

I feel like that, in general, and I’m making a general assumption here, most people, I don’t think, like to be micromanaged. So by having some sort of, like what you were talking about, this process here would encourage more people to want to use it.

So the software that you used throughout these, like you said, the Microsoft apps, CAD as far as…

Pro/E and Solidworks. Although we have recently broke AutoCAD back out.

Really? A 3-D version or 2-D version?

2-D. Layouts.

So let’s say for your power transmission project, who all assisted with that?

Technicians. Technicians and tooling guys, guys in the shop.

You didn’t have any co-op or any assistance from any of the other engineers?
I don't think I had a co-op during that time. This is when Alex had his electrical engineering co-op. This would have been late last year (2014).

**Now, do you think that a co-op could have been assigned to this project?**

Do I think a co-op could have been assigned to this project? A more senior co-op, yes, with oversight. And here’s why I say this and this is not…I need to be careful how I answer this. The level of experience they might have when taking something like that that’s malfunctioned that has a significant price tag to it and reengineering a power transmission concept for it. I would feel comfortable letting them explore some options and with guidance and oversight, possibly let them manage the project. Certainly they could take part in it. There’s a lot of CAD that had to be done. A lot of inventory that needed to be ordered. You know, things that needed to be machined certainly would be, you know, in favor of things like that but I don't know that I would say, “Hey, I’m going to turn this over to you.” Now, a senior co-op on the third or fourth rotation, possibly. I've always said that I consider 3rd and 4th rotation co-ops to be staff engineers by then, they just don’t have the title. But they have a lot of experience and know-how. They know who to talk to and, you know, there's always that intermediate action with engineering, and particularly with myself to maintain that oversight so possibly could I see turning that over to a co-op, you know.

**Was this this project, was it team-based?**

Team in as much as I was the engineer with, I think, at some point all of my technicians were involved with some level project, in addition to shop assistance. So
yeah, there was a team of folks that had deliverables. It wasn't just a solo project but for this case, I would have be the only mechanical engineer working on the project.

So you were the only mechanical engineer working on the job, period?

Yes, yes, I would say so.

And you said all of the technicians, so five of them?

Yeah, at some point they were all involved with some level of working on the project.

Just wanted to make sure it was first shift or third shift.

Everybody had some level of responsibility.

What about with the buggies?

For Kaizen, it is very team based. We have multiple engineers, multiple technicians, and even some operator assistance with that. Certainly when we were in the planning and presentation phase, everybody was heavily involved. Now that we are in implementation phase, it’s primarily technician with engineering oversight. And both our IE and ME co-ops are heavily involved with it.

So why would you say that they are more involved with the kaizen projects?

What was the primary purpose?

The Kaizen project is huge. It’s basically re-envisioning an entire work cell. That's a bit too big for one person to maintain unless, given the timeframe. It’s a very aggressive timeframe, a very aggressive budget and it needs multiple sets of eyes to make sure one
person doesn’t miss something. If you go back to what I said in the beginning about your deliverables, having your knowns and unknowns, it’s one thing to do it for a singular station, a singular process but you’re talking about an entire workcell. And even though we’re methodical and can break it down into sub-components, at some point you’re going to miss something. With multiple sets of eyes, they’re going to look at it from a different slant whether it’s an IE, a EE, a technician. It's critical for something that big to have a team-based process. And so co-ops, where they plug-in, they’re very involved with designing of the workstations, the process. I’m very pleased with their progress, I think they’re doing a great job.

How would you describe the overall size of the projects? So let’s continue on with the Kaizen project, you’ve been talking that it’s larger in terms of the overall scope, the number of people involved. So how many people would you say were directly involved?

We had a dozen people involved at the beginning. We probably have half as many, to three quarters made that are actively involved in the implementation. This is the most expensive Kaizen project we’ve done to date in the factory and it has visibility all the way from the top.

Really?

Oh absolutely. We just presented a pared down version of this to our CEO. So it has visibility from the top, down. Particularly, I mean, from the factory level, specifically you know, the general manager on down. All major senior managers are well aware of what
we’re doing. It has, in the last couple days, we presented to the CEO what we’re doing so it has visibility for [Company A]. It’s one of those…and when we have our senior managers coming in from overseas, this is going to be one of the things they’re going to be looking at. How are we doing on the Kaizen, absolutely.

**What about comparing the Kaizen to the transmission problem? You said it was you, five technicians, and…**

A couple of guys in the shop. The scope of the problem didn’t require a huge team. You have to be realistic in how you allocate your resources and so resources in this case are people, okay. I don't need more than one engineer for that, you know. I used all five technicians so they all have a hand in it. So they all have some experience in a project like this. Had I had a co-op during that time, I definitely would have had them involved. It would have been a great learning tool, learning experience. For the Kaizen, there’s no question it's team-based. It has to be team-based to handle something that big, that quick.

**And the more point of view?**

To make sure we don’t miss stuff. But for something like that where it’s more of a mechanical design, what’s funny about that project is it had a coolness factor to it because every ME, at least on the side (the residential department), including ME managers, stopped by to see how it was going and to watch it run.

**I can imagine. I want to see it right now.**
I’ve got it on my phone I’ll show you. But yeah, there was definitely a coolness factor to it that you don't get to do that every day. So yeah, I mean, it did necessitate more than one engineer and I was kind of protecting my turf a little bit cause I was having fun with it and I didn’t want some goober like Gibson to come in and ruin it for me. But yeah, that’s kind of how it went.

I can definitely see that. So how many man-hours were required to complete each of these projects?

Well, the one’s (the Kaizen project) is in process. It’s 1500+ man-hours so far in the Kaizen.

How many are I've been allocated to it against a PSR?

Well, that’s what I’m saying. On paper, 1500 hours so far. In actuality, there is just no way to calculate it, there’s no way to track it. It's an estimate based on, you start with your initial guess and at some point, you say, I probably have three times as many people working on it as I originally intended. So you just scale form there. At best, it’s just a guesstimate.

And can you give any kind of guesstimate on the transmission problem?

Couple hundred hours. Couple hundred dollars when you tally up everybody’s time because it's a project that went over about two months time from start to completion. And so you look at all the shop, the technician time, how much time we spent out there. The odds and ends, it was probably a couple hundred hours.
That’s a really good comparison, especially in terms of size. I know these are different because one is more mechanical while the Kaizen is more process but how would you describe the overall complexity of each of these projects? Which one to you is more complex?

Well, certainly the Kaizen is more complex inasmuch as we’re talking about an entire work cell that you are looking at redesigning processes to make it more efficient. There’s just so many more deliverables. As far as the mechanism itself, having to re-envision from a pure engineering standpoint, mechanical engineering standpoint, the power transmission unit was more complex in that you had to re-envision: How do I get this kinetic energy transferred from this motor/gear reduction unit to this rotary transmission to drive this dial table and meet my requirements of getting it on a tabletop, getting it easily accessible. What was literally a bevel gear type set up, now I’m going to a blower belt equivalent, you know. So re-envisioning how to do that effectively was the more difficult engineering challenge. Complexity is strictly a function, in this case, of the Kaizen event being a bigger scale.

Larger in scale.

Not more difficult engineering-wise, but just bigger scale.

Would you also say dealing with more people also affects that complexity too?

It should simplify it because you’ve got more eyes on it.
Even with the interactions with each other, it wouldn’t affect the complexity there?

I mean I wouldn't say it makes it any more difficult. Everybody has their part.

What type of tools or resources did you use to communicate your ideas with others? Whether it being others on the team or others for the tooling and die for the transmission project?

I think I’m missing something here, I’m not following you here.

If we just focus, let’s say, on the transmission project. So focusing on that, what type of resources did you use to communicate your ideas with others? Whether it be your ideas with the technicians or your ideas with the tool and die guys. Did you use a PowerPoint with them, did you print out prints?

I mean, prints, email, vocal. Very basic, you know.

And then for the Kaizen?

I mean, you've got PowerPoint, you’ve got stuff on paper, you know. I hope I’m not simplifying it too much but stuff on the whiteboard. Your basic, you sit around the table and, you know, put stuff on Excel. I don’t know if that makes sense?

Oh no, it does. If you had an idea outside a meeting, would you email it to the group or would you just write it down and save it for later?
It could be either one, it really depends on how crucial it is to disseminate that information quickly. I mean, if you want it documented, obviously email because you can always go back and say, “Hey, I sent you those.”

**And these projects, how were you first introduced to them?**

Well, I was introduced to the transmission unit when it failed and we couldn’t run the machine. I was introduced to the Kaizen event when the boss comes in and says, “Hey, you’re in charge of this.”

**So, it’s primarily verbal communication?**

The coil former was quite auditory: crunch, uh oh. Technicians walk in, you might want to come see this.

**No good. And the Kaizen one, when you said the boss came.**

The boss sat in that very chair and said, you’re in charge of this. Ok, thanks…

**With the exception of parts breaking down, would you say someone coming in and telling you, “Hey, I need you to work on this project,” is that most common or is it more common to receive an email?**

Both.

**Both equally common?**

Yeah.
Is there any kind of format to any of this?

This is [Company A] (no).

I have to ask… I’m pretty sure I know the answer.

You know the answer. No, there’s no format to it. I mean, you may get assigned something in one of the weekly (continuous improvement) meetings but in general, he’s going to come in and say, “Hey, I want you on this.” Usually, it’s verbal because he’s got to explain to you what he wants done. There’s going to be a lot of questions and whatnot.

So it’s almost better to have that interview type introduction?

I’d say it’s absolutely required.

How were these projects initially defined? Not the transmission project because you said that was a crunch and you were brought out there by the technicians.

Quite literally.

The Kaizen project, how did your boss initially come in here and be like, “Hey, I need you to work on this.” Did he give you just a general explanation that we need this line redesigned for a Kaizen event or was it just, I need you to do something, get it done, and it’s up to you as to how you get it done.

No, I mean, it was explained that this was the next Kaizen event and it’s kind of understood when you’re going to do a Kaizen event, you know, what’s the goal of a Kaizen event? Now, they had to call me in and break down what were the specific
management driven objectives, budget, things of that nature; give you your goals and constraints. But once you have those, it’s kind of a blank sheet. Assemble the team and, you know, list out the goals and constraints and start going through the process. Now, to me, it’s probably not as documented as it should be but there is a process to going through a Kaizen event. So, as you go through the process, it forces you to answer specific questions that help you to get to your solution, or your proposed solution.

**So now while you’re going through these projects, how often do you have design reviews? Well, for the transmission project, how often would you have peer reviews and at least review your design with someone?**

I say this half cocked, with that project, it was almost daily review because I always had someone crawling over it looking at it with me and, “Hey man, what’re you doing? How’re you going to solve this? What’s this for? Why are you doing this?”

**Because of all the interest in it?**

Oh yeah, it was more informal. Like I said, there was a coolness factor to it that we don’t normally get to work on. Usually, it’s very cut and dry, replace this, fix that. This one was like, there was no obvious solution. We had to reengineer it mechanically to see if we could even get it to work. There was a little bit of trepidation once we had it all bolted together to see if we could get it to work. Confidence was high, but until you see it in operation, is it going to go?

**The uncertainty there…**
Yeah, there was a little bit of uncertainty. The best laid plans are only as good as their execution. That executes well or they execute me.

Well, good thing it executed well... So then, how many formal design reviews did you have for that project?

Maybe one.

Who was involved in that?

Manager and other ME’s. Anyone that could give me constructed feedback.

Was it mainly just the manufacturing group or did you invite anyone from R&D?

No, absolutely not. Just manufacturing guys.

You were talking about having presented the Kaizen stuff to the CEO.

Oh, that was senior management.

You’ve done that with senior management and with local level?

Every senior manager in the factory plus our CEO has been represented to at this point.

That’s incredible now that I think about it that it has the direct attention of the CEO there.
Well, it was one of those where he comes in to visit and you want to show him a lot of the work that has been going on in the factory. This was one of the projects that was selected cause it’s in implementation phase so it was easy to say, “Hey, it’s already been approved, there’s already a presentation. Cut it down to 15 minutes and you’ve got his full attention.”

Ok

One of those deals.

Alrighty, so the transmission, that’s still in use?

Yep.

Have any modifications been made to it since it was first put out there?

Tweaks, tuning.

Ok. Do you think anything could have been prevented with the checklist? Could any of those tweaks have been prevented or is that just one of those things?

No, it’s one of those where when you get to fit and function… CAD’s going to get you so far.

Any major concerns about it? Anticipated lifespan?

No, because of the way it’s designed, all components should be readily accessible, replaceable. Fairly straight forward.
Any final reflections on these projects at all?

Nothing I can think of. They’re all worthy projects, fairly straight forward. Some forced upon you, the nature of the beast. Others planned but they’re cost savings at the end of the day and, I think, worthwhile.

It helps with production.

Absolutely. They both help the factory for sure.

B.7 B.ME.2 – Grace

SO: The purpose of this is for my research at Clemson where from my experiences in the capstone program and then senior program we design primarily in teams of 3, 4, or 5 students and we work on a project together as in that team. Well, when coming here, the most interaction in a team that I have received was maybe working on a project with or maybe getting some assistance from one of the test engineers whether it be like mainly it was Brian Williams. Or it would be one of the techs. And that would be it. So I just wanted to come here and get y’all’s experiences since y'all have been working here much longer than me. Y’all have more experience than I do. I just wanted to see if your insight is the same as mine but hopefully what will come out of this is that if most of the work you do is more individual rather directly in teams then there might be some sort of process of some sort of tool or even software that I could potentially develop or recommend and then you could potentially use it here or someone at some other company so the end goal
of this is to try to help increase efficiency and quality the overall ability of the engineer especially if they’re new like I was when I first started. And increasing the ability to hit the ground running might be helpful.

So I have to get these introductory questions first: what is your position title and description, and how many years have you been at this position?

Brad: Lead manufacturing engineer is the title. I’ve been in this particular role since probably 2006/2007 so 8 or 9 years.

And what exactly are your responsibilities in that role?

Well manufacturing engineer, first and foremost, supporting production, supporting departmental initiatives and filtering those down through the group such as PSR’s, manufacturing qualifications, 5S initiatives. Right now, I’m leading a Kaizen team so any number of focus factory and departmental goals that need to be filtered down to the group. Maintaining capital budget, mechanical design reviews, things like that. You know, all of the above our part my responsibilities but first and foremost of these would be supporting production, project management, things like that.

Ok. So what was your previous design experience within [Company A]?

I mean…if we’re talking in a current manufacturing engineering role, when I first started back in ’99, it might be designing fixtures, designing tooling in Pro/E for production. As I've gone room and, I guess, progressed over time, I still support that, but not to the same degree that some of the other guys in the group do. I've seen my
responsibilities shift to more project management as compared to down in the trenches, nuts and bolts, designing fixtures. I still do that from time to time but that's not one of the things it would be one of my big portion of my plate right now.

**What other companies have you worked for?**

Milliken and Company at their finishing plant in Pendleton. Co-oped at Metler Toledo back in the mid-90s. but I’ve been at [Company A] since ’99.

**What type of work did you do for those other companies?**

Very similar to what, I guess, a typical co-op or intern would do. Some basic CAD work, some basic data collection. A little bit of fixture design. At Milliken I also did some inventory control, did some 5S, stuff like that.

**Have you attended any workshops or taken any specific classes on designing, and more importantly, either design in general or how to design on your own as an individual rather than in teams?**

So let’s clarify, when talking design, you know, you mean with a CAD package designing a specific mechanism or something?

**Yeah, whether it be with CAD or whether it be just having to have something sketched out and then potentially presented to someone before actually going to CAD. Any kind of design work whether it be for fixture or tooling.**
I mean, above and beyond what I took in school, I don't believe. It’s one of those things where I’ve refined my craft over the years. Learning from mentors, learning from senior engineers, watching the process, learning as I go and perfecting it through time.

So what kind of stuff would you say you’ve learned throughout your experiences?

Learning the design process, you know, to identify what are the key parameters before you sit down on the CAD package and start to, start to sketch it out: what are you trying to accomplish? What are your space constraints? What, if any, budgetary constraints do you have which will affect your selection of materials. Are there any safety considerations that have been identified ahead of time? So mainly getting all the prep work done and answered before you sit down in front of the computer to start the design so that you don't find out halfway through it, “Oh I had to make sure this was a nonconductive material,” or “Oh it needs to be mobile. I had this on a table top.” Getting all your ducks in a row before you sit down to do it is the biggest, you know, it sounds trivial but a lot of people even now don't do that correctly, in my opinion, and they have to go back and rev their design 2, 3, 4 times because they didn't have all the information they needed. Now sometimes that information is not easily come by, but you get as much of it as you can. So one thing, if we had a designer’s kit, and this is just thinking matter of fact, a designer’s kit that forces you to answer specific questions up front, as much as possible. For example, “Are there safety considerations?”, “Is this a mobile device?”, “Is this intended to be a standalone machine?”, “Is it tabletop?” Selection of materials, you
know, does it need to be ESD? What type of product is going to go into it? Does it need to be guarded? Is it just simple mechanisms or is there going to be kinetic energy devices such as hydraulic schematics, servos that need light curtains. All of these things, if they’re answered up front, you going to design with that in mind. So, if we had a checklist, maybe the standard, you know…

**That almost sets up your design space for you.**

It really forces you down the correct path because if you can answer these questions up front, then when you actually sit down and start putting the mechanism together in your mind on the computer, “Oh yeah, I remember I’ve got to have ESD shelving. Oh, I’m going to have to have light curtains on this because I'm using, you know, half-inch four pneumatic cylinders to do this action or whatever it is. Make sure you know dot your I’s and cross your T’s. So one of those, I mean a lot of times we do it naturally, we go and write stuff down a piece of paper in a notebook but if we had a checklist that formalizes that this is part of the design process, answer these questions as much as possible. And if there's a problem you can always go back to your checklist and say, “why isn't this right?” Well, this is the assumptions I had when I went into it. Maybe the assumptions change. Maybe what was supposed to be a fixed benchtop type of mechanism, well now they want to roll it from cell to cell so it needs to be mobile. Well, if there’s changes that are required later, you can at least go back to say, “Hey, when I started the process, my checklist said this was benchtop and this was a fixed asset. Now somebody has changed into a mobile device down the road. So, if it takes three more
weeks to finish this and another 1000 to 1500 dollars to modify it, you’ve got your documentation that says, “Hey, when I started the project, these were the assumptions.” So it's always good to have that information up front.

So would having some sort of a pre-populated list of topics to go through that forces you to go through a general listing of every subject, whether it be safety, ESD, material selection, would you say that would be helpful?

I think particularly for the guys that are new, for co-ops, for those that aren’t used to the design process that need to perfect their craft. I think having something more formal like that forces them to think about some of the issues that we take for granted as a more senior designer. You know, we go through the checklist in our head and even now, we’ll miss stuff and if we had it on a paper or whatever, in front of us the whole time, you know, even that would help a seasoned engineer to make sure to keep all their information straight. It's just like solving any kind of technical problem. You list your assumptions first before you try to solve the problem. This is no different: you list your assumptions up front, you knowns, and your assumptions and then you start your design. And when you get to the end you ought to be able to look at your designs and say, “Yep, light curtains, check that out for guarding,” “yep, I’ve got ESD and that’s grounded. Check that off for that, you know.” You ought to be able to look at your finished design and look at your list of knowns and assumptions, and every one of those is satisfied in the design. And if they’re not, you’ve missed something. You didn’t pay attention to the information you had.
Now let’s get into some of the projects you’ve worked on. That’s what the remainder of these questions will focus on. So can you describe your most recent design project that you’ve completed?

We had to do a redesign on the power transmission unit for the old coil-forming machine. The rotary transmission unit for the dial table failed. The drive gear basically destructed, self-destructed and it was about a $45,000 replacement and it wasn't a drop in to get the power transmission unit. The way it was set up was not easily to work on. You had to crawl under the machine, pull the motor and the clutch. So we decided to reengineer it in-house and take the components that worked on the rotary transmission and design and install a new power transmission unit to drive the rotary to drive the dial table. So it was really cool. About a $43,000 cost-savings as well. So basically taking known mechanical concepts on power transmission, we got the drive unit from underneath table, mounted it tabletop so it’s easily accessible. Basically, took the equivalent of a blower belt, a big 1.5-inch wide belt that would transmit power from the motor gear reduction unit to the input shaft for the rotary transmission. Getting that all built and designed and operational, we can go look at that anytime you want to go look at that.

**Might have to take a look at that, that’s pretty exciting.**

It's pretty neat, I’ve got some pictures to show you. Matter of fact, I know I do on my phone. So going through that design process was neat and, you know, again having the checklist available and have it posted out there and make sure we’re meeting all those
requirements would've been an advantage. We miss some stuff, you know. It's one of those particularly, designing mechanisms for a production environment, you’ve got time pressures, you’ve got budgetary considerations, and you miss stuff. And so any information that we can get solidified up front and have it right there in our face the whole time would be a help.

Now, what about a second challenging project that you best remember. It doesn’t have to be recent.

Well, I mean, right now so when we talk design, it can be anything from fixtures to workstations. So right now, our Kaizen event for semi-auto, we’re designing new works, basically a new work cell, so the design concepts that we’re talking about are scalable you know, your checklist is still the same, your requirements, your knowns, your unknowns. It’s all of these different things. You just have to break it down into subcomponents so that even though I’ve got the big picture in mind, I need to apply these concepts to each of the subcomponents that go into that cell. So for all of our flow channels, all of our buggies, all of our carts and workstations, the process remains same even though we’re focusing on one small subcomponent of the larger cell. So right now, we’re designing carts, buggies, and workstations to do specific tasks and assembly steps. So we’re having to consider things like grounding and ESD, mobility, modular design, ergonomics. All of these things, we have to take into account so not to be a broken record but all these things we talked about for the last project and in general, these checklists, these stating your facts and knowns and assumptions, you know. For every one of these
designs that we’re doing, having that information available, it provides continuity of thought on work, how your designing each station and what not. You know, having continuity of the lessons learned. Ok, if you’re going to do something like this: if you have meters on a shelf, it needs to be this type of material. This is the part number and specs for it.

So for the transmission redesign, what type of project would you say that is? The examples I have here are tooling and fixture design, process design. I wouldn’t think that falls under that. Would you say it’s almost the station partial redesign?

Yeah, I mean that not really even tooling. Machinery redesign and upgrade, if you want.

The buggies and the flow process…

I mean, that’s machinery equipment. That’s process as much as it is anything.

In general, how many design projects are you assigned either per year, or if it is easier, per month?

How about per week?

Well we could take an average per week and multiply it by 50, assuming 2 weeks off.
I mean, you know, there's no general blanket answer for that. For me, personally, maybe not as much as the other guys. I might have one or two things going per week that carry-on over multiple weeks.

**Is it really because you’re overseeing projects?**

Yeah, I mean, it’s more project management. A lot of it is for me so I might have one or two or three designs that might go for months because they’re larger or it takes time to get stuff built and different things and you follow through to completion. So maybe a dozen to a dozen and a half over a calendar year but when you talk about but, you know, when you’re talking about buggies and carts and mechanisms and fixtures and tooling. When you talk about true design work for me, that's a good, good number of projects throughout the year when you figure you’re still doing production support, paperwork, and all the different project management that comes along with these things.

**Ok, so how about just projects in general. Not only design but also with other production, other, let’s say your you put on a 6S…**

So a couple of ways to answer that. If we’re talking just like major projects that are tracked with budgets and hours and PSR's and whatnot, probably a dozen in a calendar year is good number. But when you talk about everything else that goes with it, the smaller not as visible projects, the fire fighting, the we need to design something to repair something on the line, I mean, it could be several dozen, you know. It really depends on how granular you want to get but as far as measurable tracked projects that management
is inclined to request updates on what the tracking on and whatnot, maybe a dozen or so in a calendar year.

**Ok, and what resources do you typically use throughout these projects? Whether it be software, hardware, tooling, people.**

Oh gosh, there’s a myriad of resources between CAD packages, any number of Microsoft products like PowerPoint, Excel, Word for communications, any number of homegrown: Dashboard, EIS, RIS, we’ve got a lot of homegrown apps that we use. I guess what I’ll call indigenous software, stuff like Brainson has their own stuff or MiniTab, things like that. Reference books, you know, my mechanics book, I’ll use that quite often during the design process. Any number of webpages where you go out and do a Google search, “Ok, I need to know about pitch angle on this kind of thread,” or what kind of fasteners to use, rules of thumb for whatever it is you’re looking for. I mean, there's any number of resources that you can use. Pick your neighbor’s brain, I mean literally. If you have tooling questions, you ask your tool and die guys. Electrical questions, you’ll hit up your test engineers or whatever. Any number of places to go to get the answers you seek.

**And so, we've been talking about how you go through and look at a project and you try to break it down to what you need for the project. Do you have an overarching specified procedure that you tend to follow? Do you have that documented somewhere or is it just from your experience?**
Experience. That’s why I say when you first come on, you’ve got to refine your craft and you’re going to learn by your mistakes, you’re going to get lessons learned that you apply to subsequent projects and processes so… I don’t know that you need an overarching set of rules and documents because it tends to limit innovation. But what you need is the upfront information to get you from point A to point B. How you get to point B could be any number ways. And there’s where I wouldn’t want to be limited to I have to do this process or I have to follow this.

So that makes a lot of sense. You don't want to go...you want to set someone up help or help set a designer up but not…

A procedure should be to the benefit the designer. So when I say have a checklist of things you need to answer ahead of time, that's helpful, that's not a hindrance. Having a procedure that says okay you’ve got to do this, this, this, and this during your design process. If it's high-level, I see benefit in it. You know, for example, okay you’ve got X number of things you need to do through the whole process. Number one, fill out your free checklist, whatever you want to call it, listing your knowns and assumptions. Before you go to print have a peer review. Before you go tooling, have your designs checked for accuracy in your prints, okay. And then when you go to receive your tooling, your machined components, maybe have some quality checks on them that you have two or three dimensions checked for accuracy before you assemble, okay. And before you release to production your design, do some fit and function to make sure that all of your assumptions at the very beginning are satisfied when you go to do fit and function. I
could see something like that’s just some basic and reasonable deliverables as you go from concept to completion, but anything more rigid than that, to me, becomes a hindrance because now I’m more concerned with the process that I am the design and I don’t want to get to that point. I want to stay focused on the design, you know, if it's just meeting some basic deliverables as we go that's reasonable but beyond that, it becomes a little too rigid in my opinion. It becomes more micromanaging.

I feel like that, in general, and I’m making a general assumption here, most people, I don’t think, like to be micromanaged. So by having some sort of, like what you were talking about, this process here would encourage more people to want to use it.

So the software that you used throughout these, like you said, the Microsoft apps, CAD as far as…

Pro/E and Solidworks. Although we have recently broke AutoCAD back out.

Really? A 3-D version or 2-D version?

2-D. Layouts.

So let’s say for your power transmission project, who all assisted with that?

Technicians. Technicians and tooling guys, guys in the shop.

You didn’t have any co-op or any assistance from any of the other engineers?
I don't think I had a co-op during that time. This is when Alex had his electrical engineering co-op. This would have been late last year (2014).

**Now, do you think that a co-op could have been assigned to this project?**

Do I think a co-op could have been assigned to this project? A more senior co-op, yes, with oversight. And here’s why I say this and this is not…I need to be careful how I answer this. The level of experience they might have when taking something like that that’s malfunctioned that has a significant price tag to it and reengineering a power transmission concept for it. I would feel comfortable letting them explore some options and with guidance and oversight, possibly let them manage the project. Certainly they could take part in it. There’s a lot of CAD that had to be done. A lot of inventory that needed to be ordered. You know, things that needed to be machined certainly would be, you know, in favor of things like that but I don't know that I would say, “Hey, I’m going to turn this over to you.” Now, a senior co-op on the third or fourth rotation, possibly. I've always said that I consider 3rd and 4th rotation co-ops to be staff engineers by then, they just don’t have the title. But they have a lot of experience and know-how. They know who to talk to and, you know, there's always that intermediate action with engineering, and particularly with myself to maintain that oversight so possibly could I see turning that over to a co-op, you know.

**Was this this project, was it team-based?**

Team in as much as I was the engineer with, I think, at some point all of my technicians were involved with some level project, in addition to shop assistance. So
yeah, there was a team of folks that had deliverables. It wasn't just a solo project but for this case, I would have be the only mechanical engineer working on the project.

**So you were the only mechanical engineer working on the job, period?**

Yes, yes, I would say so.

**And you said all of the technicians, so five of them?**

Yeah, at some point they were all involved with some level of working on the project.

**Just wanted to make sure it was first shift or third shift.**

Everybody had some level of responsibility.

**What about with the buggies?**

For Kaizen, it is very team based. We have multiple engineers, multiple technicians, and even some operator assistance with that. Certainly when we were in the planning and presentation phase, everybody was heavily involved. Now that we are in implementation phase, it’s primarily technician with engineering oversight. And both our IE and ME co-ops are heavily involved with it.

**So why would you say that they are more involved with the kaizen projects?**

**What was the primary purpose?**

The Kaizen project is huge. It’s basically re-envisioning an entire work cell. That's a bit too big for one person to maintain unless, given the timeframe. It’s a very aggressive timeframe, a very aggressive budget and it needs multiple sets of eyes to make sure one
person doesn’t miss something. If you go back to what I said in the beginning about your deliverables, having your knowns and unknowns, it’s one thing to do it for a singular station, a singular process but you’re talking about an entire workcell. And even though we’re methodical and can break it down into sub-components, at some point you’re going to miss something. With multiple sets of eyes, they’re going to look at it from a different slant whether it’s an IE, a EE, a technician. It's critical for something that big to have a team-based process. And so co-ops, where they plug-in, they’re very involved with designing of the workstations, the process. I’m very pleased with their progress, I think they’re doing a great job.

How would you describe the overall size of the projects? So let’s continue on with the Kaizen project, you’ve been talking that it’s larger in terms of the overall scope, the number of people involved. So how many people would you say were directly involved?

We had a dozen people involved at the beginning. We probably have half as many, to three quarters made that are actively involved in the implementation. This is the most expensive Kaizen project we’ve done to date in the factory and it has visibility all the way from the top.

Really?

Oh absolutely. We just presented a pared down version of this to our CEO. So it has visibility from the top, down. Particularly, I mean, from the factory level, specifically you know, the general manager on down. All major senior managers are well aware of what
we’re doing. It has, in the last couple days, we presented to the CEO what we’re doing so it has visibility for [Company A]. It's one of those…and when we have our senior managers coming in from overseas, this is going to be one of the things they’re going to be looking at. How are we doing on the Kaizen, absolutely.

**What about comparing the Kaizen to the transmission problem? You said it was you, five technicians, and…**

A couple of guys in the shop. The scope of the problem didn’t require a huge team. You have to be realistic in how you allocate your resources and so resources in this case are people, okay. I don't need more than one engineer for that, you know. I used all five technicians so they all have a hand in it. So they all have some experience in a project like this. Had I had a co-op during that time, I definitely would have had them involved. It would have been a great learning tool, learning experience. For the Kaizen, there’s no question it's team-based. It has to be team-based to handle something that big, that quick.

**And the more point of view?**

To make sure we don’t miss stuff. But for something like that where it’s more of a mechanical design, what’s funny about that project is it had a coolness factor to it because every ME, at least on the side (the residential department), including ME managers, stopped by to see how it was going and to watch it run.

**I can imagine. I want to see it right now.**
I’ve got it on my phone I’ll show you. But yeah, there was definitely a coolness factor to it that you don't get to do that every day. So yeah, I mean, it did necessitate more than one engineer and I was kind of protecting my turf a little bit cause I was having fun with it and I didn’t want some goober like Gibson to come in and ruin it for me. But yeah, that’s kind of how it went.

I can definitely see that. So how many man-hours were required to complete each of these projects?

Well, the one’s (the Kaizen project) is in process. It’s 1500+ man-hours so far in the Kaizen.

How many are I've been allocated to it against a PSR?

Well, that’s what I’m saying. On paper, 1500 hours so far. In actuality, there is just no way to calculate it, there’s no way to track it. It's an estimate based on, you start with your initial guess and at some point, you say, I probably have three times as many people working on it as I originally intended. So you just scale form there. At best, it’s just a guesstimate.

And can you give any kind of guesstimate on the transmission problem?

Couple hundred hours. Couple hundred dollars when you tally up everybody’s time because it's a project that went over about two months time from start to completion. And so you look at all the shop, the technician time, how much time we spent out there. The odds and ends, it was probably a couple hundred hours.
That’s a really good comparison, especially in terms of size. I know these are different because one is more mechanical while the Kaizen is more process but how would you describe the overall complexity of each of these projects? Which one to you is more complex?

Well, certainly the Kaizen is more complex inasmuch as we’re talking about an entire work cell that you are looking at redesigning processes to make it more efficient. There’s just so many more deliverables. As far as the mechanism itself, having to re-envision from a pure engineering standpoint, mechanical engineering standpoint, the power transmission unit was more complex in that you had to re-envision: How do I get this kinetic energy transferred from this motor/gear reduction unit to this rotary transmission to drive this dial table and meet my requirements of getting it on a tabletop, getting it easily accessible. What was literally a bevel gear type set up, now I’m going to a blower belt equivalent, you know. So re-envisioning how to do that effectively was the more difficult engineering challenge. Complexity is strictly a function, in this case, of the Kaizen event being a bigger scale.

Larger in scale.

Not more difficult engineering-wise, but just bigger scale.

Would you also say dealing with more people also affects that complexity too?

It should simplify it because you’ve got more eyes on it.
Even with the interactions with each other, it wouldn’t affect the complexity there?

I mean I wouldn't say it makes it any more difficult. Everybody has their part.

What type of tools or resources did you use to communicate your ideas with others? Whether it being others on the team or others for the tooling and die for the transmission project?

I think I’m missing something here, I’m not following you here.

If we just focus, let’s say, on the transmission project. So focusing on that, what type of resources did you use to communicate your ideas with others? Whether it be your ideas with the technicians or your ideas with the tool and die guys. Did you use a PowerPoint with them, did you print out prints?

I mean, prints, email, vocal. Very basic, you know.

And then for the Kaizen?

I mean, you've got PowerPoint, you’ve got stuff on paper, you know. I hope I’m not simplifying it too much but stuff on the whiteboard. Your basic, you sit around the table and, you know, put stuff on Excel. I don’t know if that makes sense?

Oh no, it does. If you had an idea outside a meeting, would you email it to the group or would you just write it down and save it for later?
It could be either one, it really depends on how crucial it is to disseminate that information quickly. I mean, if you want it documented, obviously email because you can always go back and say, “Hey, I sent you those.”

**And these projects, how were you first introduced to them?**

Well, I was introduced to the transmission unit when it failed and we couldn’t run the machine. I was introduced to the Kaizen event when the boss comes in and says, “Hey, you’re in charge of this.”

**So, it’s primarily verbal communication?**

The coil former was quite auditory: crunch, uh oh. Technicians walk in, you might want to come see this.

**No good. And the Kaizen one, when you said the boss came.**

The boss sat in that very chair and said, you’re in charge of this. Ok, thanks…

**With the exception of parts breaking down, would you say someone coming in and telling you, “Hey, I need you to work on this project,” is that most common or is it more common to receive an email?**

Both.

**Both equally common?**

Yeah.
Is there any kind of format to any of this?

This is [Company A] (no).

I have to ask… I’m pretty sure I know the answer.

You know the answer. No, there’s no format to it. I mean, you may get assigned something in one of the weekly (continuous improvement) meetings but in general, he’s going to come in and say, “Hey, I want you on this.” Usually, it’s verbal because he’s got to explain to you what he wants done. There’s going to be a lot of questions and whatnot.

So it’s almost better to have that interview type introduction?

I’d say it’s absolutely required.

How were these projects initially defined? Not the transmission project because you said that was a crunch and you were brought out there by the technicians.

Quite literally.

The Kaizen project, how did your boss initially come in here and be like, “Hey, I need you to work on this.” Did he give you just a general explanation that we need this line redesigned for a Kaizen event or was it just, I need you to do something, get it done, and it’s up to you as to how you get it done.

No, I mean, it was explained that this was the next Kaizen event and it’s kind of understood when you’re going to do a Kaizen event, you know, what’s the goal of a Kaizen event? Now, they had to call me in and break down what were the specific
management driven objectives, budget, things of that nature; give you your goals and constraints. But once you have those, it’s kind of a blank sheet. Assemble the team and, you know, list out the goals and constraints and start going through the process. Now, to me, it’s probably not as documented as it should be but there is a process to going through a Kaizen event. So, as you go through the process, it forces you to answer specific questions that help you to get to your solution, or your proposed solution.

So now while you’re going through these projects, how often do you have design reviews? Well, for the transmission project, how often would you have peer reviews and at least review your design with someone?

I say this half cocked, with that project, it was almost daily review because I always had someone crawling over it looking at it with me and, “Hey man, what’re you doing? How’re you going to solve this? What’s this for? Why are you doing this?”

Because of all the interest in it?

Oh yeah, it was more informal. Like I said, there was a coolness factor to it that we don’t normally get to work on. Usually, it’s very cut and dry, replace this, fix that. This one was like, there was no obvious solution. We had to reengineer it mechanically to see if we could even get it to work. There was a little bit of trepidation once we had it all bolted together to see if we could get it to work. Confidence was high, but until you see it in operation, is it going to go?

The uncertainty there…
Yeah, there was a little bit of uncertainty. The best laid plans are only as good as their execution. That executes well or they execute me.

Well, good thing it executed well… So then, how many formal design reviews did you have for that project?

Maybe one.

Who was involved in that?

Manager and other ME’s. Anyone that could give me constructed feedback.

Was it mainly just the manufacturing group or did you invite anyone from R&D?

No, absolutely not. Just manufacturing guys.

You were talking about having presented the Kaizen stuff to the CEO.

Oh, that was senior management.

You’ve done that with senior management and with local level?

Every senior manager in the factory plus our CEO has been represented to at this point.

That’s incredible now that I think about it that it has the direct attention of the CEO there.
Well, it was one of those where he comes in to visit and you want to show him a lot of the work that has been going on in the factory. This was one of the projects that was selected because it’s in implementation phase so it was easy to say, “Hey, it’s already been approved, there’s already a presentation. Cut it down to 15 minutes and you’ve got his full attention.”

Ok

One of those deals.

Alright, so the transmission, that’s still in use?

Yep.

Have any modifications been made to it since it was first put out there?

Tweaks, tuning.

Ok. Do you think anything could have been prevented with the checklist? Could any of those tweaks have been prevented or is that just one of those things?

No, it’s one of those where when you get to fit and function… CAD’s going to get you so far.

Any major concerns about it? Anticipated lifespan?

No, because of the way it’s designed, all components should be readily accessible, replaceable. Fairly straight forward.
Any final reflections on these projects at all?

Nothing I can think of. They’re all worthy projects, fairly straight forward. Some forced upon you, the nature of the beast. Others planned but they’re cost savings at the end of the day and, I think, worthwhile.

It helps with production.

Absolutely. They both help the factory for sure.

B.8 B.EE.1 – Hank

SO: The purpose of this is for my research at Clemson where from my experiences in the capstone program and then senior program we design primarily in teams of 3, 4, or 5 students and we work on a project together as in that team. Well, when coming here, the most interaction in a team that I have received was maybe working on a project with or maybe getting some assistance from one of the test engineers whether it be like mainly it was Brian Williams. Or it would be one of the techs. And that would be it. So I just wanted to come here and get y’all’s experiences since y'all have been working here much longer than me. Y’all have more experience than I do. I just wanted to see if your insight is the same as mine but hopefully what will come out of this is that if most of the work you do is more individual rather directly in teams then there might be some sort of process of some sort of tool or even software that I could potentially develop or recommend and then you could potentially use it here or someone at some other company so the end goal
of this is to try to help increase efficiency and quality the overall ability of the
ingineer especially if they’re new like I was when I first started. And increasing the
ability to hit the ground running might be helpful.

So I have to get these introductory questions first: what is your position title and
description, and how many years have you been at this position?

Brad: Lead manufacturing engineer is the title. I’ve been in this particular role since
probably 2006/2007 so 8 or 9 years.

And what exactly are your responsibilities in that role?

Well manufacturing engineer, first and foremost, supporting production, supporting
departmental initiatives and filtering those down through the group such as PSR’s,
manufacturing qualifications, 5S initiatives. Right now, I’m leading a Kaizen team so any
number of focus factory and departmental goals that need to be filtered down to the
group. Maintaining capital budget, mechanical design reviews, things like that. You
know, all of the above our part my responsibilities but first and foremost of these would
be supporting production, project management, things like that.

Ok. So what was your previous design experience within [Company A]?

I mean…if we’re talking in a current manufacturing engineering role, when I first
started back in ’99, it might be designing fixtures, designing tooling in Pro/E for
production. As I’ve gone room and, I guess, progressed over time, I still support that, but
not to the same degree that some of the other guys in the group do. I’ve seen my
responsibilities shift to more project management as compared to down in the trenches, nuts and bolts, designing fixtures. I still do that from time to time but that's not one of the things it would be one of my big portion of my plate right now.

**What other companies have you worked for?**

Milliken and Company at their finishing plant in Pendleton. Co-oped at Metler Toledo back in the mid-90s. but I’ve been at [Company A] since ’99.

**What type of work did you do for those other companies?**

Very similar to what, I guess, a typical co-op or intern would do. Some basic CAD work, some basic data collection. A little bit of fixture design. At Milliken I also did some inventory control, did some 5S, stuff like that.

**Have you attended any workshops or taken any specific classes on designing, and more importantly, either design in general or how to design on your own as an individual rather than in teams?**

So let’s clarify, when talking design, you know, you mean with a CAD package designing a specific mechanism or something?

**Yeah, whether it be with CAD or whether it be just having to have something sketched out and then potentially presented to someone before actually going to CAD. Any kind of design work whether it be for fixture or tooling.**
I mean, above and beyond what I took in school, I don't believe. It’s one of those things where I’ve refined my craft over the years. Learning from mentors, learning from senior engineers, watching the process, learning as I go and perfecting it through time.

So what kind of stuff would you say you’ve learned throughout your experiences?

Learning the design process, you know, to identify what are the key parameters before you sit down on the CAD package and start to, start to sketch it out: what are you trying to accomplish? What are your space constraints? What, if any, budgetary constraints do you have which will affect your selection of materials. Are there any safety considerations that have been identified ahead of time? So mainly getting all the prep work done and answered before you sit down in front of the computer to start the design so that you don't find out halfway through it, “Oh I had to make sure this was a nonconductive material,” or “Oh it needs to be mobile. I had this on a table top.” Getting all your ducks in a row before you sit down to do it is the biggest, you know, it sounds trivial but a lot of people even now don't do that correctly, in my opinion, and they have to go back and rev their design 2, 3, 4 times because they didn't have all the information they needed. Now sometimes that information is not easily come by, but you get as much of it as you can. So one thing, if we had a designer’s kit, and this is just thinking matter of fact, a designer’s kit that forces you to answer specific questions up front, as much as possible. For example, “Are there safety considerations?”, “Is this a mobile device?”, “Is this intended to be a standalone machine?”, “Is it tabletop?” Selection of materials, you
know, does it need to be ESD? What type of product is going to go into it? Does it need to be guarded? Is it just simple mechanisms or is there going to be kinetic energy devices such as hydraulic schematics, servos that need light curtains. All of these things, if they’re answered up front, you going to design with that in mind. So, if we had a checklist, maybe the standard, you know…

That almost sets up your design space for you.

It really forces you down the correct path because if you can answer these questions up front, then when you actually sit down and start putting the mechanism together in your mind on the computer, “Oh yeah, I remember I’ve got to have ESD shelving. Oh, I’m going to have to have light curtains on this because I'm using, you know, half-inch four pneumatic cylinders to do this action or whatever it is. Make sure you know dot your I’s and cross your T’s. So one of those, I mean a lot of times we do it naturally, we go and write stuff down a piece of paper in a notebook but if we had a checklist that formalizes that this is part of the design process, answer these questions as much as possible. And if there's a problem you can always go back to your checklist and say, “why isn't this right?” Well, this is the assumptions I had when I went into it. Maybe the assumptions change. Maybe what was supposed to be a fixed benchtop type of mechanism, well now they want to roll it from cell to cell so it needs to be mobile. Well, if there’s changes that are required later, you can at least go back to say, “Hey, when I started the process, my checklist said this was benchtop and this was a fixed asset. Now somebody has changed into a mobile device down the road. So, if it takes three more
weeks to finish this and another 1000 to 1500 dollars to modify it, you’ve got your documentation that says, “Hey, when I started the project, these were the assumptions.” So it's always good to have that information up front.

So would having some sort of a pre-populated list of topics to go through that forces you to go through a general listing of every subject, whether it be safety, ESD, material selection, would you say that would be helpful?

I think particularly for the guys that are new, for co-ops, for those that aren’t used to the design process that need to perfect their craft. I think having something more formal like that forces them to think about some of the issues that we take for granted as a more senior designer. You know, we go through the checklist in our head and even now, we’ll miss stuff and if we had it on a paper or whatever, in front of us the whole time, you know, even that would help a seasoned engineer to make sure to keep all their information straight. It's just like solving any kind of technical problem. You list your assumptions first before you try to solve the problem. This is no different: you list your assumptions up front, you knowns, and your assumptions and then you start your design. And when you get to the end you ought to be able to look at your designs and say, “Yep, light curtains, check that out for guarding,” “yep, I’ve got ESD and that’s grounded. Check that off for that, you know.” You ought to be able to look at your finished design and look at your list of knowns and assumptions, and every one of those is satisfied in the design. And if they’re not, you’ve missed something. You didn’t pay attention to the information you had.
Now let’s get into some of the projects you’ve worked on. That’s what the remainder of these questions will focus on. So can you describe your most recent design project that you’ve completed?

We had to do a redesign on the power transmission unit for the old coil-forming machine. The rotary transmission unit for the dial table failed. The drive gear basically destructed, self-destructed and it was about a $45,000 replacement and it wasn't a drop in to get the power transmission unit. The way it was set up was not easily to work on. You had to crawl under the machine, pull the motor and the clutch. So we decided to reengineer it in-house and take the components that worked on the rotary transmission and design and install a new power transmission unit to drive the rotary to drive the dial table. So it was really cool. About a $43,000 cost-savings as well. So basically taking known mechanical concepts on power transmission, we got the drive unit from underneath table, mounted it tabletop so it’s easily accessible. Basically, took the equivalent of a blower belt, a big 1.5-inch wide belt that would transmit power from the motor gear reduction unit to the input shaft for the rotary transmission. Getting that all built and designed and operational, we can go look at that anytime you want to go look at that.

Might have to take a look at that, that’s pretty exciting.

It's pretty neat, I’ve got some pictures to show you. Matter of fact, I know I do on my phone. So going through that design process was neat and, you know, again having the checklist available and have it posted out there and make sure we’re meeting all those
requirements would've been an advantage. We miss some stuff, you know. It's one of
those particularly, designing mechanisms for a production environment, you’ve got time
pressures, you’ve got budgetary considerations, and you miss stuff. And so any
information that we can get solidified up front and have it right there in our face the
whole time would be a help.

Now, what about a second challenging project that you best remember. It
doesn’t have to be recent.

Well, I mean, right now so when we talk design, it can be anything from fixtures to
workstations. So right now, our Kaizen event for semi-auto, we’re designing new works,
basically a new work cell, so the design concepts that we’re talking about are scalable
you know, your checklist is still the same, your requirements, your knowns, your
unknowns. It’s all of these different things. You just have to break it down into
subcomponents so that even though I've got the big picture in mind, I need to apply these
concepts to each of the subcomponents that go into that cell. So for all of our flow
channels, all of our buggies, all of our carts and workstations, the process remains same
even though we’re focusing on one small subcomponent of the larger cell. So right now,
we’re designing carts, buggies, and workstations to do specific tasks and assembly steps.
So we’re having to consider things like grounding and ESD, mobility, modular design,
ergonomics. All of these things, we have to take into account so not to be a broken record
but all these things we talked about for the last project and in general, these checklists,
these stating your facts and knowns and assumptions, you know. For every one of these
designs that we’re doing, having that information available, it provides continuity of 
thought on work, how your designing each station and what not. You know, having 
continuity of the lessons learned. Ok, if you’re going to do something like this: if you 
have meters on a shelf, it needs to be this type of material. This is the part number and 
specs for it.

So for the transmission redesign, what type of project would you say that is? The 
examples I have here are tooling and fixture design, process design. I wouldn’t think 
that falls under that. Would you say it’s almost the station partial redesign?

Yeah, I mean that not really even tooling. Machinery redesign and upgrade, if you 
want.

The buggies and the flow process…

I mean, that’s machinery equipment. That’s process as much as it is anything.

In general, how many design projects are you assigned either per year, or if it is 
easier, per month?

How about per week?

Well we could take an average per week and multiply it by 50, assuming 2 weeks 
off.
I mean, you know, there's no general blanket answer for that. For me, personally, maybe not as much as the other guys. I might have one or two things going per week that carry-on over multiple weeks.

**Is it really because you’re overseeing projects?**

Yeah, I mean, it’s more project management. A lot of it is for me so I might have one or two or three designs that might go for months because they’re larger or it takes time to get stuff built and different things and you follow through to completion. So maybe a dozen to a dozen and a half over a calendar year but when you talk about but, you know, when you’re talking about buggies and carts and mechanisms and fixtures and tooling. When you talk about true design work for me, that's a good, good number of projects throughout the year when you figure you’re still doing production support, paperwork, and all the different project management that comes along with these things.

**Ok, so how about just projects in general. Not only design but also with other production, other, let’s say your you put on a 6S…**

So a couple of ways to answer that. If we’re talking just like major projects that are tracked with budgets and hours and PSR's and whatnot, probably a dozen in a calendar year is good number. But when you talk about everything else that goes with it, the smaller not as visible projects, the fire fighting, the we need to design something to repair something on the line, I mean, it could be several dozen, you know. It really depends on how granular you want to get but as far as measurable tracked projects that management
is inclined to request updates on what the tracking on and whatnot, maybe a dozen or so in a calendar year.

**Ok, and what resources do you typically use throughout these projects? Whether it be software, hardware, tooling, people.**

Oh gosh, there’s a myriad of resources between CAD packages, any number of Microsoft products like PowerPoint, Excel, Word for communications, any number of homegrown: Dashboard, EIS, RIS, we’ve got a lot of homegrown apps that we use. I guess what I’ll call indigenous software, stuff like Brainson has their own stuff or MiniTab, things like that. Reference books, you know, my mechanics book, I’ll use that quite often during the design process. Any number of webpages where you go out and do a Google search, “Ok, I need to know about pitch angle on this kind of thread,” or what kind of fasteners to use, rules of thumb for whatever it is you’re looking for. I mean, there's any number of resources that you can use. Pick your neighbor’s brain, I mean literally. If you have tooling questions, you ask your tool and die guys. Electrical questions, you’ll hit up your test engineers or whatever. Any number of places to go to get the answers you seek.

**And so, we've been talking about how you go through and look at a project and you try to break it down to what you need for the project. Do you have an overarching specified procedure that you tend to follow? Do you have that documented somewhere or is it just from your experience?**
Experience. That’s why I say when you first come on, you’ve got to refine your craft and you’re going to learn by your mistakes, you’re going to get lessons learned that you apply to subsequent projects and processes so… I don’t know that you need an overarching set of rules and documents because it tends to limit innovation. But what you need is the upfront information to get you from point A to point B. How you get to point B could be any number ways. And there’s where I wouldn’t want to be limited to I have to do this process or I have to follow this.

So that makes a lot of sense. You don't want to go…you want to set someone up help or help set a designer up but not…

A procedure should be to the benefit the designer. So when I say have a checklist of things you need to answer ahead of time, that's helpful, that's not a hindrance. Having a procedure that says okay you’ve got to do this, this, this, and this during your design process. If it's high-level, I see benefit in it. You know, for example, okay you’ve got X number of things you need to do through the whole process. Number one, fill out your free checklist, whatever you want to call it, listing your knowns and assumptions. Before you go to print have a peer review. Before you go tooling, have your designs checked for accuracy in your prints, okay. And then when you go to receive your tooling, your machined components, maybe have some quality checks on them that you have two or three dimensions checked for accuracy before you assemble, okay. And before you release to production your design, do some fit and function to make sure that all of your assumptions at the very beginning are satisfied when you go to do fit and function. I
could see something like that’s just some basic and reasonable deliverables as you go from concept to completion, but anything more rigid than that, to me, becomes a hindrance because now I’m more concerned with the process that I am the design and I don’t want to get to that point. I want to stay focused on the design, you know, if it's just meeting some basic deliverables as we go that's reasonable but beyond that, it becomes a little too rigid in my opinion. It becomes more micromanaging.

I feel like that, in general, and I’m making a general assumption here, most people, I don’t think, like to be micromanaged. So by having some sort of, like what you were talking about, this process here would encourage more people to want to use it.

So the software that you used throughout these, like you said, the Microsoft apps, CAD as far as…

Pro/E and Solidworks. Although we have recently broke AutoCAD back out.

Really? A 3-D version or 2-D version?

2-D. Layouts.

So let’s say for your power transmission project, who all assisted with that?

Technicians. Technicians and tooling guys, guys in the shop.

You didn’t have any co-op or any assistance from any of the other engineers?
I don't think I had a co-op during that time. This is when Alex had his electrical engineering co-op. This would have been late last year (2014).

**Now, do you think that a co-op could have been assigned to this project?**

Do I think a co-op could have been assigned to this project? A more senior co-op, yes, with oversight. And here’s why I say this and this is not…I need to be careful how I answer this. The level of experience they might have when taking something like that that’s malfunctioned that has a significant price tag to it and reengineering a power transmission concept for it. I would feel comfortable letting them explore some options and with guidance and oversight, possibly let them manage the project. Certainly they could take part in it. There’s a lot of CAD that had to be done. A lot of inventory that needed to be ordered. You know, things that needed to be machined certainly would be, you know, in favor of things like that but I don't know that I would say, “Hey, I’m going to turn this over to you.” Now, a senior co-op on the third or fourth rotation, possibly. I've always said that I consider 3rd and 4th rotation co-ops to be staff engineers by then, they just don’t have the title. But they have a lot of experience and know-how. They know who to talk to and, you know, there's always that intermediate action with engineering, and particularly with myself to maintain that oversight so possibly could I see turning that over to a co-op, you know.

**Was this this project, was it team-based?**

Team in as much as I was the engineer with, I think, at some point all of my technicians were involved with some level project, in addition to shop assistance. So
yeah, there was a team of folks that had deliverables. It wasn't just a solo project but for this case, I would have be the only mechanical engineer working on the project.

So you were the only mechanical engineer working on the job, period?

Yes, yes, I would say so.

And you said all of the technicians, so five of them?

Yeah, at some point they were all involved with some level of working on the project.

Just wanted to make sure it was first shift or third shift.

Everybody had some level of responsibility.

What about with the buggies?

For Kaizen, it is very team based. We have multiple engineers, multiple technicians, and even some operator assistance with that. Certainly when we were in the planning and presentation phase, everybody was heavily involved. Now that we are in implementation phase, it’s primarily technician with engineering oversight. And both our IE and ME co-ops are heavily involved with it.

So why would you say that they are more involved with the kaizen projects?

What was the primary purpose?

The Kaizen project is huge. It’s basically re-envisioning an entire work cell. That's a bit too big for one person to maintain unless, given the timeframe. It’s a very aggressive timeframe, a very aggressive budget and it needs multiple sets of eyes to make sure one
person doesn’t miss something. If you go back to what I said in the beginning about your deliverables, having your knowns and unknowns, it’s one thing to do it for a singular station, a singular process but you’re talking about an entire workcell. And even though we’re methodical and can break it down into sub-components, at some point you’re going to miss something. With multiple sets of eyes, they’re going to look at it from a different slant whether it’s an IE, a EE, a technician. It's critical for something that big to have a team-based process. And so co-ops, where they plug-in, they’re very involved with designing of the workstations, the process. I’m very pleased with their progress, I think they’re doing a great job.

How would you describe the overall size of the projects? So let’s continue on with the Kaizen project, you’ve been talking that it’s larger in terms of the overall scope, the number of people involved. So how many people would you say were directly involved?

We had a dozen people involved at the beginning. We probably have half as many, to three quarters made that are actively involved in the implementation. This is the most expensive Kaizen project we’ve done to date in the factory and it has visibility all the way from the top.

Really?

Oh absolutely. We just presented a pared down version of this to our CEO. So it has visibility from the top, down. Particularly, I mean, from the factory level, specifically you know, the general manager on down. All major senior managers are well aware of what
we’re doing. It has, in the last couple days, we presented to the CEO what we’re doing so it has visibility for [Company A]. It's one of those…and when we have our senior managers coming in from overseas, this is going to be one of the things they’re going to be looking at. How are we doing on the Kaizen, absolutely.

What about comparing the Kaizen to the transmission problem? You said it was you, five technicians, and…

A couple of guys in the shop. The scope of the problem didn’t require a huge team. You have to be realistic in how you allocate your resources and so resources in this case are people, okay. I don't need more than one engineer for that, you know. I used all five technicians so they all have a hand in it. So they all have some experience in a project like this. Had I had a co-op during that time, I definitely would have had them involved. It would have been a great learning tool, learning experience. For the Kaizen, there’s no question it's team-based. It has to be team-based to handle something that big, that quick.

And the more point of view?

To make sure we don’t miss stuff. But for something like that where it’s more of a mechanical design, what’s funny about that project is it had a coolness factor to it because every ME, at least on the side (the residential department), including ME managers, stopped by to see how it was going and to watch it run.

I can imagine. I want to see it right now.
I’ve got it on my phone I’ll show you. But yeah, there was definitely a coolness factor to it that you don’t get to do that every day. So yeah, I mean, it did necessitate more than one engineer and I was kind of protecting my turf a little bit cause I was having fun with it and I didn’t want some goober like Gibson to come in and ruin it for me. But yeah, that’s kind of how it went.

I can definitely see that. So how many man-hours were required to complete each of these projects?

Well, the one’s (the Kaizen project) is in process. It’s 1500+ man-hours so far in the Kaizen.

How many are I've been allocated to it against a PSR?

Well, that’s what I’m saying. On paper, 1500 hours so far. In actuality, there is just no way to calculate it, there’s no way to track it. It's an estimate based on, you start with your initial guess and at some point, you say, I probably have three times as many people working on it as I originally intended. So you just scale form there. At best, it’s just a guesstimate.

And can you give any kind of guesstimate on the transmission problem?

Couple hundred hours. Couple hundred dollars when you tally up everybody’s time because it's a project that went over about two months time from start to completion. And so you look at all the shop, the technician time, how much time we spent out there. The odds and ends, it was probably a couple hundred hours.
That’s a really good comparison, especially in terms of size. I know these are different because one is more mechanical while the Kaizen is more process but how would you describe the overall complexity of each of these projects? Which one to you is more complex?

Well, certainly the Kaizen is more complex inasmuch as we’re talking about an entire work cell that you are looking at redesigning processes to make it more efficient. There’s just so many more deliverables. As far as the mechanism itself, having to re-envision from a pure engineering standpoint, mechanical engineering standpoint, the power transmission unit was more complex in that you had to re-envision: How do I get this kinetic energy transferred from this motor/gear reduction unit to this rotary transmission to drive this dial table and meet my requirements of getting it on a tabletop, getting it easily accessible. What was literally a bevel gear type set up, now I’m going to a blower belt equivalent, you know. So re-envisioning how to do that effectively was the more difficult engineering challenge. Complexity is strictly a function, in this case, of the Kaizen event being a bigger scale.

Larger in scale.

Not more difficult engineering-wise, but just bigger scale.

Would you also say dealing with more people also affects that complexity too?

It should simplify it because you’ve got more eyes on it.
Even with the interactions with each other, it wouldn’t affect the complexity there?

I mean I wouldn't say it makes it any more difficult. Everybody has their part.

What type of tools or resources did you use to communicate your ideas with others? Whether it being others on the team or others for the tooling and die for the transmission project?

I think I’m missing something here, I’m not following you here.

If we just focus, let’s say, on the transmission project. So focusing on that, what type of resources did you use to communicate your ideas with others? Whether it be your ideas with the technicians or your ideas with the tool and die guys. Did you use a PowerPoint with them, did you print out prints?

I mean, prints, email, vocal. Very basic, you know.

And then for the Kaizen?

I mean, you've got PowerPoint, you’ve got stuff on paper, you know. I hope I’m not simplifying it too much but stuff on the whiteboard. Your basic, you sit around the table and, you know, put stuff on Excel. I don’t know if that makes sense?

Oh no, it does. If you had an idea outside a meeting, would you email it to the group or would you just write it down and save it for later?
It could be either one, it really depends on how crucial it is to disseminate that information quickly. I mean, if you want it documented, obviously email because you can always go back and say, “Hey, I sent you those.”

**And these projects, how were you first introduced to them?**

Well, I was introduced to the transmission unit when it failed and we couldn’t run the machine. I was introduced to the Kaizen event when the boss comes in and says, “Hey, you’re in charge of this.”

**So, it’s primarily verbal communication?**

The coil former was quite auditory: crunch, uh oh. Technicians walk in, you might want to come see this.

**No good. And the Kaizen one, when you said the boss came.**

The boss sat in that very chair and said, you’re in charge of this. Ok, thanks…

**With the exception of parts breaking down, would you say someone coming in and telling you, “Hey, I need you to work on this project,” is that most common or is it more common to receive an email?**

Both.

**Both equally common?**

Yeah.
Is there any kind of format to any of this?

This is [Company A] (no).

I have to ask… I’m pretty sure I know the answer.

You know the answer. No, there’s no format to it. I mean, you may get assigned something in one of the weekly (continuous improvement) meetings but in general, he’s going to come in and say, “Hey, I want you on this.” Usually, it’s verbal because he’s got to explain to you what he wants done. There’s going to be a lot of questions and whatnot.

So it’s almost better to have that interview type introduction?

I’d say it’s absolutely required.

How were these projects initially defined? Not the transmission project because you said that was a crunch and you were brought out there by the technicians.

Quite literally.

The Kaizen project, how did your boss initially come in here and be like, “Hey, I need you to work on this.” Did he give you just a general explanation that we need this line redesigned for a Kaizen event or was it just, I need you to do something, get it done, and it’s up to you as to how you get it done.

No, I mean, it was explained that this was the next Kaizen event and it’s kind of understood when you’re going to do a Kaizen event, you know, what’s the goal of a Kaizen event? Now, they had to call me in and break down what were the specific
management driven objectives, budget, things of that nature; give you your goals and constraints. But once you have those, it’s kind of a blank sheet. Assemble the team and, you know, list out the goals and constraints and start going through the process. Now, to me, it’s probably not as documented as it should be but there is a process to going through a Kaizen event. So, as you go through the process, it forces you to answer specific questions that help you to get to your solution, or your proposed solution.

So now while you’re going through these projects, how often do you have design reviews? Well, for the transmission project, how often would you have peer reviews and at least review your design with someone?

I say this half cocked, with that project, it was almost daily review because I always had someone crawling over it looking at it with me and, “Hey man, what’re you doing? How’re you going to solve this? What’s this for? Why are you doing this?”

Because of all the interest in it?

Oh yeah, it was more informal. Like I said, there was a coolness factor to it that we don’t normally get to work on. Usually, it’s very cut and dry, replace this, fix that. This one was like, there was no obvious solution. We had to reengineer it mechanically to see if we could even get it to work. There was a little bit of trepidation once we had it all bolted together to see if we could get it to work. Confidence was high, but until you see it in operation, is it going to go?

The uncertainty there…
Yeah, there was a little bit of uncertainty. The best laid plans are only as good as their execution. That executes well or they execute me.

Well, good thing it executed well… So then, how many formal design reviews did you have for that project?

Maybe one.

Who was involved in that?

Manager and other ME’s. Anyone that could give me constructed feedback.

Was it mainly just the manufacturing group or did you invite anyone from R&D?

No, absolutely not. Just manufacturing guys.

You were talking about having presented the Kaizen stuff to the CEO.

Oh, that was senior management.

You’ve done that with senior management and with local level?

Every senior manager in the factory plus our CEO has been represented to at this point.

That’s incredible now that I think about it that it has the direct attention of the CEO there.
Well, it was one of those where he comes in to visit and you want to show him a lot of the work that has been going on in the factory. This was one of the projects that was selected cause it’s in implementation phase so it was easy to say, “Hey, it’s already been approved, there’s already a presentation. Cut it down to 15 minutes and you’ve got his full attention.”

Ok

One of those deals.

Alrighty, so the transmission, that’s still in use?

Yep.

Have any modifications been made to it since it was first put out there?

Tweaks, tuning.

Ok. Do you think anything could have been prevented with the checklist? Could any of those tweaks have been prevented or is that just one of those things?

No, it’s one of those where when you get to fit and function… CAD’s going to get you so far.

Any major concerns about it? Anticipated lifespan?

No, because of the way it’s designed, all components should be readily accessible, replaceable. Fairly straight forward.
Any final reflections on these projects at all?

Nothing I can think of. They’re all worthy projects, fairly straight forward. Some forced upon you, the nature of the beast. Others planned but they’re cost savings at the end of the day and, I think, worthwhile.

It helps with production.

Absolutely. They both help the factory for sure.

B.9 B.ID.1 – Isaac

SO: The purpose of this is for my research at Clemson where from my experiences in the capstone program and then senior program we design primarily in teams of 3, 4, or 5 students and we work on a project together as in that team. Well, when coming here, the most interaction in a team that I have received was maybe working on a project with or maybe getting some assistance from one of the test engineers whether it be like mainly it was Brian Williams. Or it would be one of the techs. And that would be it. So I just wanted to come here and get y’all’s experiences since y'all have been working here much longer than me. Y’all have more experience than I do. I just wanted to see if your insight is the same as mine but hopefully what will come out of this is that if most of the work you do is more individual rather directly in teams then there might be some sort of process of some sort of tool or even software that I could potentially develop or recommend and then you could potentially use it here or someone at some other company so the end goal
of this is to try to help increase efficiency and quality the overall ability of the engineer especially if they’re new like I was when I first started. And increasing the ability to hit the ground running might be helpful.

So I have to get these introductory questions first: what is your position title and description, and how many years have you been at this position?

Brad: Lead manufacturing engineer is the title. I’ve been in this particular role since probably 2006/2007 so 8 or 9 years.

And what exactly are your responsibilities in that role?

Well manufacturing engineer, first and foremost, supporting production, supporting departmental initiatives and filtering those down through the group such as PSR's, manufacturing qualifications, 5S initiatives. Right now, I’m leading a Kaizen team so any number of focus factory and departmental goals that need to be filtered down to the group. Maintaining capital budget, mechanical design reviews, things like that. You know, all of the above our part my responsibilities but first and foremost of these would be supporting production, project management, things like that.

Ok. So what was your previous design experience within [Company A]?

I mean…if we’re talking in a current manufacturing engineering role, when I first started back in ’99, it might be designing fixtures, designing tooling in Pro/E for production. As I’ve gone room and, I guess, progressed over time, I still support that, but not to the same degree that some of the other guys in the group do. I’ve seen my
responsibilities shift to more project management as compared to down in the trenches, nuts and bolts, designing fixtures. I still do that from time to time but that's not one of the things it would be one of my big portion of my plate right now.

**What other companies have you worked for?**

Milliken and Company at their finishing plant in Pendleton. Co-oped at Metler Toledo back in the mid-90s. but I’ve been at [Company A] since ’99.

**What type of work did you do for those other companies?**

Very similar to what, I guess, a typical co-op or intern would do. Some basic CAD work, some basic data collection. A little bit of fixture design. At Milliken I also did some inventory control, did some 5S, stuff like that.

**Have you attended any workshops or taken any specific classes on designing, and more importantly, either design in general or how to design on your own as an individual rather than in teams?**

So let’s clarify, when talking design, you know, you mean with a CAD package designing a specific mechanism or something?

**Yeah, whether it be with CAD or whether it be just having to have something sketched out and then potentially presented to someone before actually going to CAD. Any kind of design work whether it be for fixture or tooling.**
I mean, above and beyond what I took in school, I don't believe. It’s one of those things where I’ve refined my craft over the years. Learning from mentors, learning from senior engineers, watching the process, learning as I go and perfecting it through time.

So what kind of stuff would you say you’ve learned throughout your experiences?

Learning the design process, you know, to identify what are the key parameters before you sit down on the CAD package and start to, start to sketch it out: what are you trying to accomplish? What are your space constraints? What, if any, budgetary constraints do you have which will affect your selection of materials. Are there any safety considerations that have been identified ahead of time? So mainly getting all the prep work done and answered before you sit down in front of the computer to start the design so that you don't find out halfway through it, “Oh I had to make sure this was a nonconductive material,” or “Oh it needs to be mobile. I had this on a table top.” Getting all your ducks in a row before you sit down to do it is the biggest, you know, it sounds trivial but a lot of people even now don't do that correctly, in my opinion, and they have to go back and rev their design 2, 3, 4 times because they didn't have all the information they needed. Now sometimes that information is not easily come by, but you get as much of it as you can. So one thing, if we had a designer’s kit, and this is just thinking matter of fact, a designer’s kit that forces you to answer specific questions up front, as much as possible. For example, “Are there safety considerations?”, “Is this a mobile device?”, “Is this intended to be a standalone machine?”, “Is it tabletop?” Selection of materials, you
know, does it need to be ESD? What type of product is going to go into it? Does it need to be guarded? Is it just simple mechanisms or is there going to be kinetic energy devices such as hydraulic schematics, servos that need light curtains. All of these things, if they’re answered up front, you going to design with that in mind. So, if we had a checklist, maybe the standard, you know…

**That almost sets up your design space for you.**

It really forces you down the correct path because if you can answer these questions up front, then when you actually sit down and start putting the mechanism together in your mind on the computer, “Oh yeah, I remember I’ve got to have ESD shelving. Oh, I’m going to have to have light curtains on this because I'm using, you know, half-inch four pneumatic cylinders to do this action or whatever it is. Make sure you know dot your I’s and cross your T’s. So one of those, I mean a lot of times we do it naturally, we go and write stuff down a piece of paper in a notebook but if we had a checklist that formalizes that this is part of the design process, answer these questions as much as possible. And if there's a problem you can always go back to your checklist and say, “why isn't this right?” Well, this is the assumptions I had when I went into it. Maybe the assumptions change. Maybe what was supposed to be a fixed benchtop type of mechanism, well now they want to roll it from cell to cell so it needs to be mobile. Well, if there’s changes that are required later, you can at least go back to say, “Hey, when I started the process, my checklist said this was benchtop and this was a fixed asset. Now somebody has changed into a mobile device down the road. So, if it takes three more
weeks to finish this and another 1000 to 1500 dollars to modify it, you’ve got your documentation that says, “Hey, when I started the project, these were the assumptions.” So it's always good to have that information up front.

So would having some sort of a pre-populated list of topics to go through that forces you to go through a general listing of every subject, whether it be safety, ESD, material selection, would you say that would be helpful?

I think particularly for the guys that are new, for co-ops, for those that aren’t used to the design process that need to perfect their craft. I think having something more formal like that forces them to think about some of the issues that we take for granted as a more senior designer. You know, we go through the checklist in our head and even now, we’ll miss stuff and if we had it on a paper or whatever, in front of us the whole time, you know, even that would help a seasoned engineer to make sure to keep all their information straight. It's just like solving any kind of technical problem. You list your assumptions first before you try to solve the problem. This is no different: you list your assumptions up front, you knowns, and your assumptions and then you start your design. And when you get to the end you ought to be able to look at your designs and say, “Yep, light curtains, check that out for guarding,” “yep, I’ve got ESD and that’s grounded. Check that off for that, you know.” You ought to be able to look at your finished design and look at your list of knowns and assumptions, and every one of those is satisfied in the design. And if they’re not, you’ve missed something. You didn’t pay attention to the information you had.
Now let’s get into some of the projects you’ve worked on. That’s what the remainder of these questions will focus on. So can you describe your most recent design project that you’ve completed?

We had to do a redesign on the power transmission unit for the old coil-forming machine. The rotary transmission unit for the dial table failed. The drive gear basically destructed, self-destructed and it was about a $45,000 replacement and it wasn't a drop in to get the power transmission unit. The way it was set up was not easily to work on. You had to crawl under the machine, pull the motor and the clutch. So we decided to reengineer it in-house and take the components that worked on the rotary transmission and design and install a new power transmission unit to drive the rotary to drive the dial table. So it was really cool. About a $43,000 cost-savings as well. So basically taking known mechanical concepts on power transmission, we got the drive unit from underneath table, mounted it tabletop so it’s easily accessible. Basically, took the equivalent of a blower belt, a big 1.5-inch wide belt that would transmit power from the motor gear reduction unit to the input shaft for the rotary transmission. Getting that all built and designed and operational, we can go look at that anytime you want to go look at that.

Might have to take a look at that, that’s pretty exciting.

It's pretty neat, I’ve got some pictures to show you. Matter of fact, I know I do on my phone. So going through that design process was neat and, you know, again having the checklist available and have it posted out there and make sure we’re meeting all those
requirements would've been an advantage. We miss some stuff, you know. It's one of those particularly, designing mechanisms for a production environment, you’ve got time pressures, you’ve got budgetary considerations, and you miss stuff. And so any information that we can get solidified up front and have it right there in our face the whole time would be a help.

Now, what about a second challenging project that you best remember. It doesn’t have to be recent.

Well, I mean, right now so when we talk design, it can be anything from fixtures to workstations. So right now, our Kaizen event for semi-auto, we’re designing new works, basically a new work cell, so the design concepts that we’re talking about are scalable you know, your checklist is still the same, your requirements, your knowns, your unknowns. It’s all of these different things. You just have to break it down into subcomponents so that even though I've got the big picture in mind, I need to apply these concepts to each of the subcomponents that go into that cell. So for all of our flow channels, all of our buggies, all of our carts and workstations, the process remains same even though we’re focusing on one small subcomponent of the larger cell. So right now, we’re designing carts, buggies, and workstations to do specific tasks and assembly steps. So we’re having to consider things like grounding and ESD, mobility, modular design, ergonomics. All of these things, we have to take into account so not to be a broken record but all these things we talked about for the last project and in general, these checklists, these stating your facts and knowns and assumptions, you know. For every one of these
designs that we’re doing, having that information available, it provides continuity of thought on work, how your designing each station and what not. You know, having continuity of the lessons learned. Ok, if you’re going to do something like this: if you have meters on a shelf, it needs to be this type of material. This is the part number and specs for it.

So for the transmission redesign, what type of project would you say that is? The examples I have here are tooling and fixture design, process design. I wouldn’t think that falls under that. Would you say it’s almost the station partial redesign?

Yeah, I mean that not really even tooling. Machinery redesign and upgrade, if you want.

The buggies and the flow process…

I mean, that’s machinery equipment. That’s process as much as it is anything.

In general, how many design projects are you assigned either per year, or if it is easier, per month?

How about per week?

Well we could take an average per week and multiply it by 50, assuming 2 weeks off.
I mean, you know, there's no general blanket answer for that. For me, personally, maybe not as much as the other guys. I might have one or two things going per week that carry-on over multiple weeks.

**Is it really because you’re overseeing projects?**

Yeah, I mean, it’s more project management. A lot of it is for me so I might have one or two or three designs that might go for months because they’re larger or it takes time to get stuff built and different things and you follow through to completion. So maybe a dozen to a dozen and a half over a calendar year but when you talk about but, you know, when you’re talking about buggies and carts and mechanisms and fixtures and tooling. When you talk about true design work for me, that's a good, good number of projects throughout the year when you figure you’re still doing production support, paperwork, and all the different project management that comes along with these things.

**Ok, so how about just projects in general. Not only design but also with other production, other, let’s say your you put on a 6S…**

So a couple of ways to answer that. If we’re talking just like major projects that are tracked with budgets and hours and PSR's and whatnot, probably a dozen in a calendar year is good number. But when you talk about everything else that goes with it, the smaller not as visible projects, the fire fighting, the we need to design something to repair something on the line, I mean, it could be several dozen, you know. It really depends on how granular you want to get but as far as measurable tracked projects that management
is inclined to request updates on what the tracking on and whatnot, maybe a dozen or so in a calendar year.

**Ok, and what resources do you typically use throughout these projects? Whether it be software, hardware, tooling, people.**

Oh gosh, there’s a myriad of resources between CAD packages, any number of Microsoft products like PowerPoint, Excel, Word for communications, any number of homegrown: Dashboard, EIS, RIS, we’ve got a lot of homegrown apps that we use. I guess what I’ll call indigenous software, stuff like Brainson has their own stuff or MiniTab, things like that. Reference books, you know, my mechanics book, I’ll use that quite often during the design process. Any number of webpages where you go out and do a Google search, “Ok, I need to know about pitch angle on this kind of thread,” or what kind of fasteners to use, rules of thumb for whatever it is you’re looking for. I mean, there's any number of resources that you can use. Pick your neighbor’s brain, I mean literally. If you have tooling questions, you ask your tool and die guys. Electrical questions, you’ll hit up your test engineers or whatever. Any number of places to go to get the answers you seek.

**And so, we've been talking about how you go through and look at a project and you try to break it down to what you need for the project. Do you have an overarching specified procedure that you tend to follow? Do you have that documented somewhere or is it just from your experience?**
Experience. That’s why I say when you first come on, you’ve got to refine your craft and you’re going to learn by your mistakes, you’re going to get lessons learned that you apply to subsequent projects and processes so... I don’t know that you need an overarching set of rules and documents because it tends to limit innovation. But what you need is the upfront information to get you from point A to point B. How you get to point B could be any number ways. And there’s where I wouldn’t wouldn't want to be limited to I have to do this process or I have to follow this.

So that makes a lot of sense. You don't want to go...you want to set someone up help or help set a designer up but not...

A procedure should be to the benefit the designer. So when I say have a checklist of things you need to answer ahead of time, that's helpful, that's not a hindrance. Having a procedure that says okay you’ve got to do this, this, this, and this during your design process. If it's high-level, I see benefit in it. You know, for example, okay you’ve got X number of things you need to do through the whole process. Number one, fill out your free checklist, whatever you want to call it, listing your knowns and assumptions. Before you go to print have a peer review. Before you go tooling, have your designs checked for accuracy in your prints, okay. And then when you go to receive your tooling, your machined components, maybe have some quality checks on them that you have two or three dimensions checked for accuracy before you assemble, okay. And before you release to production your design, do some fit and function to make sure that all of your assumptions at the very beginning are satisfied when you go to do fit and function. I
could see something like that’s just some basic and reasonable deliverables as you go from concept to completion, but anything more rigid than that, to me, becomes a hindrance because now I’m more concerned with the process that I am the design and I don't want to get to that point. I want to stay focused on the design, you know, if it's just meeting some basic deliverables as we go that's reasonable but beyond that, it becomes a little too rigid in my opinion. It becomes more micromanaging.

I feel like that, in general, and I’m making a general assumption here, most people, I don’t think, like to be micromanaged. So by having some sort of, like what you were talking about, this process here would encourage more people to want to use it.

So the software that you used throughout these, like you said, the Microsoft apps, CAD as far as…

Pro/E and Solidworks. Although we have recently broke AutoCAD back out.

Really? A 3-D version or 2-D version?

2-D. Layouts.

So let’s say for your power transmission project, who all assisted with that?

Technicians. Technicians and tooling guys, guys in the shop.

You didn’t have any co-op or any assistance from any of the other engineers?
I don't think I had a co-op during that time. This is when Alex had his electrical engineering co-op. This would have been late last year (2014).

**Now, do you think that a co-op could have been assigned to this project?**

Do I think a co-op could have been assigned to this project? A more senior co-op, yes, with oversight. And here’s why I say this and this is not…I need to be careful how I answer this. The level of experience they might have when taking something like that that’s malfunctioned that has a significant price tag to it and reengineering a power transmission concept for it. I would feel comfortable letting them explore some options and with guidance and oversight, possibly let them manage the project. Certainly they could take part in it. There’s a lot of CAD that had to be done. A lot of inventory that needed to be ordered. You know, things that needed to be machined certainly would be, you know, in favor of things like that but I don't know that I would say, “Hey, I’m going to turn this over to you.” Now, a senior co-op on the third or fourth rotation, possibly. I've always said that I consider 3\textsuperscript{rd} and 4\textsuperscript{th} rotation co-ops to be staff engineers by then, they just don’t have the title. But they have a lot of experience and know-how. They know who to talk to and, you know, there's always that intermediate action with engineering, and particularly with myself to maintain that oversight so possibly could I see turning that over to a co-op, you know.

**Was this this project, was it team-based?**

Team in as much as I was the engineer with, I think, at some point all of my technicians were involved with some level project, in addition to shop assistance. So
yeah, there was a team of folks that had deliverables. It wasn't just a solo project but for this case, I would have be the only mechanical engineer working on the project.

**So you were the only mechanical engineer working on the job, period?**

Yes, yes, I would say so.

**And you said all of the technicians, so five of them?**

Yeah, at some point they were all involved with some level of working on the project.

**Just wanted to make sure it was first shift or third shift.**

Everybody had some level of responsibility.

**What about with the buggies?**

For Kaizen, it is very team based. We have multiple engineers, multiple technicians, and even some operator assistance with that. Certainly when we were in the planning and presentation phase, everybody was heavily involved. Now that we are in implementation phase, it’s primarily technician with engineering oversight. And both our IE and ME co-ops are heavily involved with it.

**So why would you say that they are more involved with the kaizen projects?**

**What was the primary purpose?**

The Kaizen project is huge. It’s basically re-envisioning an entire work cell. That's a bit too big for one person to maintain unless, given the timeframe. It’s a very aggressive timeframe, a very aggressive budget and it needs multiple sets of eyes to make sure one
person doesn’t miss something. If you go back to what I said in the beginning about your deliverables, having your knowns and unknowns, it’s one thing to do it for a singular station, a singular process but you’re talking about an entire workcell. And even though we’re methodical and can break it down into sub-components, at some point you’re going to miss something. With multiple sets of eyes, they’re going to look at it from a different slant whether it’s an IE, a EE, a technician. It's critical for something that big to have a team-based process. And so co-ops, where they plug-in, they’re very involved with designing of the workstations, the process. I’m very pleased with their progress, I think they’re doing a great job.

How would you describe the overall size of the projects? So let’s continue on with the Kaizen project, you’ve been talking that it’s larger in terms of the overall scope, the number of people involved. So how many people would you say were directly involved?

We had a dozen people involved at the beginning. We probably have half as many, to three quarters made that are actively involved in the implementation. This is the most expensive Kaizen project we’ve done to date in the factory and it has visibility all the way from the top.

Really?

Oh absolutely. We just presented a pared down version of this to our CEO. So it has visibility from the top, down. Particularly, I mean, from the factory level, specifically you know, the general manager on down. All major senior managers are well aware of what
we’re doing. It has, in the last couple days, we presented to the CEO what we’re doing so it has visibility for [Company A]. It’s one of those…and when we have our senior managers coming in from overseas, this is going to be one of the things they’re going to be looking at. How are we doing on the Kaizen, absolutely.

What about comparing the Kaizen to the transmission problem? You said it was you, five technicians, and…

A couple of guys in the shop. The scope of the problem didn’t require a huge team. You have to be realistic in how you allocate your resources and so resources in this case are people, okay. I don't need more than one engineer for that, you know. I used all five technicians so they all have a hand in it. So they all have some experience in a project like this. Had I had a co-op during that time, I definitely would have had them involved. It would have been a great learning tool, learning experience. For the Kaizen, there’s no question it's team-based. It has to be team-based to handle something that big, that quick.

And the more point of view?

To make sure we don’t miss stuff. But for something like that where it’s more of a mechanical design, what’s funny about that project is it had a coolness factor to it because every ME, at least on the side (the residential department), including ME managers, stopped by to see how it was going and to watch it run.

I can imagine. I want to see it right now.
I’ve got it on my phone I’ll show you. But yeah, there was definitely a coolness factor to it that you don’t get to do that every day. So yeah, I mean, it did necessitate more than one engineer and I was kind of protecting my turf a little bit cause I was having fun with it and I didn’t want some goober like Gibson to come in and ruin it for me. But yeah, that’s kind of how it went.

I can definitely see that. So how many man-hours were required to complete each of these projects?

Well, the one’s (the Kaizen project) is in process. It’s 1500+ man-hours so far in the Kaizen.

How many are I've been allocated to it against a PSR?

Well, that’s what I’m saying. On paper, 1500 hours so far. In actuality, there is just no way to calculate it, there’s no way to track it. It's an estimate based on, you start with your initial guess and at some point, you say, I probably have three times as many people working on it as I originally intended. So you just scale form there. At best, it’s just a guesstimate.

And can you give any kind of guesstimate on the transmission problem?

Couple hundred hours. Couple hundred dollars when you tally up everybody’s time because it's a project that went over about two months time from start to completion. And so you look at all the shop, the technician time, how much time we spent out there. The odds and ends, it was probably a couple hundred hours.
That’s a really good comparison, especially in terms of size. I know these are different because one is more mechanical while the Kaizen is more process but how would you describe the overall complexity of each of these projects? Which one to you is more complex?

Well, certainly the Kaizen is more complex inasmuch as we’re talking about an entire work cell that you are looking at redesigning processes to make it more efficient. There’s just so many more deliverables. As far as the mechanism itself, having to re-envision from a pure engineering standpoint, mechanical engineering standpoint, the power transmission unit was more complex in that you had to re-envision: How do I get this kinetic energy transferred from this motor/gear reduction unit to this rotary transmission to drive this dial table and meet my requirements of getting it on a tabletop, getting it easily accessible. What was literally a bevel gear type set up, now I’m going to a blower belt equivalent, you know. So re-envisioning how to do that effectively was the more difficult engineering challenge. Complexity is strictly a function, in this case, of the Kaizen event being a bigger scale.

Larger in scale.

Not more difficult engineering-wise, but just bigger scale.

Would you also say dealing with more people also affects that complexity too?

It should simplify it because you’ve got more eyes on it.
Even with the interactions with each other, it wouldn’t affect the complexity there?

I mean I wouldn't say it makes it any more difficult. Everybody has their part.

What type of tools or resources did you use to communicate your ideas with others? Whether it being others on the team or others for the tooling and die for the transmission project?

I think I’m missing something here, I’m not following you here.

If we just focus, let’s say, on the transmission project. So focusing on that, what type of resources did you use to communicate your ideas with others? Whether it be your ideas with the technicians or your ideas with the tool and die guys. Did you use a PowerPoint with them, did you print out prints?

I mean, prints, email, vocal. Very basic, you know.

And then for the Kaizen?

I mean, you've got PowerPoint, you’ve got stuff on paper, you know. I hope I’m not simplifying it too much but stuff on the whiteboard. Your basic, you sit around the table and, you know, put stuff on Excel. I don’t know if that makes sense?

Oh no, it does. If you had an idea outside a meeting, would you email it to the group or would you just write it down and save it for later?
It could be either one, it really depends on how crucial it is to disseminate that information quickly. I mean, if you want it documented, obviously email because you can always go back and say, “Hey, I sent you those.”

**And these projects, how were you first introduced to them?**

Well, I was introduced to the transmission unit when it failed and we couldn’t run the machine. I was introduced to the Kaizen event when the boss comes in and says, “Hey, you’re in charge of this.”

**So, it’s primarily verbal communication?**

The coil former was quite auditory: crunch, uh oh. Technicians walk in, you might want to come see this.

**No good. And the Kaizen one, when you said the boss came.**

The boss sat in that very chair and said, you’re in charge of this. Ok, thanks…

**With the exception of parts breaking down, would you say someone coming in and telling you, “Hey, I need you to work on this project,” is that most common or is it more common to receive an email?**

Both.

**Both equally common?**

Yeah.
Is there any kind of format to any of this?

This is [Company A] (no).

I have to ask… I’m pretty sure I know the answer.

You know the answer. No, there’s no format to it. I mean, you may get assigned something in one of the weekly (continuous improvement) meetings but in general, he’s going to come in and say, “Hey, I want you on this.” Usually, it’s verbal because he’s got to explain to you what he wants done. There’s going to be a lot of questions and whatnot.

So it’s almost better to have that interview type introduction?

I’d say it’s absolutely required.

How were these projects initially defined? Not the transmission project because you said that was a crunch and you were brought out there by the technicians.

Quite literally.

The Kaizen project, how did your boss initially come in here and be like, “Hey, I need you to work on this.” Did he give you just a general explanation that we need this line redesigned for a Kaizen event or was it just, I need you to do something, get it done, and it’s up to you as to how you get it done.

No, I mean, it was explained that this was the next Kaizen event and it’s kind of understood when you’re going to do a Kaizen event, you know, what’s the goal of a Kaizen event? Now, they had to call me in and break down what were the specific
management driven objectives, budget, things of that nature; give you your goals and constraints. But once you have those, it’s kind of a blank sheet. Assemble the team and, you know, list out the goals and constraints and start going through the process. Now, to me, it’s probably not as documented as it should be but there is a process to going through a Kaizen event. So, as you go through the process, it forces you to answer specific questions that help you to get to your solution, or your proposed solution.

**So now while you’re going through these projects, how often do you have design reviews?** Well, for the transmission project, how often would you have peer reviews and at least review your design with someone?

I say this half cocked, with that project, it was almost daily review because I always had someone crawling over it looking at it with me and, “Hey man, what’re you doing? How’re you going to solve this? What’s this for? Why are you doing this?”

**Because of all the interest in it?**

Oh yeah, it was more informal. Like I said, there was a coolness factor to it that we don’t normally get to work on. Usually, it’s very cut and dry, replace this, fix that. This one was like, there was no obvious solution. We had to reengineer it mechanically to see if we could even get it to work. There was a little bit of trepidation once we had it all bolted together to see if we could get it to work. Confidence was high, but until you see it in operation, is it going to go?

**The uncertainty there…**
Yeah, there was a little bit of uncertainty. The best laid plans are only as good as their execution. That executes well or they execute me.

Well, good thing it executed well… So then, how many formal design reviews did you have for that project?

Maybe one.

Who was involved in that?

Manager and other ME’s. Anyone that could give me constructed feedback.

Was it mainly just the manufacturing group or did you invite anyone from R&D?

No, absolutely not. Just manufacturing guys.

You were talking about having presented the Kaizen stuff to the CEO.

Oh, that was senior management.

You’ve done that with senior management and with local level?

Every senior manager in the factory plus our CEO has been represented to at this point.

That’s incredible now that I think about it that it has the direct attention of the CEO there.
Well, it was one of those where he comes in to visit and you want to show him a lot of the work that has been going on in the factory. This was one of the projects that was selected cause it’s in implementation phase so it was easy to say, “Hey, it’s already been approved, there’s already a presentation. Cut it down to 15 minutes and you’ve got his full attention.”

Ok

One of those deals.

Alrighty, so the transmission, that’s still in use?

Yep.

Have any modifications been made to it since it was first put out there?

Tweaks, tuning.

Ok. Do you think anything could have been prevented with the checklist? Could any of those tweaks have been prevented or is that just one of those things?

No, it’s one of those where when you get to fit and function… CAD’s going to get you so far.

Any major concerns about it? Anticipated lifespan?

No, because of the way it’s designed, all components should be readily accessible, replaceable. Fairly straight forward.
Any final reflections on these projects at all?

Nothing I can think of. They’re all worthy projects, fairly straight forward. Some forced upon you, the nature of the beast. Others planned but they’re cost savings at the end of the day and, I think, worthwhile.

It helps with production.

Absolutely. They both help the factory for sure.

B.10 C.ME.1 – Jordan

SO: The purpose of this is for my research at Clemson where from my experiences in the capstone program and then senior program we design primarily in teams of 3, 4, or 5 students and we work on a project together as in that team. Well, when coming here, the most interaction in a team that I have received was maybe working on a project with or maybe getting some assistance from one of the test engineers whether it be like mainly it was Brian Williams. Or it would be one of the techs. And that would be it. So I just wanted to come here and get y’all’s experiences since y'all have been working here much longer than me. Y’all have more experience than I do. I just wanted to see if your insight is the same as mine but hopefully what will come out of this is that if most of the work you do is more individual rather directly in teams then there might be some sort of process of some sort of tool or even software that I could potentially develop or recommend and then you could potentially use it here or someone at some other company so the end goal
of this is to try to help increase efficiency and quality the overall ability of the engineer especially if they’re new like I was when I first started. And increasing the ability to hit the ground running might be helpful.

So I have to get these introductory questions first: what is your position title and description, and how many years have you been at this position?

Brad: Lead manufacturing engineer is the title. I’ve been in this particular role since probably 2006/2007 so 8 or 9 years.

And what exactly are your responsibilities in that role?

Well manufacturing engineer, first and foremost, supporting production, supporting departmental initiatives and filtering those down through the group such as PSR's, manufacturing qualifications, 5S initiatives. Right now, I’m leading a Kaizen team so any number of focus factory and departmental goals that need to be filtered down to the group. Maintaining capital budget, mechanical design reviews, things like that. You know, all of the above our part my responsibilities but first and foremost of these would be supporting production, project management, things like that.

Ok. So what was your previous design experience within [Company A]?

I mean…if we’re talking in a current manufacturing engineering role, when I first started back in ’99, it might be designing fixtures, designing tooling in Pro/E for production. As I've gone room and, I guess, progressed over time, I still support that, but not to the same degree that some of the other guys in the group do. I've seen my
responsibilities shift to more project management as compared to down in the trenches, nuts and bolts, designing fixtures. I still do that from time to time but that's not one of the things it would be one of my big portion of my plate right now.

**What other companies have you worked for?**

Milliken and Company at their finishing plant in Pendleton. Co-oped at Metler Toledo back in the mid-90s. but I’ve been at [Company A] since ‘99.

**What type of work did you do for those other companies?**

Very similar to what, I guess, a typical co-op or intern would do. Some basic CAD work, some basic data collection. A little bit of fixture design. At Milliken I also did some inventory control, did some 5S, stuff like that.

**Have you attended any workshops or taken any specific classes on designing, and more importantly, either design in general or how to design on your own as an individual rather than in teams?**

So let’s clarify, when talking design, you know, you mean with a CAD package designing a specific mechanism or something?

**Yeah, whether it be with CAD or whether it be just having to have something sketched out and then potentially presented to someone before actually going to CAD. Any kind of design work whether it be for fixture or tooling.**
I mean, above and beyond what I took in school, I don't believe. It’s one of those things where I’ve refined my craft over the years. Learning from mentors, learning from senior engineers, watching the process, learning as I go and perfecting it through time.

So what kind of stuff would you say you’ve learned throughout your experiences?

Learning the design process, you know, to identify what are the key parameters before you sit down on the CAD package and start to, start to sketch it out: what are you trying to accomplish? What are your space constraints? What, if any, budgetary constraints do you have which will affect your selection of materials. Are there any safety considerations that have been identified ahead of time? So mainly getting all the prep work done and answered before you sit down in front of the computer to start the design so that you don't find out halfway through it, “Oh I had to make sure this was a nonconductive material,” or “Oh it needs to be mobile. I had this on a table top.” Getting all your ducks in a row before you sit down to do it is the biggest, you know, it sounds trivial but a lot of people even now don't do that correctly, in my opinion, and they have to go back and rev their design 2, 3, 4 times because they didn't have all the information they needed. Now sometimes that information is not easily come by, but you get as much of it as you can. So one thing, if we had a designer’s kit, and this is just thinking matter of fact, a designer’s kit that forces you to answer specific questions up front, as much as possible. For example, “Are there safety considerations?”, “Is this a mobile device?”, “Is this intended to be a standalone machine?”, “Is it tabletop?” Selection of materials, you
know, does it need to be ESD? What type of product is going to go into it? Does it need to be guarded? Is it just simple mechanisms or is there going to be kinetic energy devices such as hydraulic schematics, servos that need light curtains. All of these things, if they’re answered up front, you going to design with that in mind. So, if we had a checklist, maybe the standard, you know…

That almost sets up your design space for you.

It really forces you down the correct path because if you can answer these questions up front, then when you actually sit down and start putting the mechanism together in your mind on the computer, “Oh yeah, I remember I’ve got to have ESD shelving. Oh, I’m going to have to have light curtains on this because I'm using, you know, half-inch four pneumatic cylinders to do this action or whatever it is. Make sure you know dot your I’s and cross your T’s. So one of those, I mean a lot of times we do it naturally, we go and write stuff down a piece of paper in a notebook but if we had a checklist that formalizes that this is part of the design process, answer these questions as much as possible. And if there's a problem you can always go back to your checklist and say, “why isn't this right?” Well, this is the assumptions I had when I went into it. Maybe the assumptions change. Maybe what was supposed to be a fixed benchtop type of mechanism, well now they want to roll it from cell to cell so it needs to be mobile. Well, if there’s changes that are required later, you can at least go back to say, “Hey, when I started the process, my checklist said this was benchtop and this was a fixed asset. Now somebody has changed into a mobile device down the road. So, if it takes three more
weeks to finish this and another 1000 to 1500 dollars to modify it, you’ve got your documentation that says, “Hey, when I started the project, these were the assumptions.” So it's always good to have that information up front.

So would having some sort of a pre-populated list of topics to go through that forces you to go through a general listing of every subject, whether it be safety, ESD, material selection, would you say that would be helpful?

I think particularly for the guys that are new, for co-ops, for those that aren’t used to the design process that need to perfect their craft. I think having something more formal like that forces them to think about some of the issues that we take for granted as a more senior designer. You know, we go through the checklist in our head and even now, we’ll miss stuff and if we had it on a paper or whatever, in front of us the whole time, you know, even that would help a seasoned engineer to make sure to keep all their information straight. It's just like solving any kind of technical problem. You list your assumptions first before you try to solve the problem. This is no different: you list your assumptions up front, you knowns, and your assumptions and then you start your design. And when you get to the end you ought to be able to look at your designs and say, “Yep, light curtains, check that out for guarding,” “yep, I’ve got ESD and that’s grounded. Check that off for that, you know.” You ought to be able to look at your finished design and look at your list of knowns and assumptions, and every one of those is satisfied in the design. And if they’re not, you’ve missed something. You didn’t pay attention to the information you had.
Now let’s get into some of the projects you’ve worked on. That’s what the remainder of these questions will focus on. So can you describe your most recent design project that you’ve completed?

We had to do a redesign on the power transmission unit for the old coil-forming machine. The rotary transmission unit for the dial table failed. The drive gear basically destructed, self-destructed and it was about a $45,000 replacement and it wasn't a drop in to get the power transmission unit. The way it was set up was not easily to work on. You had to crawl under the machine, pull the motor and the clutch. So we decided to reengineer it in-house and take the components that worked on the rotary transmission and design and install a new power transmission unit to drive the rotary to drive the dial table. So it was really cool. About a $43,000 cost-savings as well. So basically taking known mechanical concepts on power transmission, we got the drive unit from underneath table, mounted it tabletop so it’s easily accessible. Basically, took the equivalent of a blower belt, a big 1.5-inch wide belt that would transmit power from the motor gear reduction unit to the input shaft for the rotary transmission. Getting that all built and designed and operational, we can go look at that anytime you want to go look at that.

Might have to take a look at that, that’s pretty exciting.

It's pretty neat, I’ve got some pictures to show you. Matter of fact, I know I do on my phone. So going through that design process was neat and, you know, again having the checklist available and have it posted out there and make sure we’re meeting all those
requirements would've been an advantage. We miss some stuff, you know. It's one of those particularly, designing mechanisms for a production environment, you’ve got time pressures, you’ve got budgetary considerations, and you miss stuff. And so any information that we can get solidified up front and have it right there in our face the whole time would be a help.

Now, what about a second challenging project that you best remember. It doesn’t have to be recent.

Well, I mean, right now so when we talk design, it can be anything from fixtures to workstations. So right now, our Kaizen event for semi-auto, we’re designing new works, basically a new work cell, so the design concepts that we’re talking about are scalable you know, your checklist is still the same, your requirements, your knowns, your unknowns. It’s all of these different things. You just have to break it down into subcomponents so that even though I've got the big picture in mind, I need to apply these concepts to each of the subcomponents that go into that cell. So for all of our flow channels, all of our buggies, all of our carts and workstations, the process remains same even though we’re focusing on one small subcomponent of the larger cell. So right now, we’re designing carts, buggies, and workstations to do specific tasks and assembly steps. So we’re having to consider things like grounding and ESD, mobility, modular design, ergonomics. All of these things, we have to take into account so not to be a broken record but all these things we talked about for the last project and in general, these checklists, these stating your facts and knowns and assumptions, you know. For every one of these
designs that we’re doing, having that information available, it provides continuity of thought on work, how your designing each station and what not. You know, having continuity of the lessons learned. Ok, if you’re going to do something like this: if you have meters on a shelf, it needs to be this type of material. This is the part number and specs for it.

**So for the transmission redesign, what type of project would you say that is?** The examples I have here are tooling and fixture design, process design. I wouldn’t think that falls under that. Would you say it’s almost the station partial redesign?

Yeah, I mean that not really even tooling. Machinery redesign and upgrade, if you want.

**The buggies and the flow process...**

I mean, that’s machinery equipment. That’s process as much as it is anything.

**In general, how many design projects are you assigned either per year, or if it is easier, per month?**

How about per week?

**Well we could take an average per week and multiply it by 50, assuming 2 weeks off.**
I mean, you know, there's no general blanket answer for that. For me, personally, maybe not as much as the other guys. I might have one or two things going per week that carry-on over multiple weeks.

**Is it really because you’re overseeing projects?**

Yeah, I mean, it’s more project management. A lot of it is for me so I might have one or two or three designs that might go for months because they’re larger or it takes time to get stuff built and different things and you follow through to completion. So maybe a dozen to a dozen and a half over a calendar year but when you talk about but, you know, when you’re talking about buggies and carts and mechanisms and fixtures and tooling. When you talk about true design work for me, that's a good, good number of projects throughout the year when you figure you’re still doing production support, paperwork, and all the different project management that comes along with these things.

**Ok, so how about just projects in general. Not only design but also with other production, other, let’s say your you put on a 6S…**

So a couple of ways to answer that. If we’re talking just like major projects that are tracked with budgets and hours and PSR's and whatnot, probably a dozen in a calendar year is good number. But when you talk about everything else that goes with it, the smaller not as visible projects, the fire fighting, the we need to design something to repair something on the line, I mean, it could be several dozen, you know. It really depends on how granular you want to get but as far as measurable tracked projects that management
is inclined to request updates on what the tracking on and whatnot, maybe a dozen or so in a calendar year.

**Ok, and what resources do you typically use throughout these projects?** Whether it be software, hardware, tooling, people.

Oh gosh, there’s a myriad of resources between CAD packages, any number of Microsoft products like PowerPoint, Excel, Word for communications, any number of homegrown: Dashboard, EIS, RIS, we’ve got a lot of homegrown apps that we use. I guess what I’ll call indigenous software, stuff like Brainson has their own stuff or MiniTab, things like that. Reference books, you know, my mechanics book, I’ll use that quite often during the design process. Any number of webpages where you go out and do a Google search, “Ok, I need to know about pitch angle on this kind of thread,” or what kind of fasteners to use, rules of thumb for whatever it is you’re looking for. I mean, there's any number of resources that you can use. Pick your neighbor’s brain, I mean literally. If you have tooling questions, you ask your tool and die guys. Electrical questions, you’ll hit up your test engineers or whatever. Any number of places to go to get the answers you seek.

**And so, we've been talking about how you go through and look at a project and you try to break it down to what you need for the project. Do you have an overarching specified procedure that you tend to follow?** Do you have that documented somewhere or is it just from your experience?
Experience. That’s why I say when you first come on, you’ve got to refine your craft and you’re going to learn by your mistakes, you’re going to get lessons learned that you apply to subsequent projects and processes so… I don’t know that you need an overarching set of rules and documents because it tends to limit innovation. But what you need is the upfront information to get you from point A to point B. How you get to point B could be any number ways. And there’s where I wouldn’t wouldn't want to be limited to I have to do this process or I have to follow this.

So that makes a lot of sense. You don't want to go...you want to set someone up help or help set a designer up but not…

A procedure should be to the benefit the designer. So when I say have a checklist of things you need to answer ahead of time, that's helpful, that's not a hindrance. Having a procedure that says okay you’ve got to do this, this, this, and this during your design process. If it's high-level, I see benefit in it. You know, for example, okay you’ve got X number of things you need to do through the whole process. Number one, fill out your free checklist, whatever you want to call it, listing your knowns and assumptions. Before you go to print have a peer review. Before you go tooling, have your designs checked for accuracy in your prints, okay. And then when you go to receive your tooling, your machined components, maybe have some quality checks on them that you have two or three dimensions checked for accuracy before you assemble, okay. And before you release to production your design, do some fit and function to make sure that all of your assumptions at the very beginning are satisfied when you go to do fit and function. I
could see something like that’s just some basic and reasonable deliverables as you go from concept to completion, but anything more rigid than that, to me, becomes a hindrance because now I’m more concerned with the process that I am the design and I don't want to get to that point. I want to stay focused on the design, you know, if it's just meeting some basic deliverables as we go that's reasonable but beyond that, it becomes a little too rigid in my opinion. It becomes more micromanaging.

I feel like that, in general, and I’m making a general assumption here, most people, I don’t think, like to be micromanaged. So by having some sort of, like what you were talking about, this process here would encourage more people to want to use it.

So the software that you used throughout these, like you said, the Microsoft apps, CAD as far as…

Pro/E and Solidworks. Although we have recently broke AutoCAD back out.

Really? A 3-D version or 2-D version?

2-D. Layouts.

So let’s say for your power transmission project, who all assisted with that?

Technicians. Technicians and tooling guys, guys in the shop.

You didn’t have any co-op or any assistance from any of the other engineers?
I don't think I had a co-op during that time. This is when Alex had his electrical engineering co-op. This would have been late last year (2014).

**Now, do you think that a co-op could have been assigned to this project?**

Do I think a co-op could have been assigned to this project? A more senior co-op, yes, with oversight. And here’s why I say this and this is not…I need to be careful how I answer this. The level of experience they might have when taking something like that that’s malfunctioned that has a significant price tag to it and reengineering a power transmission concept for it. I would feel comfortable letting them explore some options and with guidance and oversight, possibly let them manage the project. Certainly they could take part in it. There’s a lot of CAD that had to be done. A lot of inventory that needed to be ordered. You know, things that needed to be machined certainly would be, you know, in favor of things like that but I don't know that I would say, “Hey, I’m going to turn this over to you.” Now, a senior co-op on the third or fourth rotation, possibly. I've always said that I consider 3\(^{rd}\) and 4\(^{th}\) rotation co-ops to be staff engineers by then, they just don’t have the title. But they have a lot of experience and know-how. They know who to talk to and, you know, there's always that intermediate action with engineering, and particularly with myself to maintain that oversight so possibly could I see turning that over to a co-op, you know.

**Was this this project, was it team-based?**

Team in as much as I was the engineer with, I think, at some point all of my technicians were involved with some level project, in addition to shop assistance. So
yeah, there was a team of folks that had deliverables. It wasn't just a solo project but for this case, I would have be the only mechanical engineer working on the project.

**So you were the only mechanical engineer working on the job, period?**

Yes, yes, I would say so.

**And you said all of the technicians, so five of them?**

Yeah, at some point they were all involved with some level of working on the project.

**Just wanted to make sure it was first shift or third shift.**

Everybody had some level of responsibility.

**What about with the buggies?**

For Kaizen, it is very team based. We have multiple engineers, multiple technicians, and even some operator assistance with that. Certainly when we were in the planning and presentation phase, everybody was heavily involved. Now that we are in implementation phase, it’s primarily technician with engineering oversight. And both our IE and ME co-ops are heavily involved with it.

**So why would you say that they are more involved with the kaizen projects?**

**What was the primary purpose?**

The Kaizen project is huge. It’s basically re-envisioning an entire work cell. That's a bit too big for one person to maintain unless, given the timeframe. It’s a very aggressive timeframe, a very aggressive budget and it needs multiple sets of eyes to make sure one
person doesn’t miss something. If you go back to what I said in the beginning about your deliverables, having your knowns and unknowns, it’s one thing to do it for a singular station, a singular process but you’re talking about an entire workcell. And even though we’re methodical and can break it down into sub-components, at some point you’re going to miss something. With multiple sets of eyes, they’re going to look at it from a different slant whether it’s an IE, a EE, a technician. It's critical for something that big to have a team-based process. And so co-ops, where they plug-in, they’re very involved with designing of the workstations, the process. I’m very pleased with their progress, I think they’re doing a great job.

How would you describe the overall size of the projects? So let’s continue on with the Kaizen project, you’ve been talking that it’s larger in terms of the overall scope, the number of people involved. So how many people would you say were directly involved?

We had a dozen people involved at the beginning. We probably have half as many, to three quarters made that are actively involved in the implementation. This is the most expensive Kaizen project we’ve done to date in the factory and it has visibility all the way from the top.

Really?

Oh absolutely. We just presented a pared down version of this to our CEO. So it has visibility from the top, down. Particularly, I mean, from the factory level, specifically you know, the general manager on down. All major senior managers are well aware of what
we’re doing. It has, in the last couple days, we presented to the CEO what we’re doing so it has visibility for [Company A]. It's one of those…and when we have our senior managers coming in from overseas, this is going to be one of the things they’re going to be looking at. How are we doing on the Kaizen, absolutely.

**What about comparing the Kaizen to the transmission problem? You said it was you, five technicians, and…**

A couple of guys in the shop. The scope of the problem didn’t require a huge team. You have to be realistic in how you allocate your resources and so resources in this case are people, okay. I don't need more than one engineer for that, you know. I used all five technicians so they all have a hand in it. So they all have some experience in a project like this. Had I had a co-op during that time, I definitely would have had them involved. It would have been a great learning tool, learning experience. For the Kaizen, there’s no question it's team-based. It has to be team-based to handle something that big, that quick.

**And the more point of view?**

To make sure we don’t miss stuff. But for something like that where it’s more of a mechanical design, what’s funny about that project is it had a coolness factor to it because every ME, at least on the side (the residential department), including ME managers, stopped by to see how it was going and to watch it run.

**I can imagine. I want to see it right now.**
I’ve got it on my phone I’ll show you. But yeah, there was definitely a coolness factor to it that you don't get to do that every day. So yeah, I mean, it did necessitate more than one engineer and I was kind of protecting my turf a little bit cause I was having fun with it and I didn’t want some goober like Gibson to come in and ruin it for me. But yeah, that’s kind of how it went.

I can definitely see that. So how many man-hours were required to complete each of these projects?

Well, the one’s (the Kaizen project) is in process. It’s 1500+ man-hours so far in the Kaizen.

How many are I've been allocated to it against a PSR?

Well, that’s what I’m saying. On paper, 1500 hours so far. In actuality, there is just no way to calculate it, there’s no way to track it. It's an estimate based on, you start with your initial guess and at some point, you say, I probably have three times as many people working on it as I originally intended. So you just scale form there. At best, it’s just a guesstimate.

And can you give any kind of guesstimate on the transmission problem?

Couple hundred hours. Couple hundred dollars when you tally up everybody’s time because it's a project that went over about two months time from start to completion. And so you look at all the shop, the technician time, how much time we spent out there. The odds and ends, it was probably a couple hundred hours.
That’s a really good comparison, especially in terms of size. I know these are different because one is more mechanical while the Kaizen is more process but how would you describe the overall complexity of each of these projects? Which one to you is more complex?

Well, certainly the Kaizen is more complex inasmuch as we’re talking about an entire work cell that you are looking at redesigning processes to make it more efficient. There’s just so many more deliverables. As far as the mechanism itself, having to re-envision from a pure engineering standpoint, mechanical engineering standpoint, the power transmission unit was more complex in that you had to re-envision: How do I get this kinetic energy transferred from this motor/gear reduction unit to this rotary transmission to drive this dial table and meet my requirements of getting it on a tabletop, getting it easily accessible. What was literally a bevel gear type set up, now I’m going to a blower belt equivalent, you know. So re-envisioning how to do that effectively was the more difficult engineering challenge. Complexity is strictly a function, in this case, of the Kaizen event being a bigger scale.

Larger in scale.

Not more difficult engineering-wise, but just bigger scale.

Would you also say dealing with more people also affects that complexity too?

It should simplify it because you’ve got more eyes on it.
Even with the interactions with each other, it wouldn’t affect the complexity there?

I mean I wouldn't say it makes it any more difficult. Everybody has their part.

What type of tools or resources did you use to communicate your ideas with others? Whether it being others on the team or others for the tooling and die for the transmission project?

I think I’m missing something here, I’m not following you here.

If we just focus, let’s say, on the transmission project. So focusing on that, what type of resources did you use to communicate your ideas with others? Whether it be your ideas with the technicians or your ideas with the tool and die guys. Did you use a PowerPoint with them, did you print out prints?

I mean, prints, email, vocal. Very basic, you know.

And then for the Kaizen?

I mean, you've got PowerPoint, you’ve got stuff on paper, you know. I hope I’m not simplifying it too much but stuff on the whiteboard. Your basic, you sit around the table and, you know, put stuff on Excel. I don’t know if that makes sense?

Oh no, it does. If you had an idea outside a meeting, would you email it to the group or would you just write it down and save it for later?
It could be either one, it really depends on how crucial it is to disseminate that information quickly. I mean, if you want it documented, obviously email because you can always go back and say, “Hey, I sent you those.”

**And these projects, how were you first introduced to them?**

Well, I was introduced to the transmission unit when it failed and we couldn’t run the machine. I was introduced to the Kaizen event when the boss comes in and says, “Hey, you’re in charge of this.”

**So, it’s primarily verbal communication?**

The coil former was quite auditory: crunch, uh oh. Technicians walk in, you might want to come see this.

**No good. And the Kaizen one, when you said the boss came.**

The boss sat in that very chair and said, you’re in charge of this. Ok, thanks…

**With the exception of parts breaking down, would you say someone coming in and telling you, “Hey, I need you to work on this project,” is that most common or is it more common to receive an email?**

Both.

**Both equally common?**

Yeah.
Is there any kind of format to any of this?

This is [Company A] (no).

I have to ask… I’m pretty sure I know the answer.

You know the answer. No, there’s no format to it. I mean, you may get assigned something in one of the weekly (continuous improvement) meetings but in general, he’s going to come in and say, “Hey, I want you on this.” Usually, it’s verbal because he’s got to explain to you what he wants done. There’s going to be a lot of questions and whatnot.

So it’s almost better to have that interview type introduction?

I’d say it’s absolutely required.

How were these projects initially defined? Not the transmission project because you said that was a crunch and you were brought out there by the technicians.

Quite literally.

The Kaizen project, how did your boss initially come in here and be like, “Hey, I need you to work on this.” Did he give you just a general explanation that we need this line redesigned for a Kaizen event or was it just, I need you to do something, get it done, and it’s up to you as to how you get it done.

No, I mean, it was explained that this was the next Kaizen event and it’s kind of understood when you’re going to do a Kaizen event, you know, what’s the goal of a Kaizen event? Now, they had to call me in and break down what were the specific
management driven objectives, budget, things of that nature; give you your goals and constraints. But once you have those, it’s kind of a blank sheet. Assemble the team and, you know, list out the goals and constraints and start going through the process. Now, to me, it’s probably not as documented as it should be but there is a process to going through a Kaizen event. So, as you go through the process, it forces you to answer specific questions that help you to get to your solution, or your proposed solution.

So now while you’re going through these projects, how often do you have design reviews? Well, for the transmission project, how often would you have peer reviews and at least review your design with someone?

I say this half cocked, with that project, it was almost daily review because I always had someone crawling over it looking at it with me and, “Hey man, what’re you doing? How’re you going to solve this? What’s this for? Why are you doing this?”

Because of all the interest in it?

Oh yeah, it was more informal. Like I said, there was a coolness factor to it that we don’t normally get to work on. Usually, it’s very cut and dry, replace this, fix that. This one was like, there was no obvious solution. We had to reengineer it mechanically to see if we could even get it to work. There was a little bit of trepidation once we had it all bolted together to see if we could get it to work. Confidence was high, but until you see it in operation, is it going to go?

The uncertainty there…
Yeah, there was a little bit of uncertainty. The best laid plans are only as good as their execution. That executes well or they execute me.

Well, good thing it executed well... So then, how many formal design reviews did you have for that project?

Maybe one.

Who was involved in that?

Manager and other ME’s. Anyone that could give me constructed feedback.

Was it mainly just the manufacturing group or did you invite anyone from R&D?

No, absolutely not. Just manufacturing guys.

You were talking about having presented the Kaizen stuff to the CEO.

Oh, that was senior management.

You’ve done that with senior management and with local level?

Every senior manager in the factory plus our CEO has been represented to at this point.

That’s incredible now that I think about it that it has the direct attention of the CEO there.
Well, it was one of those where he comes in to visit and you want to show him a lot of the work that has been going on in the factory. This was one of the projects that was selected because it’s in implementation phase so it was easy to say, “Hey, it’s already been approved, there’s already a presentation. Cut it down to 15 minutes and you’ve got his full attention.”

Ok

One of those deals.

Alrighty, so the transmission, that’s still in use?

Yep.

Have any modifications been made to it since it was first put out there?

Tweaks, tuning.

Ok. Do you think anything could have been prevented with the checklist? Could any of those tweaks have been prevented or is that just one of those things?

No, it’s one of those where when you get to fit and function… CAD’s going to get you so far.

Any major concerns about it? Anticipated lifespan?

No, because of the way it’s designed, all components should be readily accessible, replaceable. Fairly straightforward.
Any final reflections on these projects at all?

Nothing I can think of. They’re all worthy projects, fairly straightforward. Some forced upon you, the nature of the beast. Others planned but they’re cost savings at the end of the day and, I think, worthwhile.

It helps with production.

Absolutely. They both help the factory for sure.