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Comparing Change Management Processes for Requirements and Manufacturing: An Interview Based Study

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COMPARING CHANGE MANAGEMENT PROCESSES FOR REQUIREMENTS AND MANUFACTURING: AN INTERVIEW BASED STUDY

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ABSTRACT

This study compares requirement and manufacturing change management processes to determine the processes in use and if similar processes can be used for both types of changes. A literature review is used to identify prescribed process stages. Ten stages are identified for both requirements and manufacturing change management. A series of interviews are then conducted with four different population groups to determine the process stages actually used in the field. The resulting requirement and manufacturing change process models are compared with the process models from the literature and with each other. Further, a thematic analysis is performed on the interview findings. Ultimately, differences are found between the prescribed and practiced change management models for both types of changes. Formal documentation stages are more prevalent for the manufacturing domain, though documentation in practice is less than what is prescribed. This includes the issuance of change requests and change orders in manufacturing change management that are not present in requirement change management processes. Significant differences were also found between the two change types; namely, requirement changes deal with more abstract concepts and as such can afford more informal documentation, whereas manufacturing changes deal with existing artifacts and require solid documentation. Additional research thrusts are identified to help reconcile change management processes across the life cycle.

DEDICATION

This thesis is dedicated to my parents, Darleen and Jimmy Sutton, who have always supported me and never ceased to encourage me in all of my endeavors. I would also like to dedicate this thesis to my sister, Molly Sutton, who is always willing to support me and lend an ear to let me talk things through.

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TABLE OF CONTENTS

LIST OF TABLES

Table Page

LIST OF FIGURES

Figure Page

Chapter One
CHANGE MANAGEMENT: WHAT IS IT AND WHY STUDY IT?

This thesis is focused on the change management approaches used in industry, both early in the design process, referred to as requirements change management, and in manufacturing, called manufacturing change management, to determine if any underlying consistencies are present between the two processes. In this section, the different types of changes are defined, including requirement, engineering, and manufacturing changes. Change propagation is then explained, followed by a discussion of literature regarding change management processes for the different change types.

1.1 Types of Changes

Changes are frequent throughout the overall design process, and can occur at any scale at any stage of the design process. Because of this, many types of changes are categorized based on the stage of the design process, shown in Figure 1.1, in which they occur. Requirement changes, for example, occur early in the design process in the product definition stage, in which requirements are developed and reviewed. Engineering changes occur during the product development phase, after concepts have been generated and evaluated and are being refined, while manufacturing changes occur during product manufacturing, a facet of the product support stage.

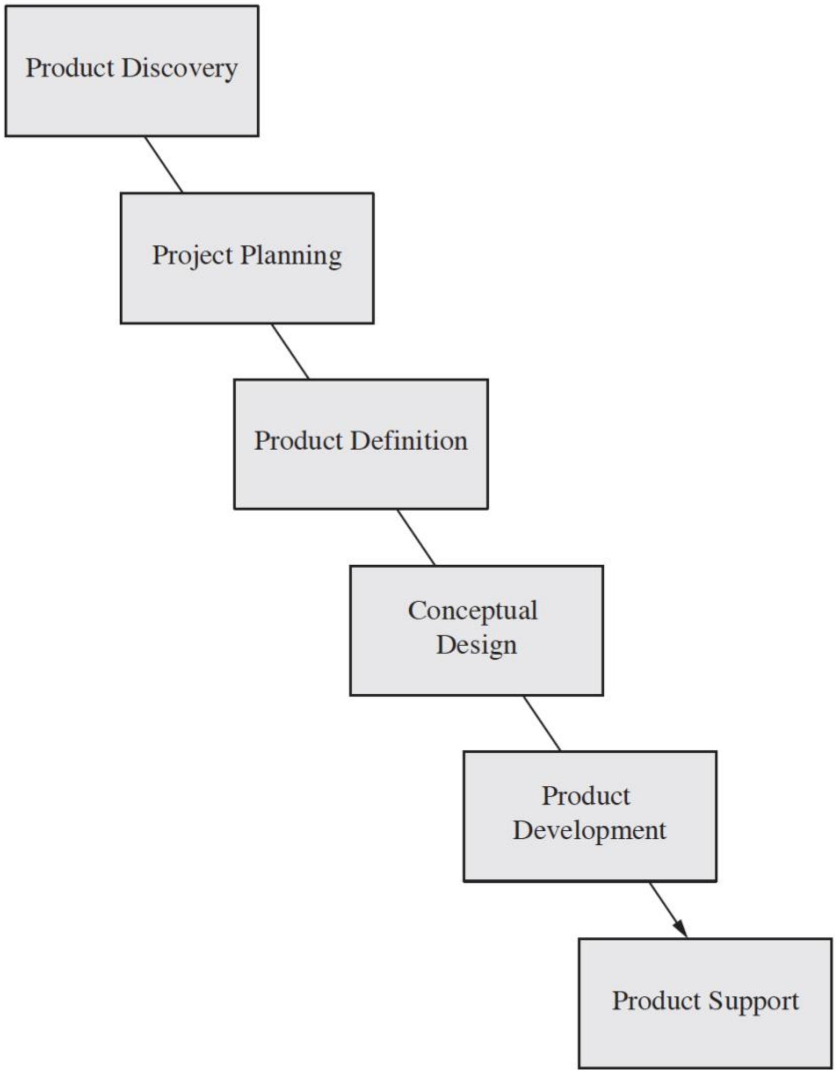

Figure 1.1: Mechanical design process (Ullman, 1992)

1.1.1 Requirement Changes

A requirement change (RC) is defined as the addition of a new requirement to a requirement set, or the modification or removal of existing requirements (Lam and Shankararaman, 1999; Lam et al., 1999; Hein et al. 2018). Changes can be prompted by customer requests and misunderstanding of initial requirements, or by discovering that a particular requirement lies outside of the overall project scope (Bhatti et al., 2010; Hein et al., 2017; Graessler et al., 2020). Other change triggers can include discovery of new requirements, reductions in project scope, revisions to improve testability, and changes to the product environment (Nurmuliani et al., 2004; Elena et al., 2019; Oduguwa et al., 2006). A detailed breakdown and characterization method for RC was presented in the form of a taxonomy (Saher et al., 2017). In this taxonomy, four taxons were specified: type of change, either addition, deletion, or modification; time of change, either or early or late in development; origin of change, including market demand, customer needs, or organizational needs; and reason for change. The reason for change taxon was further subdivided into three major categories. The first category, mutable requirements, describes RCs external to the system being developed that cater to market demand and the embracing of new technologies or opportunities. Emergent requirements, the second RC category, are explained as those that appear during requirement elicitation phases, as the experience and understanding of developers as well as overall project clarity increases. Consequential requirements describe the RCs that occur when the designed system has been implemented, generally focused on addressing redundant or obsolete functionality, fixing errors or defects, and conflict resolution (Saher et al., 2017).

1.1.2 Engineering Changes

Engineering changes (EC) are defined as a modification to a particular component or subassembly of a product after that product is in production (Shankar et al., 2012; Wright, 1997; Jarratt et al., 2005; Terwiesch and Loch, 1999, Raffaeli et al., 2013). With increased study, the definition has evolved to include more detail: any modification in the form, fit, dimensions, functions, or material of a component after the release of the production design (Huang and Mak, 1999; Rouibah and Caskey, 2003; Huang et al., 2003). Other literature adds additional bounds on the scope of EC, defining the term as an alternation made to a part at any point from the embodiment design phase through to production that alters the form, fit and function or already-released drawings or software (Shankar et al., 2012; Shankar et al., 2017). Engineering changes may be made for reasons related to quality or product improvement, or to decrease costs (Knackstedt and Summers, 2017).

Engineering changes can be broken down into two categories: initiated changes and emergent changes (Eckert et al., 2004; Giffin et al., 2009; Jarratt et al. 2002). Initiated changes stem from a response to altered customer requirements or from internal innovations in design. Some of the driving factors of initiated changes from the outset of a product design include customer requirements, from general capability statistics to specific equipment; certification requirements, including government codes and environmental standards; innovations, in materials or in processes; and problems identified from past designs. Other factors that can introduce initiated changes even later into the product design process involve new customer requirements, such as changing operation environments or marketplaces; recent innovations, which are more common for products with a long design period; and retrofits, common for products with a long life cycle (Eckert et al., 2004). Emergent changes are caused in response to problems occurring during the design process, or from weaknesses identified in the product. The aforementioned problems could occur during the initial part design, as some changes cannot be predicted by CAD systems, or during testing, prototyping, and manufacturing phases. Additionally, problems occurring during the use of the product could cause emergent changes as issues are addressed (Eckert et al., 2004).

1.1.3 Manufacturing Changes

A manufacturing change (MC) can be defined as a modification to a factory system or any of its elements (Koch et al., 2016). These changes may include layout changes, resource reconfiguration, assembly process modifications, or revisions to assembly instructions (Koch et al., 2016). Other literature specifies factory changes as any addition, alteration, reconfiguration, substitution, or removal of spatial arrangements, relations, and properties of infrastructure, technology, or personnel (Bauer et al., 2017). Manufacturing changes also differ from the organizational changes that are typically discussed within the context of lean manufacturing, which instead describe the process through which an organization changes corporate requirements and the distributions of power, information, and skills to transition to a new state to increase their effectiveness (Nordin and Deros, 2017). Manufacturing changes are also distinct from the incremental improvements generated as part of lean manufacturing or Kaizen events. Incremental or continuous improvements maintain the fundamental nature of the established system, as opposed the fundamental alteration of the system nature caused by manufacturing changes (Hofer et al., 2020). Additionally, continuous improvements are characterized by their never-ending nature, as there is no end to making a process better (Singh and Singh, 2009), which differs from manufacturing changes, which have distinct beginnings and ends. The different types of manufacturing changes may seem disparate, but are all connected; changes that are badly managed early in the design process can cascade into each other and create new changes.

1.2 Change Propagation

Change propagation describes the trickle-down nature of change (Knackstedt et al., 2021) and is formally defined as the effects of changes to one design aspect that can spread to other design aspects (Shankar et al., 2017). Another definition for change propagation considers it the phenomenon by which one change sparks a series of other changes, typically studied by considering the linking parameters between the changes as the root cause of the spread (Shankar et al., 2012). As the strength of the linkage between change components increases, so does the possibility that a change to one component will cause a change to another part (Rouibah and Caskey, 2003). An additional nuance is explained in the oft-cited explanation of change propagation, which defines it as the process by which a change to one part of an existing design or system configuration results in additional changes to the system, when those changes would not otherwise have been required (Eckert et al., 2004; Giffin et al., 2009; Jarratt et al. 2002).

Further breakdown of the phenomenon includes the types of behaviour exhibited by components in response to a change, as well as the characterization of propagation types. When a change is introduced to a system or environment, components can act as constants, absorbers, multipliers, resistors, or reflectors. Propagation itself can be characterized as change ripples or change blossoms, if the changes finish on time differentiated by the size of the initial change effort, or as change avalanches, if the changes do not finish on time ((Eckert et al., 2004; Giffin et al., 2009; Jarratt et al. 2002).

One study looked extensively into the reasons for change propagation (Shankar et al., 2012). In the study, 77% of all changes were internal changes, with the remaining 23% considered external changes. Internal changes were found to be caused by document error corrections, cost reduction exercises, manufacturing issues, design corrections, and inventory issues. External changes largely stemmed from changes to the customer requirements. Further examination broke down changes into propagated and initiated changes. The propagated changes were discovered to come from inventory issues, design error rectification, and manufacturing difficulties (Shankar et al., 2012). Understanding change propagation is critical because it highlights the dependencies in a system, thus allowing for easier evaluation and quantification of change impacts (Giffin et al., 2009; Masmoudi et al., 2017). The assessed impact of a change can then be minimized using a targeted change management process (Masood et al., 2020). Because of the potential for adverse effects due to change propagation, individual changes are managed using dedicated practices.

1.3 Requirement Change Management

Requirement change management (RCM) refers to the approach to managing change propagation in requirement sets. The process through which this management is done varies; different researchers decompose the process into various stages of differing lengths. A comprehensive ten-step process was proposed (Hussain and Clear, 2012) that includes:

A. Identify the need for the change
B. Initiate a change request
C. Identify the approach (solution) for the requested change
D. Develop a revision (solution)
E. Assess the revision (solution) impact
F. Review and approve the revision (solution)
G. Issue the change order
H. Implement the change
I. Verify the assessed impact
J. Document the completed change

This proposed process was developed for use with software requirements, which are prone to frequent changes, as part of the larger field of global software development. Thus, the process is intended for use among distributed teams across multiple sites (Hussain and Clear, 2012).

Another process was proposed for use to manage the changing requirements characteristic of a software development project. It consisted of six stages: initiation of the change management process, reception of the change request, evaluation of the change request, approval (or disapproval) of the change request, implementation of the approved change request, and configuration of the change request (Bhatti et al., 2010). This process overlaps with the previous process, but focuses less on the development and assessment of the revision.

Another process model developed in the context of software development as part of the larger requirement engineering process defined stages of elicitation and analysis of requirements, documentation of requirements, verification and validation of requirements, and requirement management, which included traceability (Pandey et al., 2010). The model is iterative and is intended to support software engineers in avoiding changes if possible and managing the changes when necessary. It should be noted that this proposed model has not been explicitly validated or verified in practice.

Another process model was developed for use within agile software development, which encourages requirement change more than traditional software development. The agile development philosophy focuses on rapid, iterative change with the goal of providing immediate product delivery for stakeholder review (Fowler and Highsmith, 2001). This agile change management process included only three main stages: change identification, which was subdivided into change elicitation and change representation, change analysis, and cost/effort estimation (Albuquerque et al., 2020). Recent studies have explored applying the software centric agile philosophy to hardware design, but are still in the nascent stages for formal method deployment and integration (Ullman, 2019; Schmidt et al., 2017; Garzaniti et al., 2019).

Distributed software environments saw the development of another RCM process model for use in the field of global software development. The resulting ten-stage process model shared many stages with the exemplar process described above, but added stages for prioritizing requirements, resolving conflicts and maintaining history, and circulating the change to all concerned (Hafeez et al. 2012).

Finally, in a comparative literature review study of RCM processes used with software-intensive systems, 34 RCM activities were identified with varying frequencies across ten distinct process models. These activities could be grouped in such a way as to cover all ten stages of the exemplar process (Ramzan and Ikram, 2006). This topical clustering analysis does not explicitly include activity G (issue the change order) of (Hussain and Clear, 2012), illustrating that there are still gaps and differences between the models reviewed.

These six process models are summarized in Table 1.1 with respect to the ten steps for change management proposed by (Hussain and Clear, 2012).

Table 1.1: Comparison of RCM process models from literature

Source	**10 Process Steps**									
	A	B	C	D	E	F	G	H	I	J
(Pandey et al., 2010)	X		X	X			X		X	
(Bhatti et al., 2010)	X	X			X	X		X		
(Albuquerque et al., 2020)	X	X	X	X	X	X				
(Hussain and Clear; 2012)	X	X	X	X	X	X	X	X	X	X
(Ramzan and Ikram; 2006)	X	X	X	X	X	X		X	X	X
(Hafeez et al., 2012)	X	X	X	X	X	X	X	X	X	

From the comparison of the process models specified in the literature, it is clear that most RCM processes include the similar initial stages. All models included the first step, A (identifying the need for the change). All but one model included the second step, B (initiate a change request). The same model also did not include steps E and F. One model did not include steps C and D. Thus, for steps A-F, most models generally agree on the steps. The differences in the models lie for the last four steps. These steps would be considered deployment of the change, implementation, verification, and documentation. As these are requirement focused, the change to the requirement is documented within the requirement itself as a changed requirement. The dynamic aspect of requirements change and evolution may cause organizations to resist more formal requirement change documentation, as seen in a case study on requirements culture at a medical system development company (DelSpina et al., 2018) and also at a power tool company (Elena et al., 2019).

1.4 Manufacturing Change Management

A similar approach was used to explore manufacturing change management (MCM) process models. MCM is defined as a method for controlling and organizing the process of making manufacturing changes (Koch et al., 2016). The various processes prescribed in literature, of varying lengths and complexity, are summarized in Table 1.2.

Table 1.2: Comparison of MCM process models from literature

Source	**10 Process Steps**									
	A	B	C	D	E	F	G	H	I	J
(Ullah et al., 2016)	X	X	X		X	X		X		X
(Han et al., 2015)	X	X	X	X		X	X	X		
(Quintana et al., 2012)	X	X	X	X		X	X	X		X
(Dale, 1982)	X	X	X	X	X	X	X	X		
(Jarratt et al., 2002)	X	X	X		X	X	X	X		X
(Huang et al., 2003)	X	X			X	X		X		X
(Huang and Mak, 1999)	X	X				X	X			X

(Hamraz et al., 2013)		X	X		X	X		X		X
(Storbjerg et al., 2016)	X	X		X	X	X	X	X		

Engineering and manufacturing change management processes were largely studied interchangeably in the literature. One study, examining engineering process and product design changes in the context of a literature review, proposed a generic process model comprised of seven stages. The model begins with the change trigger and includes stages for raising an engineering change request, identifying potential solutions, conducting risk and impact assessments for the solutions, selecting and approving the solution, implementing the solution, and reviewing the overall change process. These stages were then grouped into three main phases: before approval, during approval, and after approval (Ullah et al., 2016).

A different process model was proposed for use with project-based manufacturing. This process model focused heavily on the documentation, consisting of engineering change requests and engineering change orders and the approval of each. Unlike some of the other MCM process models, however, this process specifically called out the rejection of an engineering change request, if not approved, and demonstrated a cyclical approach to revising the documents that fed into the engineering change order if it was not approved (Han et al., 2015).

In the context of a drawing-less environment focused on model-based definition, a five-stage process was defined. These stages included identifying the need, selecting the solution, approving the change intent, approving and releasing updated documents, and communicating modifications. While these stages seem similar to those in drawing-inclusive environments, intermediate steps see significant change. Between selecting the solution and approving the change, the new model-based definition process sees a decrease in work, but additional steps are required between approving the change and releasing approved and updated documents when compared to the traditional process (Quintana et al., 2012).

An older study considering engineering change procedures determined a 33-step process for the flow of data surrounding an engineering change. While some stages have since become obsolete with advances in technology, the process overall addresses each of the stages described in the exemplar process, except for verifying the assessed impact of the change (Dale, 1982).

A generic change process was extracted from engineering change literature. The comprehensive process consists of six stages: raising a change request, identifying possible solutions to the change request, conducting risk and impact assessments, selecting and approving the change solution, implementing the solution, and reviewing the overall change process. The process also includes multiple break points and opportunities for recursion (Jarratt et al., 2002). This same process was used as part of a larger literature review to create a holistic categorization framework for engineering change management literature (Hamraz et al., 2013).

Other research investigated the practice of engineering change management in the field by conducting interviews with practitioners. The interviews, conducted among engineers within manufacturing industries, revealed a focus on documentation. Specific documents were discussed for proposing a need for changes, evaluating the potential impacts of a change, and notifying others of an approved change (Huang et al., 2003).

A similar study was conducted using surveys to determine the engineering change process used in manufacturing industries. From the survey responses, fourteen activities were identified as part of the overall change management process, with significant mentions of four stages: proposing changes, approving changes, notifying changes, and recording changes (Huang and Mak, 1999).

An eleven-stage process model was developed as part of a study developing a maturity model for engineering change management. The eleven stages, which were categorized into change request, change solution, and change implementation phases, mapped fairly closely to those of the exemplar process explained above, with the exception of the identification of change solution, verification of assessed impact, and documentation of change stages, which were not included (Storbjerg et al., 2016).

From the comparison of these process models, it is evident that there is less consensus between researchers as to the specific stages that should be included in the MCM processes, as shown in Table 1.2. Additionally, a distinct gap was found in the process. Across all of the surveyed models, no mention was made of any stage dedicated to verifying the impact assessment after the change was implemented.

1.5 Comparison of Requirement and Manufacturing Change Management Models

The review of the literature revealed multiple distinctions between the RCM and MCM processes recommended and developed by researchers. RCM processes are largely comprehensive, with most of the examined processes addressing the change from initial identification, through implementation to the final post-implementation documentation. This is not the case with MCM processes. There is much less consensus between the MCM processes; many of the sources left out intermediate stages, such as identifying a solution or issuing a change order. Additionally, the review suggests that RCM processes are adhered to more closely than MCM processes and are implemented more formally. Thus, the actual implementation and practice of both RCM and MCM processes in the field must be studied to understand these differences. This motivates the second element of this study: an interview study of the change management activities found within requirement and manufacturing domains.

Chapter Two
RESEARCH STUDY DESIGN

To understand the current state of both RCM and MCM as practiced in the field, a case study was conducted. Case studies are useful for research as they allow for real-time observation of ongoing events that cannot be adequately replicated in a laboratory setting (Teegavarapu et al., 2008; Yin, 2017).

2.1 Case Studies

Case studies have often been used to explore different attributes of change management, as shown in Table 2.1.

Table 2.1: Change management research conducted via case studies

Reference	Domain	Research Tool	Research Focus	Location Studied	Retrospective or live?
(Knackstedt and Summers 2017)	Automotive (OEM)	Interviews and surveys	Perceived quality of part engineering change management process	Single US manufacturing location	Live
(Huang and Mak, 1999)	UK manufacturing industries	Surveys	ECM current practice (process activities, strategies, organization)	Industries across UK	Live
(Phelan et al., 2016)	Automotive OEM	Interviews	Processes and tools used to implement configuration management	Manufacturing locations in US and Germany	Live
(Shankar et al., 2012)	Automotive OEM	Document analysis of archival records and interviews	Reasons for engineering changes and change propagation	Manufacturing facility in central US	Live interviews, retrospective document analysis

(Oduguwa et al., 2006)	Automotive OEM and Tier 1 supplier	Questionnaires and interviews	Requirement change cost impact analysis	Industries in the UK	Live
(DelSpina et al., 2018)	Medical technology development	Interviews	Requirements culture surrounding requirement change	US-based medical development company	Live
(Huang et al., 2003)	Manufacturing industries in Hong Kong	Surveys	Scope of engineering change problem and current practice for engineering change management	Hong Kong manufacturing industries	Live

For example, Knackstedt and Summers (2017) conducted a case study to explore the process of part engineering change at an automotive OEM and to answer research questions focusing on issues with the change management process and the difference in those issues across departments. This study began with interviews, conducted as a starting point for investigation and to determine the actual change process in use across the company. The results of the interviews were then used to develop survey questions for distribution to a wider audience. From analysis of the survey results, it was determined that issues were present in the process in use and that there were statistically significant differences in these issues based on departmental and years of experience groupings.

Another case study was conducted by Huang and Mak (1999), studying the ECM practices in place in manufacturing industries across the United Kingdom. This study used a 16 question survey distributed across various industries to explore different aspects of the ECM process, including organization, activities involved, documentation, and responsibilities. Results of the survey, upon analysis, revealed general trends in the ECM process, such as the main stages of the process, as well as opportunities for improvement and future work.

Case studies have also been used to study configuration management, a process that involves assessing customer needs and developing variants but also managing variant configurations and the changes that accompany different configurations. In the case study, interviews were conducted within the Launch and Change Control division of the manufacturing company. From the study, the overall configuration change management process was determined, as well as the documentation process. Interviews revealed some of the challenges that practitioners faced, which were then used to propose support tools (Phelan et al. 2016).

Change propagation was also explored using the case study methodology. Shankar et al. (2012) used document analysis and focused interviews to determine both the reasons for ECs and the propagation of those changes. Document analysis revealed that the majority of ECs were initiated internally, and were related to document error corrections. Based on the interview findings, changes were categorized as either genesis changes or propagated changes, and the linkages between changes were recorded in a change interaction matrix.

Oduguwa et al. (2006) used a case study, comprised of questionnaires and interviews, to understand the current practice of requirement change and corresponding cost impact analysis as used in the automotive industry. The researchers were then able to construct a cost impact analysis methodology that would fit within the existing practice and demonstrate its use in a targeted example.

Another case study was conducted by DelSpina et al. (2018), concerning the culture surrounding requirements and requirement change. This was done by conducting interviews within a medical technology firm. Interviews revealed three reasons for requirement changes: changes in requirement leadership, changes in regulatory scope, and the firm's learning curve with regards to requirement generation and testing. In addition, analysis of the interview findings revealed that a requirements culture was in place at the studied firm, which did influence the reasons for requirement change.

An additional case study was conducted by Huang et al. (2003), which examined engineering change management as practiced by Hong Kong manufacturing facilities. Their study used a survey instrument to determine both the current state and issues with ECs and the current process for ECM. Survey findings regarding the current state of ECs included aspects such as the volume, sources, and effects of ECs. With regards to ECM current practice, the survey explored areas including documentation, process activities, and organizational structure.

2.2 Interview Instrument

In this study, a series of interviews with various practitioners of the two change management methods were used to extract the practiced activities, building from the work done by Sutton and Summers (2021). The constituent interviews were conducted in a semi-structured format, which allowed for the preservation of information flow through flexible ordering of questions, through video-conferencing software, such as Zoom and Microsoft Teams. This was critical as the interviews were conducted from 2019-2021, a period of time including the COVID pandemic which limited direct contact with individuals. Eleven individuals were interviewed regarding RCM, while four were selected for MCM interviews. Further information about the case study protocol can be found in Table 2.2. Two sets of interview questions were developed, one for RCM and the other for MCM.

Table 2.2: Details of Interview Protocol

Topic	RCM Study	MCM Study
Purpose of research study	Understanding	Understanding
Purpose of interview	Core	Core
Context of study	Automotive	Automotive/healthcare
Organization studied	Design	Quality and manufacturing
Relationship between interviewee and interviewer	No prior relationship	No prior relationship
Interviewer type	Individual	Individual
Interview location	Video conferencing	Video conferencing
Interview type	Semi-structured	Semi-structured
Number of interviews	9	3
Duration	~60 minutes	~30 minutes

2.2.1 RCM Questions

The RCM interview questions were developed based on the process models from the literature, shown in Section 1.3. Questions regarding requirement elicitation and development were also included, since RC can entail the addition of new requirements as well as modification and deletion of extant requirements. Additionally, questions were added that asked about any limitations or areas for improvement in the current processes, or that proposed hypothetical additions to the process for the interviewees to evaluate. The resulting interview question set can be seen in Table 2.3.

Table 2.3: RCM-focused question set for interviews

Q #	Question	Purpose
1	What is your job title? What department do you work with?	Background
2	What is your role, especially with regards to new projects?	
3	How long have you been in this role?	
4	How do you interact with requirements in this position?	

5	How often do you interact with requirements in this position?	
6	How do you define “requirements?”	
7	What is the source of your requirement definition?	
8	How do you develop requirements?	Requirement development
9	Who is involved in requirement creation?	
10	How do you write requirements? Do you write them in plain text, or do you identify specific elements and construct them?	
11	When do you review created requirements?	Requirement review
12	Who is involved in the requirement review?	
13	How is feedback from the review captured and communicated?	
14	How are lessons learned in requirement generation captured?	
15	How are requirement changes managed?	Requirement changes
16	What sort of documents or tools are used to manage requirement changes?	
17	What is an example of a requirement change?	
18	How do you determine what type of change has occurred?	
19	How are requirements written?	Requirement writing and tools
20	How are people trained to write requirements?	
21	Are there any tools or other systems that you use to automate or guide the requirement generation process?	
22	What tools did you use as part of the process when you were starting out? What tools do you use now?	
23	How are requirements related to other requirements?	Requirement networks
24	If you had a network of requirements, would you use it to make predictions on requirement evolution?	
25	If you had a requirement network, would you use it to determine potential conflicts between requirements?	
26	Once a change is made to a requirement, how do you justify the change? How do you make sure that the change can be undone?	Requirement changes

The question set was then reviewed to ensure that the data would provide adequate coverage of the subject area, through the use of data triangulation. Data triangulation refers to the use of multiple data sources or collection methods to develop a comprehensive understanding of the overall data, and is a key component of qualitative research necessary to establish validity (Carter et al., 2014; Guion et al., 2011). The triangulation matrix that displays the overlap and connections between the current-process questions is shown in

Table 2.4. This matrix is symmetrical apart from the total column, meaning that a pair of related questions are equally related to each other. The matrix was constructed manually by the interviewer, with no outside input or inter-rater checks. However, this is sufficient since the purpose of the triangulation matrix is to demonstrate the coverage given by the question set, thus serving as a verification criterion (LeDain et al., 2013). This coverage is demonstrated by the green-colored cells in the table, which represent overlaps and interactions between a pair of questions. These relationships are summarized in the Total column at the far right, which shows the total number of questions that align or overlap in a given row. At least one overlap is needed to demonstrate triangulation and increase confidence in the findings gleaned from the question set. The triangulation between hypothetical questions is not shown, as these were largely intended to provoke thought and greater consideration for requirement elicitation and requirement management systems.

Table 2.4: Triangulation matrix for RCM interview questions

Q #	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**Total**
1																											2
2																											3
3																											3
4																											1
5																											1
6																											1
7																											3
8																											4
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21																											2
22																											1
23																											2
24																											2
25																											2
26																											2

In addition to the questions discussing the current requirement process, shown in Table 2.3, a set of hypothetical questions was developed to encourage interviewees to further consider the potential limitations and needs within the extant processes. These questions asked specifics about aspects of the process that could cause potential issues, and also posed potential solutions to encourage interviewees to consider the problems those solutions could solve. These hypothetical questions are shown in Table 2.5.

Table 2.5: Hypothetical questions used to provoke discussion in RCM interviews

Q#	Question
27	Are there any problems with standardization between departments?
28	How many requirements do you have per project, on average?
29	What information is most important to capture in a requirement (subject, value, scope)?
30	Do you have any problems with requirement redundancy?
31	If you had a search feature for requirements, what would you like to search for and organize requirements by?
32	Would it be useful to have a method for visualizing requirements - graph based (links for relationships), clusters of requirements?
33	Are most requirements separate in nature or are they coupled/related to the same topic?
34	Would auto recognition of free typed requirements be useful for requirement quality/training?
35	Is there a database of requirement documents from past vehicles/projects?

36	What format are requirements typically shared?
37	In a requirements app what you like to use or see?
38	Would it be useful to know if requirements conflict (within a document or set of requirements)?

2.2.2 MCM Questions

The MCM question set was developed with inspiration for the questions drawn from the process models in literature explained in Section 1.4. The question set was then reviewed to ensure that the data would provide adequate coverage of the subject area, through the use of data triangulation. The MCM-focused question set is shown in Table 2.6. In the questions, the term "engineering change" was used, as most practitioners used the term to refer to both engineering changes and manufacturing changes and used the change's relationship to production to distinguish between the two change types.

Table 2.6: MCM-focused question set for interviews

Q #	Questions
1.	What is your role in the engineering change (EC) process?
2.	What has been your experience with the EC process?
3.	What does the EC process look like from your experience? Who is involved?
4.	How is a needed change identified?
5.	Who gives input on a change solution? Which departments are included in the discussion?
6.	Who is involved in the review and approval process?
7.	How quickly is the solution implemented?
8.	When is the solution and implementation documented? Is a schedule used, or just whenever the time arises?
9.	What sort of methods or tools are you using to aid in the EC process?
10.	What does "normal" look like for your process? After a change is implemented, how long does it take before the process goes back to normal?
11.	How long do you monitor new changes?
12.	How long do you worry about new changes?
13.	How often do you have to go and fix things after implementing new changes? Who is involved in fixing these things?
14.	How is root cause analysis connected to EC? How often does root cause analysis reveal an issue is because of an EC?

15.	What sort of verification and validation methods do you use?
16.	Is there a formal EC process defined for your company? Is there a flowchart that depicts the process?
17.	For an average-size change, how long does the change management process take from start to finish?

The accompanying triangulation matrix, demonstrating how the various questions relate to and validate each other, is shown in Table 2.7. This matrix is symmetric, except for the Total column, meaning that a pair of related questions can be considered to have a bidirectional relationship. The matrix was manually constructed by the interviewer and no inter-rater checks were conducted; however, this was considered to be sufficient since the purpose of the triangulation matrix was merely to demonstrate the coverage given by the question set. This coverage is summarized by the Total column, which demonstrates the total number of questions that overlap or align in a given row.

Table 2.7: Triangulation Matrix for MCM Interview Questions

Q#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total
1																		2
2																		1
3																		6
4																		1
5																		2
6																		2
7																		3
8																		1
9																		2
10																		2
11																		1
12																		1
13																		2
14																		2
15																		1
16																		1
17																		2

2.2.3 Interview Participants

RCM and MCM practitioners were initially elicited from professional networks; the first interviewees were then asked to identify other potential participants as part of the "snowball sampling" method. RCM practitioners represented the automotive industry and presented a design-focused perspective. RCM interviewees were clustered into three distinct groups based on project involvement. One group involved faculty and students involved in a graduate-level automotive prototyping project (Qattawi et al., 2014; Paul and Mau, 2011; Namouz et al., 2011), another group involved engineering design faculty from various universities, while the final group included military vehicle designers and project leaders. MCM practitioners included both automotive and healthcare industrial sectors from quality and manufacturing departments.

Details for the RCM focused interviewees are found in Table 2.8. These are drawn from three academic and military populations. The roles of the individual are defined. For anonymity, fictitious names are assigned to each interviewee. Those with names starting with "C" are from the graduate-level prototyping project, including faculty sponsors responsible for supervising student progress and the student designers actually conducting the design, while those with names starting with "G" are from the military vehicle design group. Those with names beginning with "D" are design faculty, who have taught undergraduate-level design or design research courses and represent four different universities. All names are single-gender, assigned to prevent identification and bias in analysis.

Table 2.8: Details of RCM Interviewees

Name	Production Volume	Industry	Role
Charlotte	Low	Academic	Faculty Sponsor
Carmen	Low	Academic	Faculty Sponsor
Catherine	Low	Academic	Faculty Sponsor
Claire	Low	Academic	Student Designer
Carol	Low	Academic	Student Designer
Candace	Low	Academic	Student Designer
Colleen	Low	Academic	Student Designer
Gwen	Medium	Military	Requirements Engineer
Georgia	Medium	Military	Chief Scientist
Greta	Medium	Military	Requirements Engineer
Grace	Medium	Military	Requirements Engineer
Daisy	None	Academic	Design Faculty
Daphne	None	Academic	Design Faculty
Delilah	None	Academic	Design Faculty
Diana	None	Academic	Design Faculty

Similarly, the details of the four interviewees from manufacturing change organizations are found in Table 2.9. Each of these are from a different company; three are from the automotive industry and one from health care. The participants represent different departments at their respective companies. The companies are different sizes and produce products of various complexities. This is used to illustrate the breadth of the surveyed population.

Table 2.9: Details of MCM Interviewees

Name	Firm Size	Product Complexity	Industry	Department
Lucy	Large	Medium	Automotive (Tier 1 Supplier)	Quality
Susan	Medium	Medium	Healthcare	Quality
Jill	Large	High	Automotive (OEM)	Manufacturing
Helen	Medium	Low	Automotive (Tier 1 Supplier)	Change Management

At each interview, handwritten notes were taken along with audio recordings when available or allowed by the interviewee's organization. The audio recordings were used to generate transcripts, which were reviewed alongside the written notes and used to develop summaries for each interview. The summaries included key points from the interview as well as process flow models, similar to that shown in Figure 3.1. The summaries were then sent to the interviewees for review and approval.

Chapter Three
EXPLANATION OF PROCESS MODELS

From each of the fifteen RCM interviews, a distinct process model was developed. Participant responses were mapped to the ten stages (Table 1.1) and were coded as either an explicit mention, implicit mention, or no mention. An explicit mention of a process stage meant that the interviewed individual specifically discussed part or all of the stage by name. An example of an explicit mention occurred when Carmen said "…the students wanted to change a target. They had to propose that at the design review and the company had to agree to it." This explicitly referred to both reviewing and approving the revision steps.

An implicit mention meant that the individual may have discussed the stage as part of another stage, or in a way that was not immediately apparent to be a distinct stage but was later revealed with analysis. This was shown when Charlotte said "the students discuss something and they come up with a solution for the issue that they were struggling with. And the solution is, of course, to change one of the requirements." By this, Charlotte implies that there is an "identify need" activity associated with requirement change.

The three types of mentions (explicit, implicit, none) were denoted using a blue-yellow-red color scheme, in which blue represents an explicit mention, yellow an implicit mention, and red no mention. This color scheme is shown in the example process model in Figure 3.1 for the interview with Georgia. In the interview she explicitly discussed five of the stages (A, C, D, F, and H), did not mention four of the stages (B, G, I, and J), and implied or suggested an activity on one stage (E). Separate models were generated for each of the interviewees.

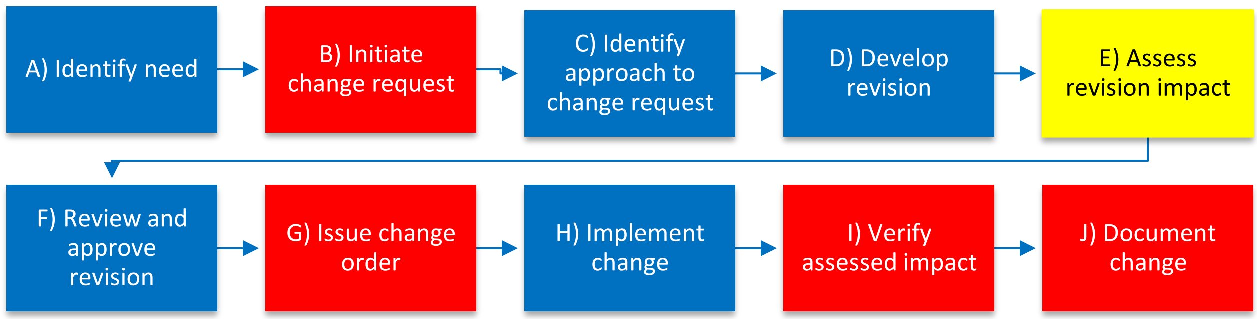

Figure 3.1: Georgia's process model showing color coding for explicit (blue) and implicit (yellow) mentions as well as no mention (red).

3.1 RCM Process Models

The first interview, conducted with Charlotte, yielded the process model shown in Figure 3.2. In it, one stage was explicitly mentioned, four stages were implicitly mentioned, and five stages were not mentioned. The only stage she explicitly named as part of the process was implementation of the change. The inclusion of other aspects of the RCM process were hinted at, such as the identification of a need and the approach to the change request, the development of a revision, and the review and approval of that revision.

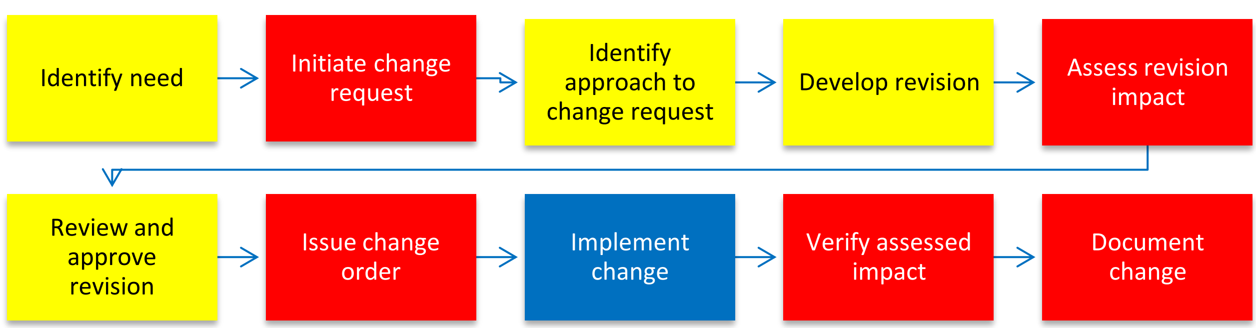

Figure 3.2: Charlotte's RCM process model

The interview with Carmen, another faculty sponsor on the design project, revealed a different understanding of the RCM process, shown in Figure 3.3. Her process model included five explicitly mentioned stages, two implicitly mentioned stages, and three stages that were not mentioned. Like Charlotte, Carmen explicitly mentioned the implementation of a change and implied that identifying the need for a change and developing the revision were part of the process as well. However, Carmen explicitly mentioned some stages, such as the identification of the approach to the change request and the review and approval of the revision, as part of the process, where Charlotte only implicitly mentioned them. Carmen also identified two additional stages as part of the process that had not been mentioned at all by Charlotte: initiating a change request and documenting the change. This indicates a difference in approach that more strongly emphasized formal documentation.

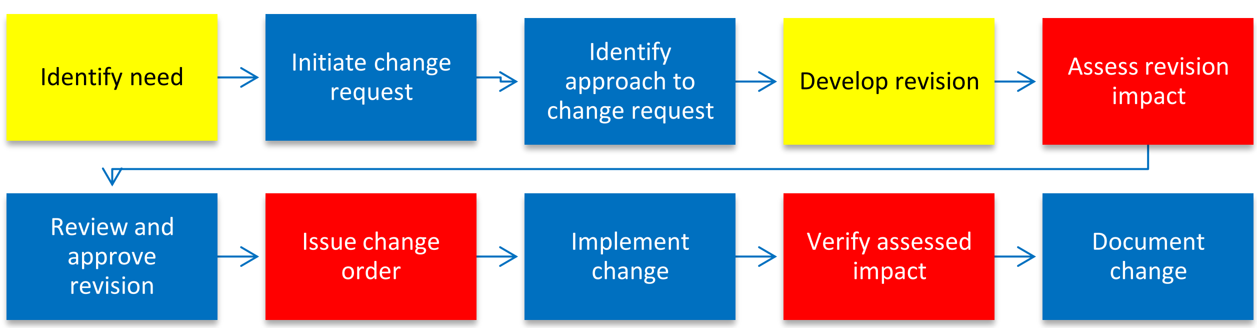

Figure 3.3: Carmen's RCM process model

Catherine's process model, shown in Figure 3.4, demonstrated another faculty approach to RCM, one more closely aligned with Charlotte's than Carmen's process model. Catherine explicitly mentioned two process stages: reviewing and approving the revision and implementing the change. She also alluded to the inclusion of four other stages: identifying the need for a change, identifying the approach to a change request, developing the revision, and assessing the impact of the revision. Like Charlotte, Catherine did not mention the stages of initiating a change request, issuing a change order, verifying the assessed impact of a change, or documenting the change after implementation.

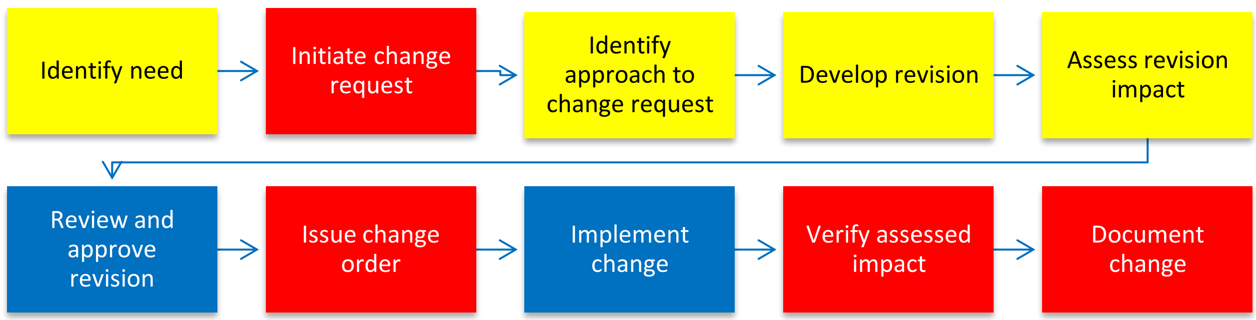

Figure 3.4: Catherine's RCM process model

The RCM process model generated from the interview with Claire, in Figure 3.5, presents one of the student perspectives on the process, and aligns with the model sourced from Charlotte. Only a single stage was explicitly mentioned in the course of the interview, that of actually implementing the change. Other stages in the process were implied, but were not explicitly mentioned as necessary or common actions, including the identification of a need or the approach to a change request, the development of a revision, and the review and approval of that revision. No mention was made of any formal documentation stages, such as the initiation of a change request, issuance of a change order, or documentation after change implementation. Additionally, Claire did not mention any consideration of the impact of a revision, either before or after change implementation.

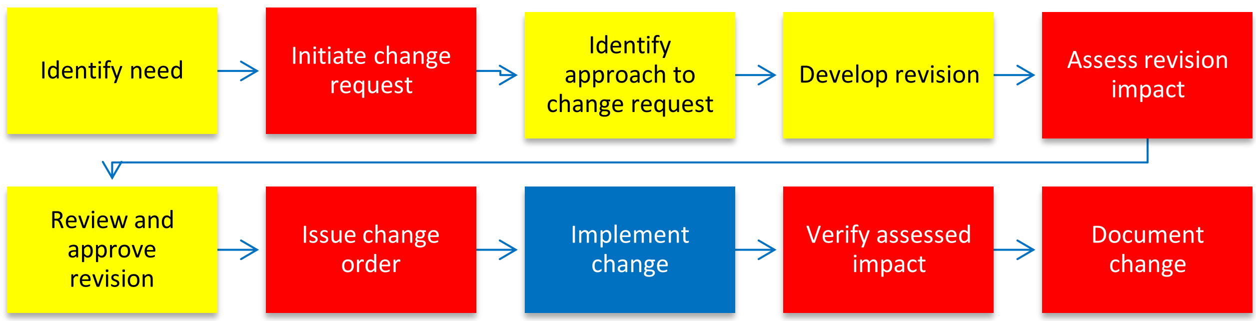

Figure 3.5: Claire's RCM process model

Carol's RCM process model, shown in Figure 3.6, was largely similar to Claire's model, with only a few changes between the two. Carol only explicitly mentioned change implementation as a stage of the process, but implied that need identification, change request initiation, identification of the approach to the change request, and development of the revision were at least considered as part of the early stages of the process. She also mentioned attempts to review and document changes that were occasionally part of the RCM process. With regards to the revision impact, Carol mentioned a specific example that illustrated the need for the impact of a revision to be considered, but noted that such stages were not in place in the overall process. The similarity between Carol and Claire's RCM process models is expected, as both were co-located students working on the same project, with the same initial instruction regarding the process.

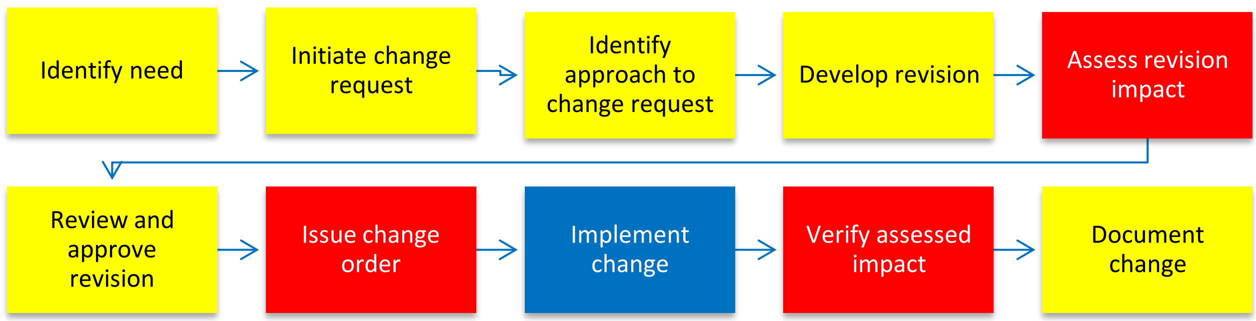

Figure 3.6: Carol's RCM process model

The RCM process model generated from the interview with Candace, shown in Figure 3.7, differed from the previous two student-sourced process models. This difference was expected, since Candace was a member of a different project and thus had access to alternate resources and instruction and subsequently may have developed a different process. In the interview, she explicitly identified three stages: assessing the revision impact, implementing the change, and documenting the change. Other stages that she implied were part of the process included identification of the need and the corresponding approach to the change request, development of the revision, and the review and approval of the chosen revision. Candace did not mention more formal documentation stages such as the initiation of a change request or the issuance of a change order, nor did she mention any post-implementation verification of the impact assessment.

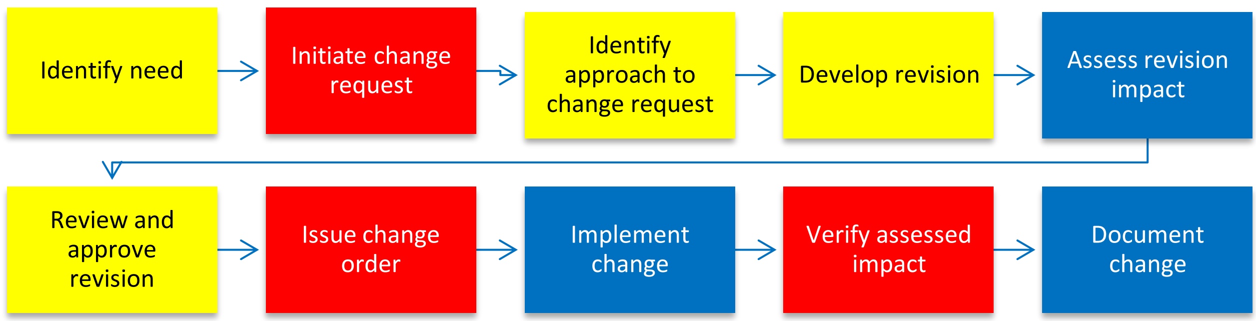

Figure 3.7: Candace's RCM process model

Colleen's RCM process model, in Figure 3.8, included similar stages to those specified by Candace. Colleen explicitly mentioned the review and approval of a revision and the implementation of the change, and alluded to the inclusion of need identification, change request approach identification, revision development, and change documentation stages as part of the overall process. She did not, however, mention any of the formal documentation steps, such as change request initiation and change order issuance, nor did she address the impact of the change, either before or after implementation.

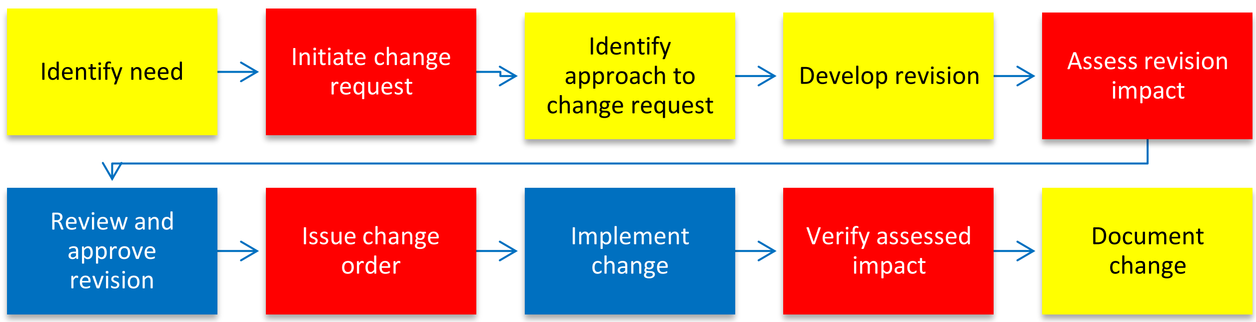

Figure 3.8: Colleen's RCM process model

Significant differences were found between the academic and military-sourced process models. For example, Gwen's RCM process model, shown in Figure 3.9, included eight explicitly mentioned stages, compared with the average of three explicitly mentioned stages from the academic process models. The only stages that Gwen did not mention were the initiation of the change request and the post-implementation verification of the assessed impact.

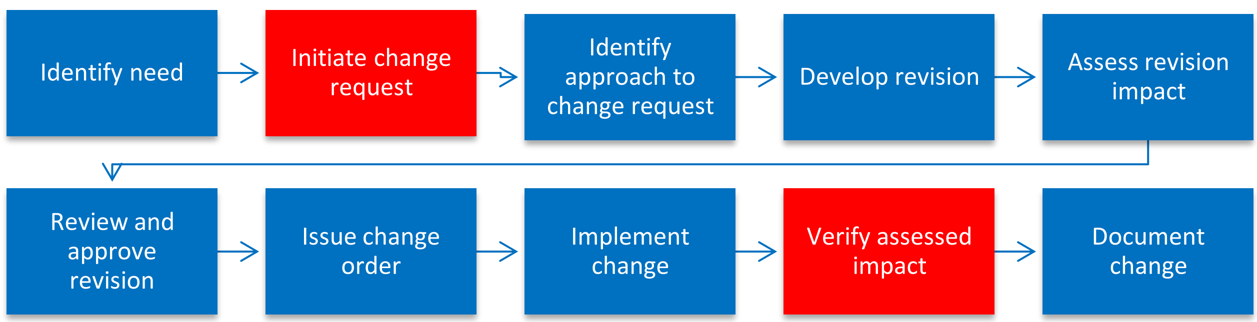

Figure 3.9: Gwen's RCM process model

Georgia's process model, shown in Figure 3.10, was fairly similar to Gwen's. In the interview, she explicitly identified five stages as part of the process: identification of need and the approach to the change request, development of the revision, review and approval of the revision, and implementation of the change. She also implied that the assessment of the revision's impact was part of the process. Gwen did not, however, mention documentation-related stages, such as initiation of a change request, issuance of a change order, or documentation of the change after implementation, nor did she mention verifying the initial impact assessment after the change was implemented.

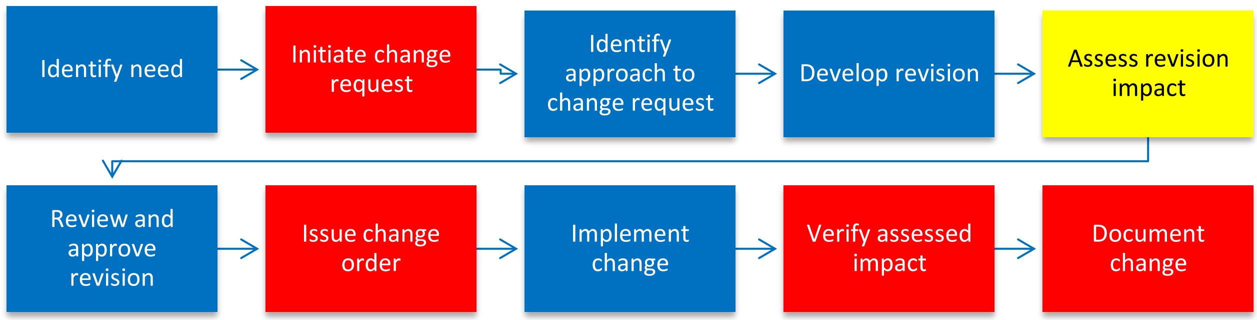

Figure 3.10: Georgia's RCM process model

The process model elicited from the interview with Greta and shown in Figure 3.11 very closely aligned with Georgia's process model. Greta explicitly mentioned five stages of the process: identification of the need, identification of the approach to the change request, review and approval of the revision, and implementation and documentation of the change. Greta also implied that developing the revision and assessing the impact were part of the process, but did not explicitly discuss the inclusion of the stages in the process.

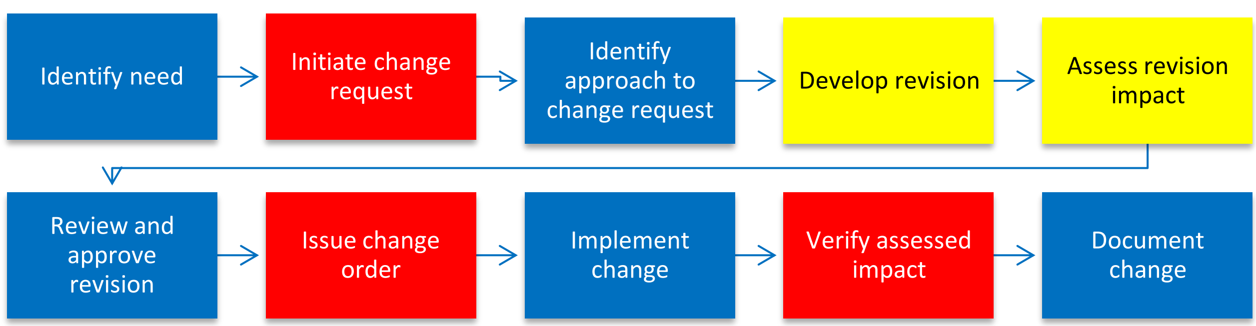

Figure 3.11: Greta's RCM process model

Grace's RCM process, in Figure 3.12, also closely aligned with the processes generated by Greta and Georgia. Grace explicitly noted all of the same process stages as Greta. In addition, she implied that developing the revision, assessing the impact of the revision, and issuing a change order were also steps of the process. She did not mention the initiation of a formal change request, nor the verification of any impact assessments after the change was implemented.

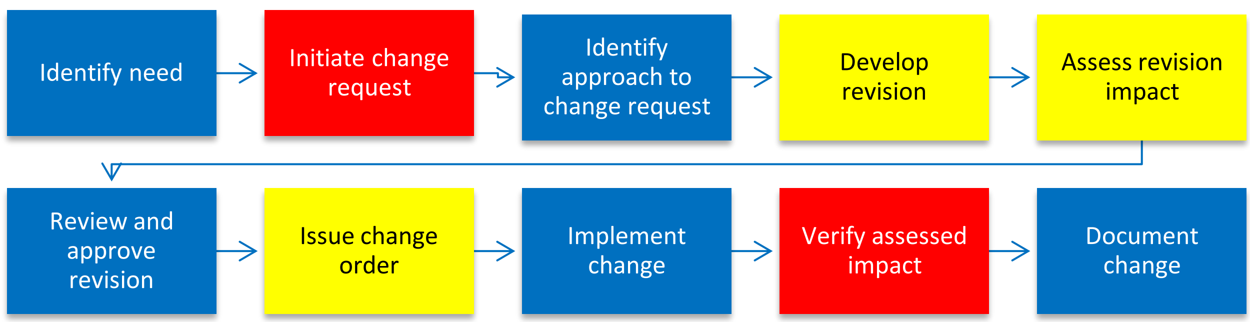

Figure 3.12: Grace's RCM process model

Daisy's RCM process model, which is shown in Figure 3.13, reflected the methods used by the students she taught and only included one explicitly-mentioned stage: change implementation. She also implied that four other stages were included in the process, including the identification of a need and the approach to the change request, development of a revision, and review and approval of the revision. This brief process matches that described by Charlotte, as both process models included the same singular explicit stage and four additional implicit stages.

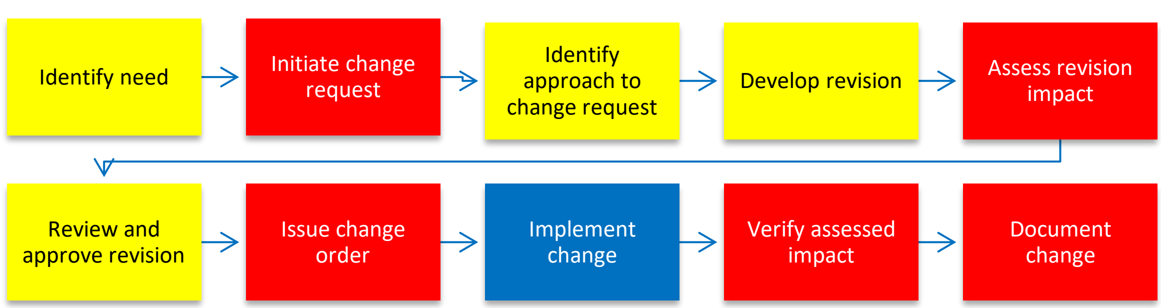

Figure 3.13: Daisy's RCM process model

The process model in Figure 3.14, elicited from the interview with Daphne, was the shortest RCM process yet discussed. The implementation of a change was the only explicitly mentioned stage in the process, but three others were implied to be considered part of the process: identification of a need, development of a revision, and review and approval of the revision. Daphne's process model, which includes no documentation or assessment stages as seen in the process models from the military, instead closely aligns with Daisy and Charlotte's process models. This is to be expected, as all three models were created by faculty describing the processes used by the students they instruct over the course of relatively short-term projects.

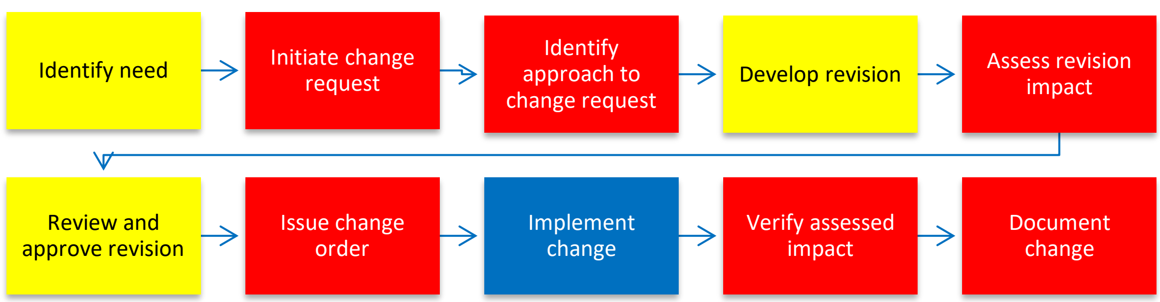

Figure 3.14: Daphne's RCM process model

The interview with Delilah yielded an even simpler three-stage RCM process, shown in Figure 3.15. Delilah only explicitly mentioned the inclusion of one process stage: change implementation. She also implied that her students identified the need for a change and developed the revision before implementing the change, but did not discuss any other stages such as impact assessment, review and approval of the change, or change documentation. Despite the brevity of Delilah's specified process model, it does align closely with that specified by Daphne, which is expected due to the similar short-term and low-continuity nature of the projects the RCM processes are used for.

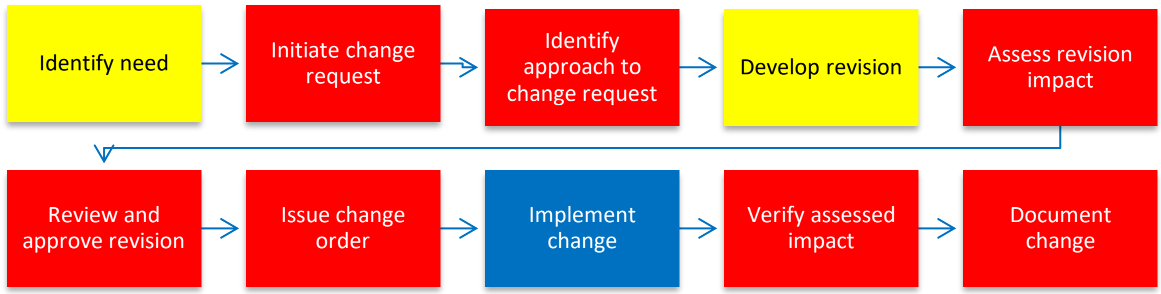

Figure 3.15: Delilah's RCM process model

Diana’s RCM process model included four stages, which are shown in Figure 3.16. The only explicitly included stage in her process was change implementation, but she also implied that need identification, revision development, and revision review and approval were also included. She did not mention any stages relating to impact assessment or change documentation. Diana’s process model matches Daphne’s, but also closely aligns with the process models created by the other design faculty.

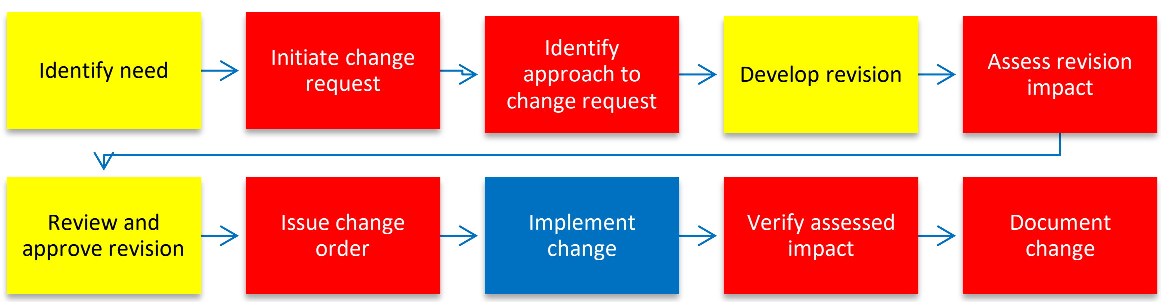

Figure 3.16: Diana's RCM process model

The process models for all participants were then compiled for easier comparison and analysis of trends, as shown in Table 3.1.

Table 3.1: Summary of RCM process models

Interviewee	Identify need	Initiate change request	Identify approach to change request	Develop revision	Assess revision impact	Review and approve revision	Issue change order	Implement change	Verify assessed impact	Document change
Charlotte	I		I	I		I		E		
Carmen	I	E	E	I		E		E		E
Catherine	I		I	I	I	E		E		
Claire	I		I	I		I		E		
Carol	I	I	I	I		I		E		I
Candace	I		I	I	E	I		E		E
Colleen	I		I	I		E		E		I
Gwen	E		E	E	E	E	E	E		E
Georgia	E		E	E	I	E		E		
Greta	E		E	I	I	E		E		E
Grace	E		E	I	I	E	I	E		E
Daisy	I		I	I		I		E		
Daphne	I			I		I		E		
Delilah	I			I				E		
Diana	I			I		I		E		
TOTAL I	11	1	7	13	4	7	1	0	0	2
TOTAL E	4	1	5	2	2	7	1	15	0	5
TOTAL(E+I)	**15**	**2**	**12**	**15**	**6**	**14**	**2**	**15**	**0**	**7**

From the summary table, major trends can be determined from the columns and rows of interest. For instance, three stages were mentioned by all 15 interviewees: identification of the need, development of the revision and implementation of the change.

Identification of the need and development of the revision were predominantly implied to be included in the process, while the implementation of the change was the only stage explicitly discussed by all interviewees. Other stages were more uncommon: initiation of the change request and issuing change orders both were only mentioned by two out of the fifteen interviewees. One stage was not mentioned, either explicitly or implicitly, by any interviewees: verification of the assessed impact.

Consideration of the rows of interest in the table reveals another trend in the relative completeness of the process models. Design faculty, from Daisy to Diana, presented the shortest RCM processes; in addition, the process stages that were mentioned were predominantly implied. The student designers, including Claire through Colleen, discussed slightly more complete processes that included more stages and had some explicit mentions of stages, demonstrating increased understanding and ownership of the process. Process completeness and ownership increased again with the faculty sponsor group, which included Charlotte, Carmen, and Catherine. Their RCM processes included yet more additional stages and explicit mentions of those stages. The most complete process models were presented by the military designers, including Gwen through Grace. They discussed the majority of stages in the process model, and mentioned these stages explicitly, demonstrating a clear understanding and strong ownership of the process.

3.2 MCM Process Models

A similar approach is used for the four interviews for the manufacturing change management processes. Process models were constructed based on the discussion in the interviews, and each process stage was color-coded to correspond to the way it was mentioned by the interviewee. A blue-colored box denotes an explicit mention of a process stage, yellow denotes an implicit mention, and red shows that the process stage was not mentioned at all in the interview.

Lucy's MCM process model, shown in Figure 3.17, includes five stages that were explicitly mentioned in the interview, including the identification of a need, initiation of a change request, review and approval of a revision, issuance of a change order, and implementation of a change. She also implied that three additional stages were considered to some degree as part of the process: identification of the approach to the change request, development of the revision, and assessment of the revision impact. While her process model covers all of the stages prior to change implementation, she did not mention any stages after the implementation as being part of the process.

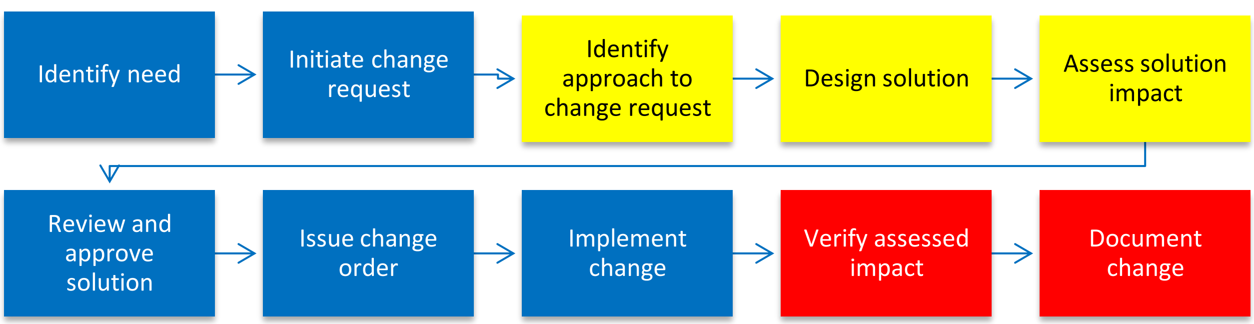

Figure 3.17: Lucy's MCM process model

Susan's process model, found in Figure 3.18, included six stages that were explicitly mentioned, including the identification of a need, development of a revision, assessment of that revision's impact, review and approval of the revision, implementation of the change, and post-implementation documentation of the change. She did not imply that any other stages were included; thus, the initiation of the change request, identification of the approach to the change request, issuance of the change order, and verification of the assessed impact were not considered part of the MCM process. Susan's process model therefore differed from that described by Lucy. Susan included fewer overall steps in her process, but did include post-implementation change documentation.

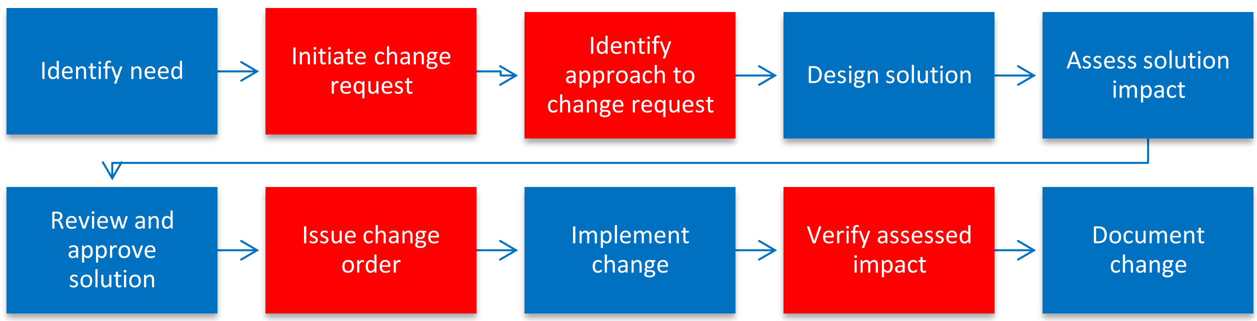

Figure 3.18: Susan's MCM process model

The process model elicited from the interview with Jill and found in Figure 3.19 was more complete than either of the two previous process models. It included eight stages that she explicitly mentioned; the only stages that she did not mention were the identification of the approach to the change request, and the verification of the assessed impact after the change was implemented. This more complex process was expected, as Jill worked for the company with the highest degree of complexity in their products and the more detailed process was required to adequately manage changes to such products.

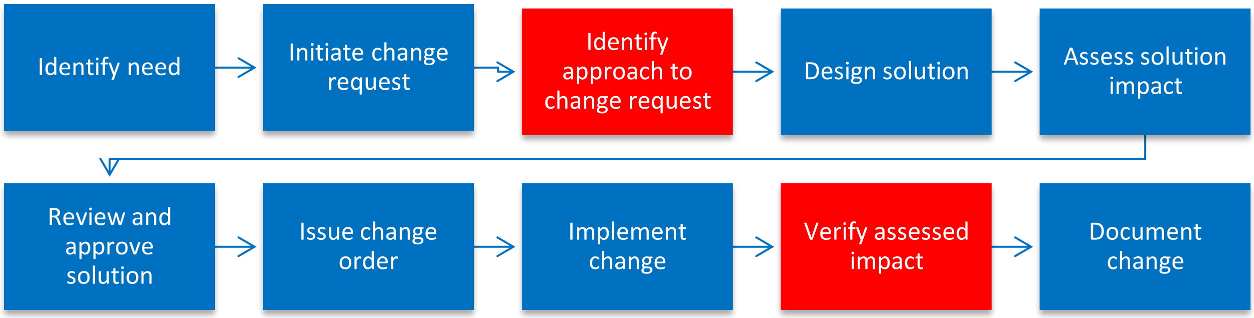

Figure 3.19: Jill's MCM process model

Helen's MCM process model, shown in Figure 3.20, was the most complete out of the four. She explicitly mentioned eight stages, and implied that another, the identification of the approach to the change request, was part of the process as well. The only stage that she did not mention was the post-implementation verification of the change impact. The completeness of her process was expected, as Helen served as a change management engineer at her firm, directly interacting with and implementing the process, as compared to other interviewees, who had more limited hands-on experience with the MCM processes.

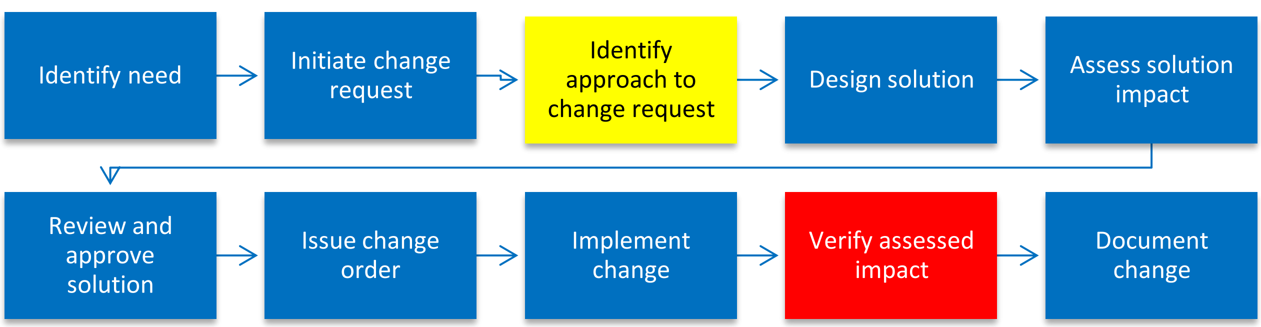

Figure 3.20: Helen's MCM process model

Table 3.2 presents the combined process models generated from the MCM interviews. The interviews revealed that most of the identified stages were common across the interviewed practitioners, with the exception of the identifying solutions to change request stage, which was only implicitly mentioned by two interviewees. None of the interviewed practitioners identified verifying the assessed impact as part of their MCM process. In addition, while most of the process models were fairly similar, Helen had the most complete process, including one additional stage. This was expected, as Helen represented the change management perspective at her company and thus may have had greater understanding of the MCM process due to the extent of her experience with the process, as opposed to the other MCM interviewees, who interacted with the process more infrequently than Helen.

Table 3.2: Summary of MCM process models

Interviewee	Identify need	Initiate change request	Identify approach to change request	Design solution	Assess solution impact	Review and approve solution	Issue change order	Implement change	Verify assessed impact	Document change
Lucy	E	E	I	I	I	E	E	E		
Susan	E			E	E	E		E		E
Jill	E	E		E	E	E	E	E		E
Helen	E	E	I	E	E	E	E	E		E
Total I	0	0	2	1	1	0	0	0	0	0
Total E	4	3	0	3	3	4	3	4	0	3
TOTAL (I+E)	4	3	2	4	4	4	3	4	0	3

In comparing the overall process models shown in Table 3.1 and Table 3.2, two trends are evident. The stage dedicated to verifying the assessed impact after change implementation was never mentioned for either RCM or MCM. This contradicts the process models discussed in the literature (Table 1.1 and Table 1.2). Additionally, the MCM process was shown to have a greater emphasis on stages devoted to formal documentation, such as the initiation of a change request, assessment of the solution impact, and issuance of a change order, than RCM processes.

Chapter Four
THEMATIC ANALYSIS

In addition to the process model comparison, thematic analysis was conducted on the interview data, in accordance with the methodology discussed in (Maguire and Delahunt, 2017; Cassell et al., 2005; Evans and Lewis, 2018; Bree and Gallagher, 2016; Judger, 2016). Thematic analysis refers to the process by which patterns and themes are identified in qualitative data (Evans and Lewis, 2018). A theme captures an aspect of the data and represents a typically recurring pattern or trend; however, the frequency with which the theme appears in the data set does not inherently indicate the relative importance of the theme (Evans and Lewis, 2018). Interview data, which included handwritten notes and generated transcripts when available, was combed through in detail to identify key quotes and phrases. These quotes from the interviews were then assigned codes. The codes and the associated speakers were recorded in a Microsoft Excel spreadsheet, and were color-coded and grouped to form initial themes, per the approach specified by Bree and Gallagher (2016). An inductive approach was used in which no themes were predetermined before the analysis process began, thus allowing the analysis to be driven by the data rather than forcing the data to conform to a pre-determined coding scheme. These themes were then revised and refined into overarching themes and more detailed subthemes. Connections between the resulting themes and subthemes were explored and recorded in a thematic map, per the approach of Maguire and Delahunt (2017).

The themes identified from the RCM interview data are shown in the map in **Error! Reference source not found.**. Three main themes are identified – requirement generation, requirement management, and issues with the current approach – with an additional eight subthemes. The interviewee groups that addressed these subthemes are illustrated by color tags: yellow designates faculty sponsors and design faculty, red designates military designers, and green denotes student designers. Both the faculty sponsors and design faculty focused on teaching primarily, with the faculty sponsors additionally concentrating on high-level project management. Thus, the topics of requirement writing, requirement management, and more general information management are of more importance than discussion on the challenges with the current approach. Conversely, the student interviewees seem to be most interested and focused on the challenges of the current approach with little focus on documentation.

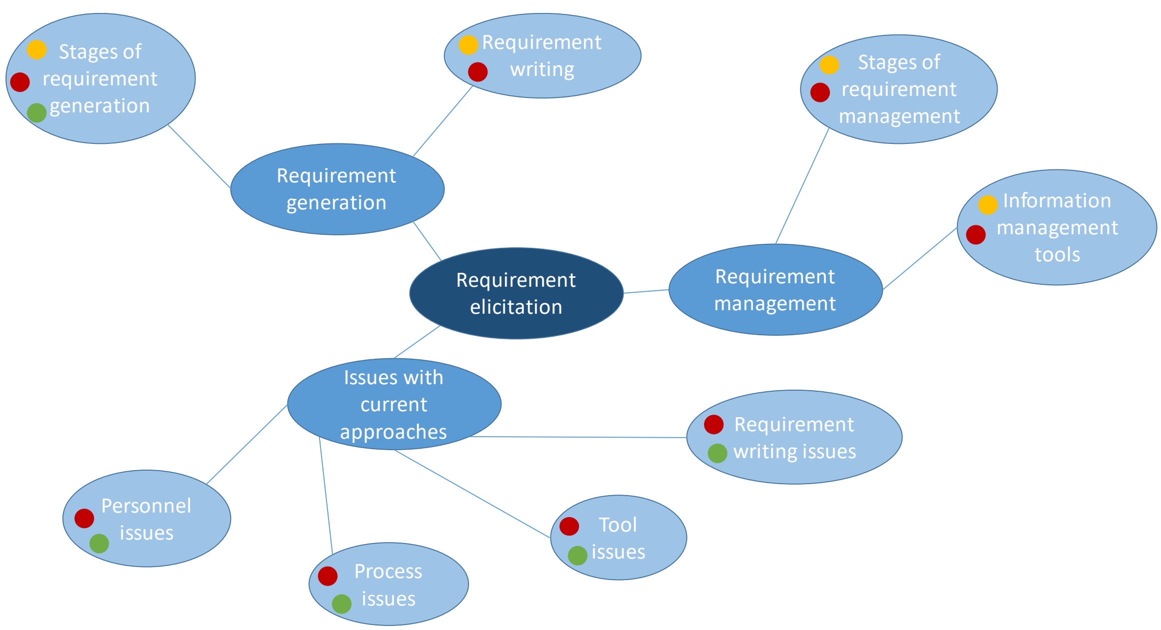

Figure 4.1: Map of themes and subthemes from RCM interviews showing color coding for population groups: yellow for faculty, red for military, and green for students.

The themes identified from the MCM interviews are shown in the map in Figure 4.2; two main themes and three subthemes were identified. Each of the developed themes and subthemes was sourced from the discussions in the interviews. Specific quotes and comments were recorded, assigned codes, and collected into the themes and subthemes. These themes will be discussed in detail with the quotes that contributed to their development.

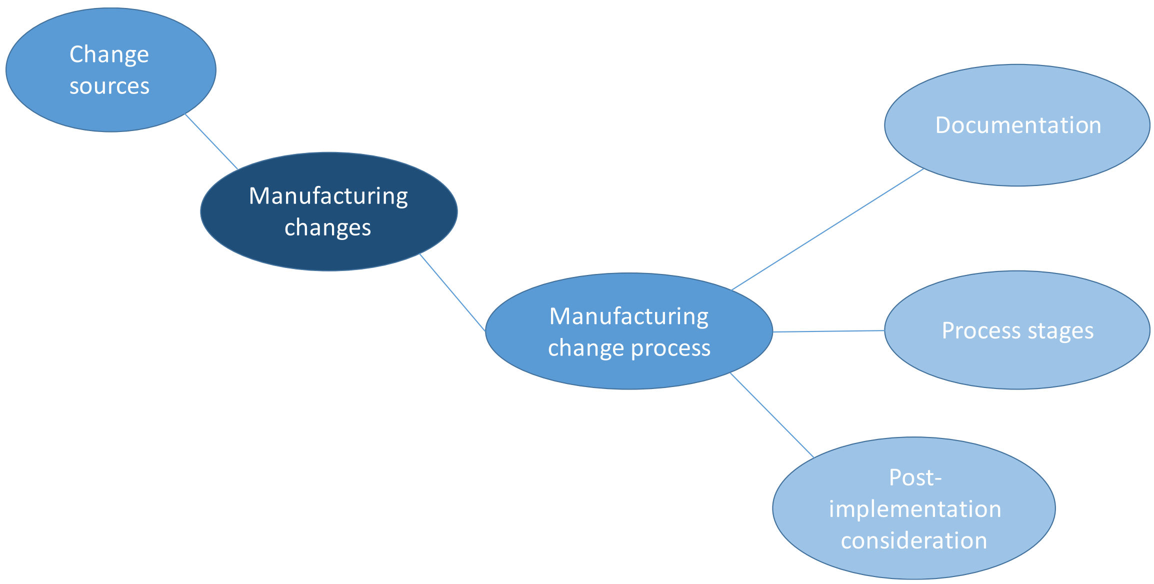

Figure 4.2: Map of themes and subthemes from MCM interviews

4.1 RCM Themes

Considering requirement generation, two subthemes were identified: stages of requirement generation and requirement writing. The stages of requirement generation largely revolved around functional decomposition, in an approach described by the military interviewees as top-down. For example, Georgia said “So how I see it being done is usually top down, basically. We want some output…and we translate that output…so you take something that's not measurable and you start making it measurable.” Thus, the desired outputs of the system are translated to functions and decomposed into individual, measurable requirements. This approach was also echoed by the faculty interviewed from academia. When asked about how requirements were developed in her program, Carmen explained that "…you start with what is the voice of the customer and how would you start to put that then into metrics and targets. Sometimes we use QFD [Quality Function Deployment] for that. That would really be based upon what did the particular OEM want. [We] would go through four phases of the QFD of how do you make the targets." Quality Function Deployment is a strategy used to translate the voice of the customer into requirements and engineering specifications that includes functional decomposition (Akao, 2004). Delilah discussed how the initial set of customer needs was mapped to requirements through the use of QFD and House of Quality. House of Quality (HOQ) is an approach that uses a matrix to identify customer requirements, display the relationships between customer requirements and design requirements, and prioritize design requirements (Park and Kim, 1998). The students interviewed also emphasized the role of functional decomposition in their requirement generation process. Claire, in discussing the breakdown of her project team's schedule, noted that "projects spent almost a semester on function definition and breaking down the requirements into [system and subsystem levels]." This semester timeframe is significant, since it consumes a full quarter of the four-semester project lifespan, signifying that great importance is ascribed to the functional decomposition and requirement generation stages of the overall design process. Carol echoed this, mentioning how the very first assignment related to the project was dedicated to functional decomposition and requirement writing, while Colleen discussed how the student teams began requirement development by determining the functional objectives.

Requirement writing, the second subtheme under the greater requirement generation theme, was largely conducted in groups. Georgia, when asked about the approach to sitting down and writing requirements, said that "it's usually done as a group. I mean, there might be one person that starts off with something, basically throwing something at the wall, but ultimately, it's all done as a group." By developing requirements in groups, contributors are able to discuss and rework the requirements as needed, incorporating different interpretations and driving towards unambiguity. The group format facilitates verbal or otherwise informal rework, rather than waiting until the requirements are formally codified. This reduces the frequency of formal RCs, decreasing the need for RCM. When the requirements are recorded, they tend to be written simply in plain text, as Carmen explained, "there's some…definitions that are 'have this verb and subject and the modifier and that sort of thing' and each piece has to be there to really be a full complete requirement, but a lot of people will just sort of write it in plain text or just 'the vehicle must have four wheels.'" This approach simplifies the overall requirement generation process and increases the accessibility of the requirements, since affiliated parties can easily read and understand the requirements. However, the lack of formal requirement components can make it more difficult to assess requirement quality or analyze the requirement set. It should be noted that there is little formal requirement engineering training provided as part of the curriculum associated with the Deep Orange program. Often, requirements education for engineering is limited to documentation and is only focused on early phases of design (Joshi et al., 2012). Previous research showed that a single lecture intervention on requirements can drastically improve student requirement definition activities (Elena and Summers, 2019). The same study found that practicing engineers performed similar to students without the intervention.

Two subthemes were identified under the requirement management theme: stages of requirement management and information management tools. In these two subthemes, the differences in approach between the faculty and military professionals become much more evident. When asked about the particular steps of managing RC, Catherine presented the faculty approach to RCM, saying “we probably prioritize…these are the requirements for this particular system which are the ones which we cannot absolutely change...so you prioritize the metrics that are absolutely needed [and] you start ignoring or, not ignoring, but putting the other ones on the backseat.” This approach to RCM is very informal, but can be suited for fast-paced product development or prototyping if well-managed. A well-structured development approach, such as SCRUM (Furuhjelm et al., 2017), is not explicitly employed in the graduate-level vehicle prototyping project. Additionally, it is sufficient according to the faculty, considering that the number of contributors working with the requirements is small and that design and production based on the requirements was conducted in-house. Other design faculty presented even less formal RCM processes. Daisy discussed an approach that involved students taking ownership of individual requirements and conducting periodic reviews of the overall requirement set to determine if the included requirements were still necessary. She also spoke about the requirement traceability matrices (RTM), which recorded the requirements as well as the linkages between them, and were used to record changes, usually additions or deletions, to the requirement set. Daphne described an RCM process that revolved around only two stages: proposal of a change and justification of that proposed change. Diana discussed an RCM process that depended on external feedback prompting students to respond with changes or rebuttals, while Delilah noted that changes were extremely infrequent and thus no real change management occurred at all.

In contrast, the military approach to RCM was much more formal. Gwen discussed an RCM process that involved multiple review stages, discussions with risk and configuration management, and final approval by a formal requirement review board. Grace also mentioned the presence of a formal change control board that had to approve any changes to already baselined requirements. This formality is expected of a more established design process that deals with larger teams of contributors and must communicate with outside contractors.

The difference in formality between faculty and military approaches to RCM can further be seen in the information management tools subtheme. When asked what tools or programs were used to manage and disseminate requirements information, Charlotte stated that her teams used "mostly Excel and PowerPoint…and I think, in practice, even those tools are not used very rigorously, to the point where some of it's basically relying on the information stored in people's head." While perhaps not sustainable as a permanent solution for a complex, long-term project, these tools are suitable for the short-term project with no risk of team turnover that they are used for. In contrast, military interviewees used dedicated requirements management software. Both Gwen and Grace identified IBM Rational DOORS as the software used to record and management requirement sets. It should be noted that IBM Rational DOORS does not support input validation of requirement completeness or quality (McLellan et al., 2010). Additionally, Grace discussed the use of Honeycomb software to manage change management proposals and workflow. The use of these more specific software packages is fitting for the larger-scale design project, conducted by multiple teams with potential for turnover and information loss.

The third major theme identified from the RCM interviews deals with issues with the current approaches, divided into four subthemes: personnel issues, process issues, tool issues, and requirement writing issues. In contrast to the other two major themes, significant overlap occurs between the student and military populations across the four subthemes. Personnel issues included poor communication across distributed teams, as identified by Carol, and a lack of dedicated personnel responsible for updating and disseminating RCs, as specifically called out by Gwen.

Additionally, attempts at group approaches to writing requirements can lead to issues, as the multiple voices and perspectives can lead to confusion. Claire noted this, saying "we thought, 'let us individually fill in what we feel are the requirements and then let us discuss them,' but that did not work out really well because everyone has a different view of looking at the system. So everyone has a different perception of the system and what is the complexity and how to break down the complexity. So it is very subjective." In addition, the multiple sources of input can lead to a lack of coherence across the overall requirement set. Georgia mentioned this issue, saying "one person writes the draft, or maybe a small handful of people write the draft and then it gets…reviewed and edited and updated and small words change here and there and then you don't really have the same voice across it." Georgia also pointed out that different contributors may, based on their prior experiences, use different terminology in the requirement set, thus leading to requirements that fundamentally provide the same constraint but are worded differently, thus potentially over constraining the solution space.

Process issues included the need for manual dissemination of information, confusion between different levels of requirements, and the fact that requirements were often written without verification and testing considerations. Georgia identified the inefficiency of manually disseminated information, and noted that it often led to different teams being out of sync, saying “our requirements at the lab end versus what the cross functional team manages aren't always in sync.” Claire found that the confusion between distinct requirement levels, such as system, subsystem, and component-level requirements, led to misplaced effort and general inefficiency, shown when she said “but when we see a level one requirement, I think it creates confusion…because generally the system level requirement is one or two, but then people start breaking it down there itself.” This confusion and the resulting inefficiency may occur because the process used does not distinguish specific stages for the generation of different requirement levels and instead considers requirement generation for the entire system as a whole. The trouble with requirements not being written for testing and verification was identified by Gwen and Claire, who both noted that the function-focused requirement breakdown may not capture the relationships between requirements that could lead to easier or more complete testing and verification.

Tool issues largely revolved around the limitations of the chosen tools and software. Grace, when asked about potential areas for improvement in either the process or tools used for RCM, noted that the existing IBM DOORS software did not provide for a common repository of requirements for reference. This aligns with previous findings (McLellan et al., 2010). Without this repository, requirements must be developed anew with each new project, rather than being modified from existing requirements or templates. Additionally, Grace mentioned that exporting requirement files in desired file formats from DOORS was difficult; the limited file formats restricted the types of analysis that could be conducted and caused much of the analysis to be conducted on isolated data sets, rather than the live, updated requirement set. Carol, one of the student designers, noted that the limitations of the Microsoft Excel spreadsheet used for recording requirements restricted how dependencies and connections could be shown between requirements, thus reducing the analysis that could be conducted. This was echoed by Daphne, who mentioned that the tool used to prompt students to think about requirement linkages only grouped requirements but did not show clear relationships. In addition, by obscuring the relationships between requirements, the tool limitations hinder the RCM process, in that it is more difficult to predict how a change may propagate. This challenge of information management and relational modeling aligns with previous studies in industry (Morkos et al., 2010).

The final subtheme dealt with requirement writing issues. Again, significant overlap was observed between the student and military perspectives, as both participant groups identified ambiguous language and conflicting or redundant requirements as common issues. Gwen, Claire, and Grace all noted the potential issue caused by ambiguous language. Claire, when asked about any issues with the existing process, first mentioned ambiguous language, saying "I think the language…the nomenclature and the language of defining the requirement makes a huge difference. So initially, when we were defining the requirements, two people had the same thing in their minds, but the way they wrote it was different and that created huge confusion." By using ambiguous language, requirements become more subjective and open to individual interpretation, potentially causing confusion and increasing the difficulty of using and analyzing the requirement set. Formalizing the requirement vocabulary is a focus of current research (Shankar et al., 2020; Lash et al., 2012; Mokammel et al., 2013).

Additionally, issues with requirement writing included conflicting requirements. Gwen noted that conflicting requirements, such as a pair of requirements that specify a target vehicle weight and horsepower that cannot be mutually achieved, often lead to significant time losses. These requirement conflicts can also cause issues with securing outside contractors, who may see the conflicts and choose not to bid on a specific project.

4.2 <u>MCM Themes</u>

The first of the major themes identified from the MCM interviews dealt with the sources for the change. The interview responses largely overlapped for this theme, with five key sources of manufacturing changes being identified: design changes, supplier changes, logistics changes, specification changes, and production capability. Susan noted that changes to existing manufacturing processes could be attributed to design, production, supplier, or logistics changes. Lucy discussed that change requests came from suppliers or the in-house production teams, as well as for cost reduction purposes. Jill further corroborated these change sources, noting that design departments were typically responsible for product changes, but that other groups, such as purchasing and logistics, weighed in to evaluate the change. Helen reiterated these sources for change requests, particularly suppliers and production capability, but also focused on the fact that any individual operator at the plant level could submit a change request for consideration.

The second theme, which addressed the MCM process, was divided into three subthemes. The first subtheme dealt with the individual process stages. All four of the interviewees named change requests, change approval, pre-implementation testing, and change implementation as stages in their MCM processes. Additionally, the interviewees discussed that the processes featured gates between different stages, during which the change was reviewed.

Another subtheme discussed the documentation methods used to aid in the process. Lucy, when asked about what types of documentation were used in the process, especially after changes were implemented, responded "mostly Statistical Process Control would be the documentation." Jill also mentioned using normal control measures to monitor production after making a change, but also elaborated on some of methods used to aid in evaluation, naming specifically FMEA (Failure Mode Effects Analysis) documents and dedicated risk filter documents. Helen discussed the PPAP (Production Part Approval Process) approach, which was used to determine the level of documentation required for each change. The PPAP is used, primarily in the automotive industry, to determine that the customer engineering design requirements and specifications are fully understood by the organization; it allows the customer to validate that the manufacturing process can consistently produce products that meet the requirements (Podolak, 2019).

The final subtheme delved more specifically into the consideration given to a change after implementation. Post-implementation consideration was largely limited to traditional process monitoring, as explained by Lucy, who said “whatever is monitored after the implementation is basically the regular production inspection. Whenever we test before implementation it’s basically evaluating all capabilities. We make sure it runs the way it is supposed to, it will give you your quality metrics beforehand, and then the day you implement it, you just change over to a regular production.” Jill presented a similar approach at her company, saying “we don’t really necessarily do anything above and beyond our normal monitoring once we’ve implemented the change. We rely on the existing controls…that’s the reason we run the trial builds beforehand, to validate that the control measures we already have in place…are working properly.” Helen echoed this, but did note that each plant would assign a change owner to serve as a point of contact, if needed, after change implementation. These approaches align with other change management studies of industry practice (Knackstedt and Summers, 2017). The approaches practiced by the interviewees become essentially hands-off after the change is implemented, relying on thorough testing before implementation to unveil any potential issues, similar to the verification and validation approach of (Shankar et al., 2017). However, because of this lack of verification or validation after implementation, there is an increased risk of unforeseen change propagation once the change is implemented, thus heightening the need for a rigorous and well-practiced MCM process.

Chapter Five
DISCUSSION AND FUTURE WORK

5.1 Key Findings

From the process models and thematic analysis data, some key observations and conclusions may be drawn. To begin with, the RCM interviewees included requirement generation as part of the overall process, as shown in the thematic map in **Error! Reference source not found.**. While, at the surface level, requirement generation may not seem to be part of the RCM process, the definition of a requirement change includes adding new requirements as well as modifying or deleting existing requirements. Thus, requirement generation is a critical part of the RCM process. However, this contrasts with the MCM process, which instead addresses changes to existing artifacts or processes. This distinction then raises the question of whether the change management processes should be different when dealing with RC as opposed to MC and if so, how should the processes accommodate this distinction.

When considering the RCM thematic map and the population groups that each theme was present in, a correlation can be observed. Faculty and military largely overlapped when discussing prescriptive themes, such as the process stages and requirement writing methods. This could be attributed to ownership, as faculty and the military designers primarily developed or selected the process stages and thus had sufficient understanding to discuss them in detail. Alternately, this could be attributed to a lack of buy-in on behalf of the students. Students predominantly were instructed on which process to use, and as such may be unconvinced as to the need for particular process stages or may consider alternatives that they deem more effective or appropriate. In contrast, students and the military overlapped on descriptive themes, such as those describing issues with the current process. This difference can be explained by the fact that the students and military practitioners are the ones using the process day-to-day and experiencing any issues that may arise, while faculty are more likely to remain hands-off in order to allow students to fully experience the process. In addition, if faculty remain hands-off, their only source of information regarding any issues that may arise comes from the students who are experiencing those issues. However, students may present sanitized or idealized reports to their instructors that does not include any of the experienced issues, further limiting faculty opportunities to understand the issues in practice. The fact that the faculty population group did not identify many of these same issues illustrates that there is a gap between instruction and practice. This gap is problematic, since if the faculty instructing new students how to use the processes are not aware of the issues in practice, they cannot create and teach strategies for overcoming or eliminating such issues. To improve the overall change management practice, this gap must be closed (Joshi et al., 2012). However, to do so, communication between practitioners, researchers, and instructors must be improved. This would allow issues to be discovered in practice and communicated to incoming practitioners with methods to minimize the issues, while more permanent solutions could be sought by researchers.

Additionally, the process models developed from the interviews highlighted a difference between the practiced RCM and MCM processes. Formal document milestones, such as change requests or change orders, were much less common in RCM than in MCM.

This lack of formal documentation and stage gates could be attributed to the fact that RCM deals with more abstract concepts that present a lower cost of change than the more concrete artifacts that characterize MCM. If changes such as requirement changes are considered less costly to conduct, either by presenting less risk or being easier to reverse, then practitioners may select more informal management methods in order to save time and effort. This could also be attributed to the nature of the change types, since MCs occur later in the design process and there are fewer opportunities to detect and address issues that may result from the change before the product is released to the customer. RCs, on the other hand, occur early in the design process and thus any issues that arise can be managed in subsequent design process stages. Alternately, this difference in the presence of documentation stages could be due to the scope of the projects. Many of the RCM practitioners interviewed were working on smaller-scale, shorter time frame projects with small associated populations, which limits the amount of time and effort that can be dedicated to documentation. Conversely, MCM practitioners dealt with large-scale projects with dedicated teams and thus could afford to dedicate time and personnel to extensive documentation. This is supported by the fact that the military RCM practitioners, who dealt with projects of a similar scale to MCM practitioners, did include some of these documentation stages.

Lastly, examination of the RCM and MCM process models revealed that, while the impact of a change is assessed before the change is implemented, neither process includes a stage to verify the results of the impact assessment after the change is implemented. In RCM, the only verification and validation is conducted to ensure that the requirements are necessary and fulfilled, without significant consideration of the changes. Any impacts that may arise from RC are then passed downstream to the design and manufacturing processes. In MCM, the general assumption is that the testing conducted before full-scale implementation is sufficient to capture any issues with the change (Shankar et al., 2017). However, testing may not be conducted on a large or long enough scale to capture the full impact of a change. This, coupled with the fact that MCs occur at the end of the product development cycle, leaves nothing downstream to detect or address any issues with the product before the product is released to the customer and increases the need for a robust post-implementation verification process. The focus on the post-implementation aspects of the MCM process may serve to be one of the key differentiators between RCM and MCM processes that otherwise overlap closely.

5.2 Future Work

From these observations and conclusions, new opportunities for future work can be identified. For example, future work could explore the effects of educating students on the types of changes that could be experienced in the design process and exposing them to different change management processes. This could potentially close the gap between researchers and practitioners, since faculty instructors could be more aware of the issues with change management. Furthermore, this exposure could help mitigate some of the issues in implementing change management processes, as students with prior experience in dealing with change management may be less reluctant to use change management approaches and may be more aware of the benefits and limitations of such processes.

One of the largest opportunities for future work, however, comes in investigating the source of a prevailing trend mentioned throughout the interviews: the idea that change management is necessary and important, but not conducted well. This sentiment was common across RCM practitioners, from faculty sponsors to military designers. Georgia said “knowledge management is really hard. It's a really fundamental problem and it's really hard to get right.” Greta echoed this, noting that change management was not done well and was very variable across projects. Further discussion of this sentiment came from Charlotte, who stated “staying on the same page is actually very difficult and if anything, then this is where having some formal way of dealing with requirements will become very important.” Even when this prevailing idea of the importance of change management was not discussed, it was not because the interviewees did not perceive change management as important; rather, the projects they worked on were so small in scope that no changes were made and thus change management was not needed. This discrepancy in attitudes, that change management is important but not done well, may be attributed to a lack of buy-in. Practitioners may understand that change management is important, but may not be convinced that the prescribed processes or process stages are critical for the successful completion of the process. This relates to another common attitude: that extensive documentation does not add value. When documentation is not considered a stage of the change management process, such as in the RCM processes described by the interviewees, the sentiment that change management is conducted poorly is prevalent. However, when documentation is conducted as part of the process, such as in the MCM processes discussed by the interviewees, these attitudes were much more uncommon. Thus, complete documentation may be key to full, effective, and efficient conduction of change management processes. In this regard, the following research questions can be investigated.

- How is the value versus cost of documentation perceived?
- Is it more effective to lower the perceived cost or increase the perceived value of documentation?
- How does changing the perceived value or cost of formal documentation stages influence the attitudes towards and the completion of such stages?
- Could a universal change management process that incorporated formal documentation stages, such as change requests, change orders, and impact analysis assessments, be used to change the perception that change management is not done well?

APPENDICES

Appendix A: Notes from RCM Interviews

Charlotte Interview Notes

- Oversee all DO projects (working with Dr. P on DO 12; Dr. B on DO 13)
- Systematic engineering process based on V-model
  - Provide mission-level requirements, students must build concept vehicle that speaks to requirements
  - Provide use case, stuff that should be emphasized to make vehicle-level requirements
  - Not very formal in process; looking for better process and tools
- Constraints that we choose to impose on vehicle; discuss how to be phrased (unambiguous, testable, verifiable), matching general established rules for how requirements should be written
  - Requirements not actually required, agree to stick to requirements until we agree to change; students only really exposed to faculty-given design brief
- Students must take responsibility, faculty provide feedback/input; students lack understanding, then faculty step in (P = powertrain, Z = vehicle dynamics, S and Charlotte = higher-level control (sensors, autonomy), R = electric architecture, K = implementation) and guide students
- Meet with students 2x a week (teams, subsystem teams), also cross-cut teams; staying on same page is very difficult; formal way of dealing with requirements will be very important; example: come up with solution to change requirement, one team working under one set of assumptions but other teams with different assumptions
  - Familiarity with requirements is challenging; need tools for managing requirements
- Mostly just Excel and PPT for RCM; not used vigorously; mostly rely on information in peoples' heads; asked for requirement document but not successful; not able to capture to domain and express in similar form in requirements; even implementation of software is struggle
- Examples include interface and geometric constraints; went through huge list of engines for issues with geometric constraints
- May need to sign NDAs to see examples of requirements
- Talk about requirements briefly in Systems Engineering class; focused on understanding of subsystem and how requirements interact, not much training, to share lecture
- Learn about how influences between requirements; lessons learned on management passed through faculty; many NDAs makes information sharing difficult; information organization is challenging
- Requirement interrelationship earned over through faculty; students do not have experience with design (maximum ~2 years in industry, little experience in large-

scale architecture) goal is to learn better understanding of systems; through exploration, students do come up with new (novel) ideas

- Describe to students theme and context framing project (high-level design brief)
  - DO 12: take Dallara IL-15 chassis -> break world record for autonomous speed in LV
- Take high-level context and what does that mean
  - Integration and packaging tends to drive project
  - Could look at from autonomously in functional decomposition, what it takes to achieve
  - Explicitly told to do functional analysis (capabilities, functions…)
    - Sense and localize in environment, achieve power, safely with loss of traction
  - Ask students to go through videos; interviews with actual car designers; raises new ideas -> new requirements
  - Function -> subfunction -> working principle -> solution -> component analysis to reach non-functional requirements (performance characteristics) to reach good tradeoff (power to reach speed dominant requirement) (many tradeoffs were already decided with chassis constraint)
  - Electric power was major source of tradeoffs (alternator not big enough); every team asking for more power (how much, quality [voltage] for computer)
  - Tradeoff between power and vehicle dynamics (more traction = more hp)
- Very non-linear process -> constant flux; driving constrain is low cost; some choices change months down the line; new sponsors = new equipment
- Many people involved in process and 1000s of requirements; scalability is big issue, also requirement management is hard to do if it will be a full-time job (no student wants to do all, all students should do some)

Carmen Interview Notes

- Involved in DO 2-7, one more recent; DO 2 – first project year in completely fell apart, talked with V and suggested topic and went with new topic (DO2 different); DO 3-7 started with “grand vision” (DO5 – how does GM provide an option for young people…) often more about user experience; start with grand vision -> research (Auto Pacific surveys from new vehicle owners) for a couple of months (started before students even started, defining sandbox for students to play in) (end up with 100 slides on company and project) -> develop user personas (draft before giving to students re goals) -> lecture
- Would go over brand (history, definition, goals, is and isn’t) to make sure that what are making fits company; program manager would come and talk to students; changing student approach to match company culture; personas would have pictures (consistent) that would be loosely based on real people and ~2 hour

interview on likes and dislikes; 6-9 months of background research before developing sandbox (what vehicle is and isn't, would give basics like rough dimensions to get started); classes would teach how to go from user needs to requirements

- Would not start with explicit requirements (would put people in a box) and wanted to work on creativity; would not give requirements and instead focus on brainstorming; didn't really push or discuss requirements until the end of the first fall semester; pushed creativity as much as possible; would group students into teams to work and present to class and encourage creativity; in spring semester would work with art center in CA, partnering design students with engineering students would put bounds on creativity; then would begin introducing requirements (wheelbase, weight, time, budget, etc.); would have virtual design reviews with company project managers; once concept was picked moving forward would start to be back to reality; had some requirements until end of spring semester (historic process)
- Would do usability studies of vehicles from multiple perspectives; getting people to think about what consumer wants instead of just what they want; would look at consumer, manufacturing, etc. Needs; would go through customer criteria (JD Power data); would look at similar vehicles and look at similar features; would talk about data synthesis, customer targets, corporate targets, etc., would use QFD based on what OEM wants; QFD would start with whats and hows and how to put customer wants into engineering terms, then would focus on how to rank/cascade requirements; would incorporate legislative targets, then would look at targets; H-Point book (Macy and Wardel) does a nice job walking through subsystems and order to think through; V would talk through engineering level; used data to generate target catalogue (spreadsheet with requirements and used to make BOM)
- Requirements written as QFD, based on benchmarking from previous research and from surrounding markets; 3 levels of requirements/targets; would look at industry standards
- RCM managed at design reviews; target catalogue would be put together (first draft) then students would be involved; Carmen would do initial BS check then V would do in-depth review; students would have to propose RC at design review and it would have to be approved by company and company would/could add new requirements/targets or remove requirements; would evolve with engineering; target catalogue would track proposer, justification, faculty buy-in, design review, approved; budget would also need permission to be changed
- Extensive research and case study examples showed need; used as gates to progress; way introduced showed differences with and without requirements; help students realize why vehicles are the way they are (necessary reality)
- First DO didn't have industry sponsor so faculty were really involved; now is just project teams, industry sponsors, and some industry partners

Catherine Interview Notes

- Vehicle-level requirements -> system level requirements -> need an overall theme; DO11 theme was sustainable by design, focused on body in white and exteriors, making vehicle for fleet ownership and long usage time, goal was to maximize utilization -> designed for reconfigurable interior -> durability of materials; also part of DO13 needs mission level requirements provided/generated then presented to GVSC, then can start generating vehicle-level requirements -> structures and material
- Mission: sustainable by design; vehicle-level: reconfigurable, durable, etc.; vehicle requirements must be developed by people with different background; mission-level team -> domain teams flesh out vehicle-level requirement maps -> subsystem teams
- Requirements can be quantitative and qualitative or mixed, can start with qualitative -> quantitative
- Maintain evidence books with standard protocol; can refer back to historical evidence
- Prioritize requirements for particular system (find critical to make functional); start ignoring/deprioritize those that are not critical
- Requirements reviewed in weekly design reviews; once concepts are formalized
- Majority of students follow requirements strictly, asked to at starting meeting
- Mission level goals -> discussions with students (~5 months) to tease out possible functions tied back to mission goals -> sub-system requirements
- Also had to define personas for riders, used to define functions and users
- Vehicle defined for care, share and deliver functions; sectors defined before students started

Claire Interview Notes

- Get high level set (what car is supposed to do) then break down into simpler problems; given car must make autonomous; what functions does the driver perform?; look at functions driver does (sees, thinks, plans, acts); then gather information of sensors, etc.; concept, definition of concept; do lots of research into how to meet functions; predevelopment looks at what sensors; development defines scope for team and divides team; trying to break smaller problems; generally follow v-model, starting with system -> concept -> system; go back and test at each stage (components first before integrating)
- Do a lot of systems thinking in predevelopment (~3 months, accelerated project) deriving driver functions -> which functions do we actually need; then research what functions can be replaced with what sensor; now on component level development and into verification phase
- No real system in place for requirement change, not really tracking

- Use big excel sheet; define requirements; tried to just write requirements individually and then discuss (didn't work); then displayed as large group and brainstormed as large group, more successful
- Use big spreadsheet to record requirements (target catalogues); L1 = full vehicle; L2 = sub-system; L3 = component specification; some broken down by cost, others by functions
- Requirements don't really change once defined; do go back and make sure don't really have to change/review; scope never really shifted
- Language of defining requirements makes difference (same idea, written differently -> huge confusion); definition impacts how broken down
- Confusion in L1-L2 requirements vs. L1-L2 functional requirements; functional requirement is what this thing is supposed to do; L1 = system; L2 = sub-system; major confusion in levels, how deep do you break it down
- Standard way to break down, examples of how to break down requirements
- Method of visualizing links would be helpful in breaking down and also with verification and validation; fault tree analysis chart (something like that)
-

Carol Interview Notes

- Lot of stakeholders involved, generating for us; we are responsible for autonomy stack; initially had list of targets (vehicle structures /powertrain); "we kind of revolved it around how to we replicate the driver in the car"; spend a lot of time meeting about driver functions "what does the driver do that we need to replicate:" initially had target to see 360º around car -> needed LIDAR, radar, cameras, etc; but difficult because not all sensors equivalent
- Original targets are requirements; no prior experience in large-group project or with many subsystems; had to rely on those with more experience; had to start from the ground up; "how do we determine how fast the vehicle can refresh per second;" cameras can give 30 fps, LIDAR 10 fps -> what does it trickle down to/how fast can computer react; when actually putting car together, need to focus on requirements that we started with and start verifying and validating
- Targets are at vehicle level; system and subsystem and component level requirements derived from targets
- At beginning of process would have design review every month and a half; it was more important to hammer down requirements then; had to make sure stakeholders were happy; would have to make sure requirements made sense and were actually necessary
- In constant feedback from stakeholders; official weekly check-in; would meet with stakeholders who could come up with potential solutions and we must determine if it would be useful for the project; Claire manages Slack communication with competition teams from other universities (vehicle systems/autonomy), will give feedback regarding autonomy systems

- Requirement changes makes serious the need to consider the impact of the change -> recently had sensor change that led to complete redesign of top cover; had no formal conversation about how it would change; early in process requirements are more fluid and prompt look at higher-level requirements and how changes are propagating
- Use Excel a lot for management; had nicely formatted sheet with sheets for levels; fell off everyone's radar
- Issues with requirement generation come down to team dynamics; difficult to communicate changes across distributed teams (especially online); mainly communication issue; hard to share and make sure everyone sees/understands it; subsystem teams may not communicate back and forth -> many decisions made without communicating
- Targets from stakeholders (only 10 requirements, from Charlotte and R with ESN and Dallara) -> then give to team (whole vehicle) (would meet and have brainstorming sessions with core leads and a few members of subsystem teams -> would set up racing sim game to try to emulate driver) -> subsystems teams then had L2 requirements
- Class 881 assignment 1 dealt with functional decomposition and formal requirements (X shall achieve Y in certain amount of Z); right way to write requirements and a wrong way
- Requirement redundancy decently present issue in early phases of project (would be useful to be able to automatically detect)
- Search function not extremely useful due to scale (no key words really common, can just look at different pages/subsystems) -> may be more useful to track met/in progress/not met to be able to keep track of progress
- Adding dependencies/connections would be extremely useful (especially for physical requirements but also for non-physical)
- Way to determine/signal conflicting requirements would be useful
- Central system (like a web app with one central link so you could see impact of one requirement on another); better way to visualize how requirements are being met; don't want to spend too much time on analysis

Candace Interview Notes

- Come up with high-level mission-level requirements then fulfilled by vehicle-level requirements; when getting into vehicle-level can start high-level, then break down based on subsystems
- Begin by developing mission scenarios -> initial brief: high speed autonomous vehicle -> scenarios to determine what exactly mission will be; defining "off-road" and "high-speed" -> want to be very descriptive in terms of defining terrain

- Whole DO team split into 3 subteams -> each came up with 3 scenarios and requirements -> came together to pick 3 total scenarios as a group -> then began looking at vehicle then subsystem requirements
- Tried requirements as “shall” statements; sometimes hard to say what you want to say; mission requirements written as “will”; functional requirements have different structure
- Charlotte reviews requirements and tells us to rewrite them; have been using MATLAB Requirement Editor; generates easy to use report in outline form with traceability; feedback from N, Charlotte, VIPR, and GVSC
- Haven’t had to deal with requirement changes yet; anticipate needing more to define program; Requirement Editor and Github not supported; thought could all work on requirement document and change together but instead were overwriting in the document
- Can build MATLAB testing harnesses that link back to requirements model; testing harness should be updated and when run should verify if changed requirements are met; need to distribute access to a few people; should be easy to track; being able to link back to actual values
- Supposed to be considering relationships between requirements; not sure if have looked at it to the extend needed; structure being constructed should be able to capture
- Regarding search filters: requirements can be commented on but no way to see only requirements that have comments; maybe by day modified?; flagging requirements that are at odds; having a feature built in to suggest new non-conflicting requirements
- Clippy-style formatting guide to help make sure requirements are written well and in good format; no clear-cut examples of good and bad requirements
- Simulink model shows file hierarchy and relations between; currently use one big file, could show relations between smaller files
- When had separate meetings, had issues with redundancy; have addressed most, but could be refined; useful to highlight redundancy and conflict
- Team wrote requirements to be separate; some may be related; mostly try to keep singular requirements (easier to test singular requirements)
- Some teams have different ideas of how to write requirements -> difficult to get all written in same format; need consistency in that; room for improvement in file management (MATLAB issue)

Colleen Interview Notes

- First step of V model is coming up with functional objectives and vehicle requirements; knew it would be autonomous and sponsored by military; came up with missions (9 initially, grouped together to come up with mission scenarios (2-3 weeks)) then developed vehicle and system level requirements; end objective was not to create perfect vehicle requirements but to create something to use; difficult to be specific enough without overconstraining

- Started with functional objectives; some people discussed the nitty-gritty of some things (i.e. drone compatibility); when went back was mostly getting people on same page, tried to make requirements match scope of project (spent about 50% of time)
- Started with Excel sheet to break down levels of requirements -> then formalized in MATLAB Requirement Editor; can link between requirements and to test cases/models; had to do link establishing, all edits made in MATLAB; exported completed draft back to Excel for sharing/comments
- Spent first couple of weeks putting requirements in Excel, going back through, then went on to modeling -> needed to make decisions; looked back to requirements for guidance that wasn't really there, so had to revisit and refine/redefine
- Requirement changes done in MATLAB; had established hierarchical structure with links so was not difficult to make change; oversight and proposed in place (Charlotte presents issue and students discuss change)
- Would be nice to have some way to get started with high-level requirement skeleton/sample set of vehicle requirements; had o experience with writing
- Would be helpful to have initial starting ballpark numbers; at least an idea of what stakeholders have in mind
- Powertrain and VD teams have similar requirements -> didn't spend much time discussing overlap, instead moved ahead to discuss later
- All guidance has so far been in text regarding links; some sort of visual instruction would be useful; MATLAB creates hierarchical structure -> can export as visual linked file
- Requirements are mostly separate in nature, some are connected
- Had a really hard time finding fine line between too specific and not specific enough; some method to determine if specific enough would be good
- Conflicting requirements would be good to highlight
- Main issues throughout process were ambiguity and lack of starting points
- Would be nice to see version control implemented in MATLAB; different people cannot work simultaneously -> makes it difficult to work/causes time penalties
- Do not have a picture of how much time and effort requirements will take; some sort of scope checker to make sure on right path
- Need to know about feedback sessions (professors gave lots of feedback towards the start, but would have been better if more frequent and earlier in process)

Gwen Interview Notes

- Showed presentation about process used by combat support and combat service support; Stage 0-7, requirement engineers, process starts with set of user requirements. (capability development document), written more like functions; instead of saying how fast, will say needs to stay with certain other vehicle; usually CDD has Key Performance Parameters that make or break program; if it doesn't meet KPP system is no use

- Establishing team, cost-benefit analysis, support platform, establishing strategies (all prework); CDD requirements then imported (should have example) and written in form that must be broken up into single requirements, removing run-on sentences to reach individual requirements (CDD written for brevity), singularization, functional decomposition; can analyze user requirements to find threshold and objectives (survivability, protection, lethality, etc.); analysis of operational needs and technical analysis; then start working on performance specification; many common requirements not really rehashed (transport, top speed, etc.) then must work on unique vehicle requirements (if vehicle doing unique function must sit down with stakeholders and engineers; internal reviews and peer reviews; first 2 reviews take 1-2 weeks, stage 5 takes lot of time; evolution is much easier; new vehicle more difficult with discussion; industry then gets review, OEMs sent draft that they can respond to and pick holes in and point out conflicts; after each review, discussed and picked through; traceability done using DOORS systems (no orphans, no childless parents, all requirements/functions must trace up to singularized CDD); may be some gold plating and having to trace; then release p-spec and maintain, feedback for p-spec; for every awarded RFP to OEM must do configuration management; must do compliance checking on both sides; requirements briefed at each systems engineering review; tracking TPMs making sure to verify OEM claims
- Each step in process in slides in detail; incorporate risk management, includes checklists and guidance on functional decomposition; requirement training class takes ~2 days to go through
- Requirements written out plain text; in DOORS all boxes are text/object boxes; no going back to "what makes a requirement;" requirement building is both an art and a science, lot of variation between requirements between projects; work with test community to make sure verifiable and testable; tests must be able to be performed; common requirements are in standard form/fill-in-blank format; discuss qualifiers at length; OEM may take advantage of lack of qualifiers
- Before releasing RFP, can go in directly and make changes with just a comment, little oversight; once p-spec delivered, must do significantly more; Requirement Review Board (chief engineers on both sides) in accordance with configuration management; usually OEM wanting loosening on requirements; go back to risk management; RRB only after requirements are baselines at SRR; usually managed in DOORS; scope of work determines interface with OEM, some OEMS just send Excel sheets that must be put into DOORS, make revisions to p-spec; important thing is that all know and agree with RC
- 200-700 requirements for normal project; very few 1000+ (only system-system type projects); usually in 1000s; can run VBA scripts in DOORS to create metrics, graphs, etc.; can have all orphan requirements and put in .doc format; all reliant

on VBA and XML coding, hard to do without extensive experience; want to be able to interrogate requirements for many different statuses (not met, testing, problems, etc.)

- Would be nice to be able to make sure requirements are written well with NLP, check for presence of "bad" words in requirements; don't want to say "may, might, probably, should…;" detecting ambiguity while typing; making sure to use legally binding language "shall;" maybe even consistency in units (all in metric); engineers and subject matter experts from all over
- Being able to see conflict between requirements would be very good, saves lot of time; OEMs see them and choose not to bid on project; would be nice to see interactions (weight-horsepower, etc.); which requirements affect each other
- Traceability takes care of redundancy and extraneous (gold plating)
- Being able to see which requirements can be tested simultaneously (grouping for test management); look at it from verification perspective

Georgia Interview Notes

- GVRobotics chief scientist (senior technical expert) split between GVR and PEOs; research community is also customer, helping to generalize needs for better understanding; thinking about future and what it takes to get there; PEO side is requirement focused; helps evaluate requirements and build requirements; advisory role
- Requirement development is usually top-down -> start with a goal then break down into measurable; individually try to use bottom-up; more detailed about what I have and what I need; starting at most general idea of need and build out more detail, more minimum-constraint start then build up; thinking about end goal and what can be added re future-proofing
- For PM side (creates performance specification) and vendor (preliminary design review) and GVR (lab, vendor, PEO)
- Usually written as a group, no form of real automation, closest thing is using bottom-up
- Hasn't been involved in formal requirement review; more informal validation
- Knowledge management really hard; manually disseminated (really hard) lab requirements not always in sync with cross-functional team; familiar with DOORS but don't really use because of evolving nature
- Many people writing, editing, updating draft; no one voice across requirement list; LRRDPP examples, some are very discrete but others need unpacking; concern with context of different requirement languages; need to fundamentally understand context and purpose
- Investing heavily in SYSML to link things, better understand constraints, and reduce complexity; i.e. understanding that attributes (yaw has different

definitions); knowledge management/standards may help with that; reference architecture; system model represents intent of the modeler

- Knowledge management issues (configuration management) requires dedicated personnel to update and distribute (central role with distributed benefits)
- Look for ways to model topics/context

Greta Interview Notes

- Undergrad in software engineering, graduate in systems engineering, worked at Lockheed and GM Tech Center before Detroit Arsenal
- Currently requirements engineer, requirement manager under systems engineering umbrella; develop, clarify, review, make changes to and update requirements (largely front side of process); also work with architecture
- Requirements are shall statements; list of singular statements that system shall do; in aerospace, Requirement engineering and systems engineering is just the way to do it; automotive has been off and on, increasing lately with complexity; INCOSE definition; functional requirements are functions that the system must perform or conditions in which the system must perform; nonfunctional requirements are often hardest, thought of as –ilities; performance requirements are functional requirements with negotiated values/targets/criteria that the system must perform (subset of functional requirements); targets are performance requirements; constraints are non-functional requirements; design requirements also exist (not required from system engineering perspective, useful for interfacing with supplier)
- In terms of keeping pace, Detroit Arsenal behind where commercial automotive is; aviation most rigorous due to inherent risk and business culture; more safety-critical systems have more focus on risk management (FMEA, fault-tree analysis); function categorization leads to more risk management for more important functions; in Army, program-program rigor is not really consistent
- Start out with functions wanted in the system, assign severity (qualitative) and frequency (quantitative) values to create risk matrix, then it allows you to do risk mitigation
- Enterprise Architecture, Visio, Excel methods to generate diagrams, etc. many claim to do it (MagicDraw, IBM Rhapsody, Vitec Core) but don't do it well
- Requirement process depends on program; start with technical transfer from focus group-type groups at Maneuver Center of Excellence that gives ideas -> CDD describes overarching environment and mission, what product will do and perform for you (functions that the vehicle of interest will be able to perform) -> begin deriving requirements from CDD in committee, small focus groups, can break down to individuals and come back together -> review and discussion until get to stage where 80% happy, no big disagreements, then have the requirements set; for MAPS (modular active protection system), not given CDD, linkage between requirements to warfighter needs not extensive, less traceable ->

reviewed by program (internal) -> formal gate reviews (PDR, CDR, etc.) (very formal for large projects) process gets tailored based on size and scale of work being done, overarching milestones and gates (lot of tailoring at Arsenal; each gate has different goals (L1, L2, L3-type requirements)

- Personal view is that CM is done "very poorly;" not many standards
- Requirement generation starts with what are important functions -> decompose functions into lower-level systems; ideally start from top-down (automotive deals with legacy systems)
- Change management is "here are pieces of info I want to control" -> people confuse templates with processes with tools -> first step should be to define/determine problem (what are artefacts that you need to change control) (templated artefacts -> requirement style guide) -> make sure have good processes for workflow change control (responsibility matrix (people making, reviewing, approving change)) -> last (think about the tool; CM different from configuration management; automotive OEMs do it better (scale and frequency))
- Enterprise Architecture and IBM Rhapsody are big names in software development tools, allow to model software behavior (similar to MATLAB Simulink); tool is usually not the issue day-to-day; problems more geared towards getting everyone on same page with respect to the problem to be solved; overfamiliarity with tools (confluence tool and ticket tracking) makes them use the tool for everything
- If you want people to use the tool, it is very useful to have a champion for the tool with one specific function
- Would like to see some of these functions in a tool (mapping -> relationship modeling); tools do modeling of functional requirements well; not sure of benefit of modeling non-functional requirements not decomposable; but as part of the system overall would be good if can be automated; look into other commercial systems for comparison; powerful tools with steep learning curves can be difficult; very flexible tools can also be difficult
- What is impetus for this project? Who is target customer for tool?
- Modeling languages – SYSML, older languages DOPAF, Hatley-Prova; important to take a step back and make sure understand what we are trying to do (how using pieces of information and what are they good for?)

Grace Interview Notes

- Started in automotive -> General Dynamics (cancelled project) -> Chrysler -> government
- Bachelors in Chemistry -> self-taught on engineering/programming; not as much data to sift through (compared to Chrysler); Army vehicles designed to be in field approx. 30 years, issues with durability etc.; much data not feedback; structure much more formal i.e. "more layers to go through;" soldiers who work at Arsenal help develop requirements, let by a general representing voice of customer ->

develop CDD, trying to determine what they don't have, filling "capability gaps" -> initially go through analysis of alternatives (AOA) looking at different potential gap-fillers and determine what is best option -> go to group that develops CDD (high level capabilities and requirements necessary for the thing to actually function, should dovetail with selection criteria from AOA, CDD is always a word document around 10 pages); written very high-level from perspective of the user, providing some input into CDD development to help with process down the road -> take CDD capabilities (paragraphs, prioritized as KPP, CPP, etc.) -> singularize to get individual requirements and import into DOORS (moving to DOORS next-gen); manages traceability , change management, records change data, etc. -> essentially copy-paste each sentence/paragraph into singularized CDD; example cybersecurity: capability contains 6 requirements and copy separate requirements into new module to show traceability -> create p-spec using CDD-singularized , specific targeting requirements etc. stored in classified side of DOORS -> get reviewed -> once approved by PM and PEO can baseline p-spec -> traceability from CDD -> CDD-singularized -> P-spec -> can highlight changes in parent requirements and affected child requirements -> many opinions on unambiguity and concise and precise language (must not allow contractors to exploit loopholes) (p-spec largely done by systems engineering team, get input from other teams re technical data) -> test and evaluation group helps develop verification and validation section of p-spec (specifies test operating procedure, repetitions)

- Effort a few years ago to develop common requirement reference, some templates for text; subject matter experts reference MIL-standard specs; some have lists of preferred texts
- P-spec initially flagged as draft, flagged with each individual groups review/approval before brought to PM/PEO/supervisor/manager level for on-the-spot review, usually hours of negotiating -> will write VBA script to show changes
- Baselined requirements must go to CCB (similar to group that initially reviewed) -> flip status back to draft -> CCB -> if approved, change approved -> if not approved, revert to baseline (managed in DOORS); change management proposals and workflow managed with Honeycomb
- Common repository to draw from would be helpful, only systems engineering really has access to DOORS; common type of language; some type of database that downward the requirements to align with end user maintenance-type; method to close feedback loop and determine if requirement is "good," method is to be adaptable/agile; visual analysis would be good, helps streamline peer-review process; having a way to highlight forbidden/ambiguous text/language would be good, could be incorporated with functional hierarchy; graphical useful only really early; better robustness in exports (final export must comply with mil-spec 961?) which DOORS cannot write, must use RPE (difficult to use, limited access); flexibility to exports to be detailed in analysis (slice data, metrics views, traceability, rich text, etc.); early graphical traceability; better visualization

Daisy Interview Notes

- Requirements are a critical part of design space; represent boundaries of what is feasible and not; provide gradient of design space; try to emphasize good requirements, should be reviewed and be dynamic; students have hard time recognizing requirements are dynamic and are not all equal; understanding of requirements colored by work with DOE, use lot of DOE terms for tracking (requirement traceability matrices -> requirement test plan and results); documentation is tool to pass along understanding
- Break down understanding of project to goals of project and constraints of specification; go in with checklist to ask questions to ask what did we miss? ; make you go back systematically and look at all aspects of system (may be obvious, but should be tracked)
    - Tell teams that someone is always responsible for requirement (are we meeting it? Do we need to be meeting it?)
- Requirements written in plain test (not always written in complete sentences); differentiate between should and shall; go over pitfalls re writing clear requirements; must be careful that requirements point at right part of system; don't want to box yourself in unnecessarily
- Designee should be regularly going through requirement at a pace along with system changes; should also be periodic overall review (are these still the right requirements?)
- Manage changes with RTM by keeping requirement in document, delineate the fact it's no longer in place, and show new requirement; RTM is hierarchical and can show sub-requirements; RTM and hierarchy made it easier to roll-up test results and show test success/failure
- Requirement review and approval depended on subsystem at DOE; created 4 documents: project description, project design and specification document, project design document (takes requirements down another level (component level)), project test plan
- Give capstone students RTM matrix; PDS also contains same information
- Important to track requirement interaction; computation benefit, may not be visual benefit; requirements linked to others tend to be driving requirements
- Redundancy is common especially early in process; bigger issue is requirements that are not bounding on system
- Are some approaches to try to identify non-bounding in optimization
- Writing good requirements is difficult for students to understand (small-scale and short-term); need to illustrate need; instead focus on big-picture criteria and constraints

Daphne Interview Notes

- PhD from Clemson, now at UMaryland to supervise students doing research in design; design problems are given to freshmen students and students go through conceptual design phase
- Requirement definition is a need or demand from customer or stakeholder that must be met by product
- Students prompted to ask about implicit expectations or wishes needed from product, specific constraints existing in problem, think about what product will do for them; ask about objectives solution should meet; properties expecting product to have; first step is to better understand problem; then use objective tree to summarize/group requirements and objectives
- Requirements written plain-text, students asked to be specific with full sentences, quantified where possible
- Checked requirements after brainstorming/concept selection, may redefine requirement set (add/delete)
- No real changes made, as long as students proposed changes and justified with reason
- Reviews were conducted with students, instructor and guest faculty
- No methods for real requirement management, students just kept a list
- Had exercise with objective tree to cluster related requirements together and tried to see relationships between requirements and make sure requirements did not conflict
- Requirement change justification just discussed, not really recorded
- No specific documentation regarding requirement redundancy
- Objective tree showed clusters/grouping, not really relationships
- Validation of requirements is important (make sure design is meeting requirements); students would need to do testing/simulation with requirements; would need to have specific requirements to be able to do testing

Delilah Interview Notes

- Teach graduate design class, capstone design
- Start with customer needs, map needs to requirements through QFD and House of Quality
- May be groups, not really sure how students write requirements
- Developed with House of Quality structure, no real specifics in verbiage
- Faculty review to make sure requirements cover everything, checklist (Green’s method for customer needs analysis)
- Should revise requirements, don’t unless required to
- No real change management
- Nothing in particular regarding recording, usually House of Quality spreadsheet and PowerPoint or Word

- See examples of requirement propagation and give warning and mentoring, not explicitly part of class
- No real documentation outside of small mention in reports, not suited for scale/scope of capstone class
- Requirement redundancy occurs early, not a problem, both cover requirements partially
- Most important to quantify customer needs, something measurable to aim for
- Conflicting requirements are common, have to do TRIS to see if any way to remove conflict, other trade-off is problem specific
- More concerned with feasibility and flexibility, projects are very exploratory

Diana Interview Notes

- Assistant professor in department of engineering (non-specific field), background in ME, have been teaching design classes (design spine as part of curriculum), taught sophomore classes; requirement teaching is part of process
    - Requirement elicitation, documentation, after elicitation are all taught
- A requirement is something that needs to be fulfilled for customer satisfaction (personal definition); uses chart to teach students/make it easier to understand; chart has definitions of different terms related to requirements; also talk about writing good requirements (specificity, completeness)
- Conduct a workshop for junior design students (capstone year 1); have students examine requirements; on how to write requirements; requirement format depends on project, reported in table; must record elicitation methods, must give justification for why requirements included, any changes
- First semester of capstone focused around problem definition and requirements elicitation and definition
- Elicitation done through surveys, interviews, and focus groups; may teach additional methods if relevant to projects; conducted by students, may take input from project advisor or professor
- Requirements are reviewed as part of report, assignments regarding individual and team understanding
- Feedback from report used to revise and rebut comments, change requirements
- Students add requirements between semesters (active) as well as feedback
- Asked to strikeout deleted requirements and highlight changes in report/rebuttal
- No real requirement management techniques besides table
- Not many issues with redundancy; more common to combine requirements
- Conflicting requirements only common with project teams; TRIZ is only real time students might notice conflicts
- Linkage maps between requirements would be useful; do do it for stakeholders
- Each element of a requirement is equally important; distinction between criteria and constraint is important

- Typing characterization of requirements would be very helpful as teaching tool
- Very disjointed between requirement development and concept generation, happen in isolation
- Differences between project depth/length and how incorporated into tool
- Differences between industry-sponsored and not industry-sponsored projects

Appendix B: RCM Interview Transcripts

Interviewer: Oh yeah, there we go, there we go.

Interviewer: Now I got it.

Interviewer: Okay.

Interviewer: Yes. Can you give me a little bit of background on sort of what your role is with regards to requirements and sort of how they

Interviewer: Play into I guess what you do with deep orange.

Charlotte: It's one my my responsibility is that I oversee

Charlotte: All of the deep orange projects.

Charlotte: Typically there's another faculty member involved, who is the lead for each specific deployment project.

Charlotte: So right now I'm working with Dr Pruka on Deep Orange 12 and I will be working with doctors Pilla and Brooks.

Charlotte: We can fill out an engine on Brooks on Deep Orange 13

Charlotte: And

Charlotte: We use a

Charlotte: We try to use a

Charlotte: Systematic systems engineering process.

Charlotte: Itself inspired by the systems engineering team model.

Charlotte: Where we provide to the students initially

Charlotte: Some high level level say mission level requirements.

Charlotte: And then it's up to the students to build design and build a concept vehicle.

Charlotte: That

Charlotte: Speaks to those requirements.

Interviewer: Okay.

Charlotte: Not saying satisfies these requirements, because oftentimes we actually leave a fair amount of freedom to the students to to set the system level requirements.

Charlotte: So we may provide the US context for the vehicle and theme saying these are certain things that we would like to see emphasized in the project and we leave it up to the students to translate those

Charlotte: Project

Charlotte: The project theme and context into vehicle level requirements.

Interviewer: Okay.

Charlotte: And then ultimately, of course, we take the vehicle level to province and try to drive it down to level two level three requirements and that is up to the students.

Charlotte: Were not very formal, in which, in which way we in the way we do this at this point, to be honest with you. That's why Josh and I talked about

Charlotte: Coming up with some better instructional materials and methods and tools for helping the students improve that part of their overall

Charlotte: Project

Interviewer: Gotcha.

Interviewer: Yeah.

Interviewer: Okay.

Interviewer: So is

Interviewer: It is how do you just, what would you define requirements as like there's no, there's a bunch of different ways to do it, they all sort of mean the same thing. There's different little nuances.

Charlotte: Yeah, I

Charlotte: Mean

Charlotte: I just typically

Charlotte: Describe to the students that they are constraints that we choose to impose on the vehicle.

Charlotte: We typically discuss how

Charlotte: They should be phrased.

Charlotte: So that they can be unambiguous testable verifiable.

Charlotte: And

Charlotte: So that kind of matches the expectations of systems engineers.

Charlotte: Beyond the scope of our project.

Charlotte: To retain it. We really follow some generally established rules for how requirements are phrased so that everybody understands them properly.

Interviewer: Right.

Charlotte: And but we make it very clear that requirements are not actually required

Charlotte: And they're just a way of expressing

Charlotte: The choices that we're making about the vehicle and about the project in general.

Interviewer: Okay.

Charlotte: Let me. I mean, I guess there we agreed to stick to the requirements until we agreed to change them.

Charlotte: But I mean that's that's an important point to make, I believe, because students have only been

Charlotte: Exposed to context in which

Charlotte: A faculty member so gives them a design brief and the list of requirements and then they need to. They're responsible for satisfying the requirements, somehow, and

Charlotte: We, we really try to make it clear that these requirements are not given to you. It's a decision process and you need to understand how you decide, a lot of requirements.

Interviewer: Okay.

Charlotte: Is anything that's what I'm saying. Doesn't match quite your perspective on what you have learned

Charlotte: Working with

Charlotte: Dr. Summers and

Charlotte: Let's, let's discuss further design you know if my perspectives, but I i

Charlotte: Value the perspectives of others who may disagree with me. And there's always an opportunity to learn them multiple people disagree. So

Interviewer: I think I think what you're saying, makes sense because with what I've learned so far. I think so.

Interviewer: So you mentioned that

Interviewer: You sort of give some general mission level requirements and then this, it's up to the students to develop more, I guess, granular

Interviewer: Vehicle level requirements.

Interviewer: Is this the students, who's involved in that. Who else is involved requirement. Great. I

Charlotte: Mean we the project is a student project. So it's ultimately the students who need to take responsibility.

Charlotte: For the of course there. We have a faculty members involved.

Charlotte: Guide to students and who

Charlotte: Provide feedback and and further input.

Charlotte: In for some parts of the project.

Charlotte: Students black background.

Charlotte: And oftentimes standard becomes faculty members who will be the driving force behind those portions of the project, but we're trying to avoid that and make sure that students are the ones who carry the load.

Charlotte: But typically, so Alyssa of currently deep orange 12 besides the student team.

Charlotte: We have

Charlotte: Dr. Rocha who oversees the entire project and is the power train specialist. So he helps us with power train issues.

Charlotte: We have Dr schmoozer who is responsible for

Charlotte: Anything that relates to structures CAD modeling FEA analysis design of the structural aspects of the vehicle.

Charlotte: We have Dr. Qulin Zhu, who is responsible for vehicle dynamics works with the students on the modeling of the

Charlotte: View that dynamic properties of the vehicle and controls at that level.

Charlotte: We have Dr. Schmidt, who is responsible for the higher level of control waypoint following autonomy level control and I also participate in that aspect of the vehicle that includes not just the software, but also the suite of sensors that are necessary to make the vehicle autonomy enabled.

Charlotte: And then we have

Charlotte: Marco Rossi, who was electrical engineer and helps out with the electrical architectural vehicle.

Charlotte: Batteries alternators making sure that everything is properly powered and etc.

Charlotte: And then we have

Charlotte: Control Khan, who is more the implementation person who helps with any manufacturer ability issues that we may run into and helping the students design for manufacturing

Charlotte: And then we have one person who's not technical, but takes care of all procurement issues.

Charlotte: Okay, that's our current team.

Interviewer: Gotcha.

Charlotte: So if these projects are fairly large in scope.

Charlotte: And it's not unusual. We typically there between one and $2 million per project.

Interviewer: Oh, I

Interviewer: Didn't realize it was that large of a scope. Wow, that's impressive.

Charlotte: We actually did an estimate of the, the cost of the current vehicle.

Charlotte: If we work to purchase everything at the commercial cost a commercial prices and we're looking at about $830,000 so just just the cost of the vehicle, not the engineering cost, but just a constant, the parts and assembly.

Interviewer: Wow.

Interviewer: Impressive.

Charlotte: It's fun. Most with that way. Yeah.

Charlotte: You don't have to pay for it yourself.

Interviewer: Absolutely.

Charlotte: All right.

Charlotte: Did I answer your question. Oh, I forgot I went off on this.

Charlotte: One.

Charlotte: But the role of the faculty and yeah yeah I think

Charlotte: These are the faculty involved and we guide the students, but we don't necessarily

Charlotte: Do the work

Interviewer: Gotcha.

Interviewer: What does engine, there's like some feedback sort of loops and that sort of thing.

Interviewer: For both students and the faculty. Is there any sort of like review process on the requirements. They've made it could be formal or informal that

Charlotte: Yeah, so we have

Charlotte: We meet with the students twice a week.

Charlotte: Once, once a week to split the entire team.

Charlotte: And then once a week is in subsystem teams where they focus on their subsystem capabilities and design.

Charlotte: And then we actually have some cross cutting teams also where their capabilities that require so much coordination between the different subsystems teams.

Charlotte: That we need to have a weekly touch point in order to make sure that everybody stays on the same page.

Charlotte: Okay, but

Charlotte: Staying on the same page is actually very difficult and

Charlotte: If anything, then this is where

Charlotte: Or having some formal way of dealing with requirements will become very important.

Charlotte: Currently we

Charlotte: Mean, what happens is that in one of those meetings, the students discuss something and they come up with a solution for the issue that they were struggling with. And the solution is, of course, to change one of the requirements.

Charlotte: Either because I mean the way they flow down the current level requirement into more detailed requirements or sometimes even say, Well, you know, why are we even doing this requirement, let's just change it. And before you know it.

Charlotte: The rest of the team is working on new one set of assumptions and

Charlotte: They've moved forward with this modified set of assumptions decisions requirements and

Charlotte: It's a week later, when somebody says wait a second, but this that's not how it works, or that's not what we've been assuming, and so we kind of need to go back and fix things.

Charlotte: And

Charlotte: I don't know what what the right answer is to that having more formal requirements is fine, but keeping these requirements, up to date is challenging.

Charlotte: And making sure that everybody reads the requirements and is familiar with them is very challenging. So having some some methods and tools to manage that overall process would be extremely valuable.

Charlotte: The challenge I think in part is that in a in a real organized engineering organization you have systems engineers, whose role, it is to just do that manage these requirements.

Charlotte: And on our teams. The students are Automotive Engineers and they get excited about designing the power train or designing the suspension of the vehicle, the very few of them are excited about managing the requirements and so

Charlotte: I need somebody who's willing willing to take on the role of managing the requirements is mean students don't look at that as an exciting role.

Charlotte: And that becomes about

Interviewer: So,

Interviewer: How do you think about having some issues with requirement management. Are there any tools that you have now, even if they don't work very well that you're using for that are

Charlotte: Mostly Excel and PowerPoint.

Interviewer: Okay.

Charlotte: Can we can call that

Charlotte: And I think, in practice, even those tools are not used very rigorously, to the point where

Charlotte: Some of mean it's basically

Charlotte: Relying on the information stored in people's head.

Charlotte: I have asked students to be more precise and write a requirements document.

Charlotte: Specifically for software.

Charlotte: And it turned into a

Charlotte: No, it was not. It was not successful. And the reason was, I think that they were just not familiar enough with what

Charlotte: A requirements document should look like. So we did provide them with examples, but then once they

Charlotte: We gave them the structure of a requirements document.

Charlotte: Give them some examples of how requirements can be framed within that structure.

Charlotte: But they were not able to

Charlotte: Capture

Charlotte: Their domain and expressive in in that similar form.

Charlotte: I

Charlotte: In part of it, I think.

Charlotte: Was that they simply

Charlotte: Did not have enough software development experience to understand what software requirements should be about

Charlotte: They their approach was let us write some software. Let us develop and implement some of the features we know we definitely need and then we can come back in and expand and look at this more formally.

Charlotte: But I hate to tell you that even the implementation of the features that they would definitely will need has been a struggle.

Charlotte: That they're not software engineers and it's it's turning into a big issue.

Interviewer: You mentioned you have sort of like, I guess. Examples of requirements list. Do you have any handy that you could share with me.

Interviewer: Me now.

Interviewer: But

Interviewer: Get them for me.

Charlotte: After this mean the kinds of things that the students will do is

Charlotte: For instance, power train, they will come up with a list of requirements in terms of how many horsepower. Do they dissipate needing what's to build volume for the engine that they have to stay within so geometric integration constraints.

Charlotte: Interface constraints in terms of

Charlotte: How, what kind of

Charlotte: Embedded control unit can is it compatible with

Charlotte: The we they went through a huge analysis of different engines.

Charlotte: All almost completely focused on

Charlotte: Geometric integration issues.

Charlotte: Because it turns out that that is the most stringent constraint for the problem that we're currently working on

Charlotte: race cars are very, very close to the road surface. And that means that the distance between the center line of the crankshaft and the bottom of the engine.

Charlotte: Is extremely small.

Charlotte: So,

Charlotte: My all of the engines that we could find on the market was only one that actually

Charlotte: I click the original engine for which the vehicle was designed but

Charlotte: That engine because $90,000

Charlotte: And

Charlotte: Then a new engine or an engine made by Honda that we can modify

Charlotte: We're going to work with on the Asian

Charlotte: Culture

Interviewer: I

Charlotte: Need to be a little bit careful. I mean, I was going to say, I can share that document in which the students that the analysis of these power train requirements.

Charlotte: That some of the information in there is proprietary and

Charlotte: You can, you can, I can give it to you after you sign a bunch of NDAS

Interviewer: Okay.

Charlotte: Well, it may be worthwhile doing that. If you're gonna if you're going to work on this. And if you want access to the data in a project.

Charlotte: Then, then what

Charlotte: Would be the right thing to do is for me to give you

Charlotte: Set set you up such that you set that you can sign these and he is

Interviewer: Okay.

Charlotte: Is that something of interest.

Interviewer: I think so.

Interviewer: Okay.

Interviewer: That'd be nice to see some examples of what you've got easier sort of move forward with it, I think.

Charlotte: Okay.

Charlotte: I'm going to give you access

Charlotte: Under the assumption that you will

Charlotte: Sign these NDAs.

Charlotte: Mean, strictly speaking, I shouldn't do it in two steps. Right. First, I asked you to sign the NDA and then give you access but it's easier to do it all at once and

Charlotte: We appreciate it if you send me send us

Charlotte: Yep.

Interviewer: OK.

Interviewer: I will

Charlotte: Oh, I won't pay attention to what you're saying. So

Charlotte: I'll probably just after we are done.

Interviewer: That's fine.

Interviewer: Okay, tell me a little bit about sort of the training process on writing requirements, that sort of thing, is there one that

Charlotte: I'm sure

Charlotte: Like a class.

Charlotte: Very little.

Charlotte: So I talked about the requirements, very briefly in one of my

Charlotte: Classes for driven introductory course on systems engineering and the courses actually mostly focused on gaining a better understanding of or basic understanding of the individual subsystems of a car and how they

Charlotte: interact with each other and how

Charlotte: Requirements for one subsystem interact with requirements for a soda before another subsystem.

Charlotte: But we're writing requirements itself is actually relatively brief in them, and Josh actually share with me some slides that he uses in in his

Charlotte: Maybe Capstone design course and I will work written a few said to incorporate some of those into future

Charlotte: offerings of my course to so that we can do a better job.

Charlotte: Of it.

Charlotte: Yeah.

Charlotte: I'll be happy to share the lecture and which requirements come up

Charlotte: Yeah.

Charlotte: Basically have one lecture in which we cover this, so it's

Charlotte: Not very not very detail.

Interviewer: When you do the sort of like reviews and discussions of the requirements.

Interviewer: Do you take anything like any feedback from previous projects and then apply that towards revenue generation requirements lessons learned, that sort of thing.

Charlotte: Each project is very, very different. So

Charlotte: Are you

Charlotte: Try to understand the question.

Charlotte: Is it lessons learned about how to write requirements versus how

Charlotte: Understanding

Charlotte: We so

Charlotte: We can we can learn

Charlotte: About automotive systems in general.

Charlotte: For instance, understand gain a better understanding of how requirements for one subsystem influence for firms for their subsistence.

Charlotte: Level of learning. But then I think

Charlotte: What would you do a friend question was more

Charlotte: Given the domain in which we're working

Charlotte: What is a good process for managing the requirements and and part of lessons learned about how to manage the requirements carried over from one year to the next, that

Charlotte: Yeah, so

Charlotte: The their character carried over based on

Charlotte: Me through the faculty basically

Charlotte: There are some

Charlotte: In the past it was very strict about

Charlotte: Keeping each project.

Charlotte: Separate and

Charlotte: Because all of the NDA is that we typically have involved.

Charlotte: As usual, at the end of the project for air to be 1015 and the A's in place.

Charlotte: And so for the next generation of students then can access

Charlotte: The information they would need to we need to be confident that they abide by all of these meds.

Charlotte: And secondly, then

Charlotte: As you will see yourself. It's not necessarily easy to navigate the repository of information.

Charlotte: And find what you need.

Charlotte: I don't even try it out myself to be honest with you. If I need something done. So you look for the students. And based on that. Point me in the right direction.

Charlotte: Is

Charlotte: Keeping at all of the information organized is extremely challenging

Interviewer: Yes.

Interviewer: Can you tell me a little bit more about like sort of how you

Interviewer: I guess the other level of that sort of

Interviewer: Lessons learned about the requirement relationships and that sort of thing. And

Charlotte: The relationships to the word problems that also I think it must be carried forward.

Charlotte: Through the experience that the other faculty members.

Charlotte: I mean it happens often where the faculty member will say, Oh, yeah. But, you know, based on my experience, either from working in industry or from a previous people orange project.

Charlotte: This will not work. For this reason, or something along those lines.

Charlotte: Students typically do not have that level of experience challenges that

Charlotte: Many of them have no significant experience designing at all.

Interviewer: And

Charlotte: The ones who do

Charlotte: They have worked, maybe for two or three years and in an industry and

Charlotte: A typical entry level job and the other modes industry is very you taking responsibility for a very small portion of your overall vehicle.

Charlotte: Then really ever at the architectural level of how the vehicle comes together and what the trade offs are being them. I don't know. You may, you may, the person who does the door handles. See what I'm saying.

Charlotte: Then you're an expert in door handles, but it doesn't really help you understand at a systems level what what the trade offs are that are being made within the vehicle.

Charlotte: And

Charlotte: So that's, that's what most students come in with

Charlotte: And that's part of the learning experience of the boring just through can

Charlotte: Gain

Charlotte: Better skills in systems level thinking as well as gaining the domain knowledge then

Charlotte: At the system's level.

Charlotte: Yeah, I'm not sure what the best way is to teach them other than through experiencing it.

Charlotte: And that's basically the punch approach.

Charlotte: And we learn from students through, you know, it's not just that we're the

Charlotte: People who have all the knowledge and we share with the students. The students through their exploration and through

Charlotte: The exploration of all the technologies that they can find information about online students often come up with ideas than we initially would not have considered

Charlotte: Because just that's not how it's done. And seeing them.

Charlotte: And but then the students will explore it. And it's a no no. In this context, this is the way that

Interviewer: Can you sort of talk me through. I guess just sort of the requirement process overall from start to finish.

Interviewer: I guess for the the deep orange 12 project if you want to use an example.

Charlotte: For one second.

Charlotte: Britain Walker, just me an email saying I need access to the Deep Orange Sharepoint repository. So if that while I'm doing that.

Charlotte: I may as well send it to you to while I'm at it

Interviewer: mgsutto@clemson.edu

Charlotte: Okay.

Charlotte: giving you access as a visitor, which basically means that you have read only access to everything.

Interviewer: That's great.

Interviewer: Thank you. Yeah.

Charlotte: So due process.

Charlotte: Let's see.

Charlotte: Initially is at the at the highest level we describe to the students.

Charlotte: The theme and the context in which the project is being prayed that those things are

Charlotte: typically defined i mean it's it's you could call it a high level design brief, but it's very high level. It's something that the faculty members typically sketch out with the

Charlotte: Sponsors involved.

Charlotte: For deep orange 12 is very simple.

Charlotte: I'll give you the march 11 and 12th rights over the orange 12. It's very simple. Basically take a Dallara.

Charlotte: IL 15 chassis and

Charlotte: Turn it into a vehicle that can break the world record for

Charlotte: autonomous vehicles at time mess in Indianapolis Motor Speedway.

Charlotte: So make it autonomous and break the world record for autonomous

Charlotte: That's kind of the context.

Charlotte: And then the students and the students will

Charlotte: Take that high level context and say, okay, what does that mean

Charlotte: What, what do we get to work with. Can we get the information about the color chassis and so we understand what the constraints are in terms of

Charlotte: Integration and packaging that we need to worry about integration packaging typically drives the project packaging as usual strength that we always struggle.

Charlotte: So,

Charlotte: Given that information.

Charlotte: Yeah, you could look at it from a perspective of functional decomposition. If you are drive this vehicle Tom's then

Charlotte: The question becomes, what are the functions that it needs to

Charlotte: satisfy in order to achieve that functional requirement at the top level.

Charlotte: And

Charlotte: We actually asked the students to think through that fairly

Charlotte: Explicitly so we basically told them do a functional analysis.

Charlotte: And make sure that

Charlotte: We identify everything that needs to be implemented all capabilities that this vehicle shall have in order to meet meet that goal.

Charlotte: And so, you know, it comes down to being able to sense the environment, being able to localize relative to this environment being able to

Charlotte: generate enough power to achieve the speed necessary for the world record.

Charlotte: Being able to do so safely.

Charlotte: Without

Charlotte: any risk of losing traction and spitting out and crashing the vehicle.

Charlotte: But then it turns out that there's all kinds of additional requirements that follow from there.

Interviewer: And

Charlotte: We, we asked the students to

Charlotte: Go through some videos of how a racecar driver operates the vehicle. We actually have them interview and talk to

Charlotte: The people who designed these racecar vehicles will typically understand how it should be operated and turns out that there's all kinds of details that that come up that nobody was familiar with or talked about

Charlotte: Or yeah

Charlotte: All kinds of surprises that come out of that and that the lead to additional requirements.

Charlotte: But so, yes, we were basically

Charlotte: Trying to I what we teach the students is that they think about the vehicle and functional terms.

Charlotte: Functional analysis and decompose the functions into sub functions.

Charlotte: For each of the sub functions that they identify

Charlotte: Working principles and

Charlotte: Solution approaches for implementing these functions.

Charlotte: And then perform

Charlotte: In a hierarchical fashion first that the subsystem level. Now the component level that they perform an analysis.

Charlotte: To

Charlotte: Arrive at a step of non functional requirements are basically performance characteristics of the subsystems that need to as a reasonable trade off.

Charlotte: In terms of

Charlotte: Yeah, trade off between the different subsystems.

Charlotte: Typically there's phone subsystems that dominate and really drive the overall

Charlotte: Nickel power training for the report itself vehicle is extremely important because

Charlotte: You have to go. Hundred and 80 miles per hour. You need enough horsepower and

Charlotte: Everything else needs to be designed in our to then support that are required horsepower in order to make that vehicle.

Charlotte: Reach the world record speed.

Charlotte: And

Charlotte: So in this case, then, then that requirement really dominated

Charlotte: And normally, you have you have quite a few trade offs that you can make because you could say, well, I can do, I can get away with less horsepower, but

Charlotte: I'll just make the vehicle lighter or something along those lines. But unfortunately, given that we started from an existing chassis the stray dogs were already decided we we could not go back and change that.

Charlotte: Without changing the entire chancy so making a lighter is not possible. It's not possible. The only thing that we could do is make the engine more powerful and

Charlotte: as powerful as possible within packaging constraints and at a reasonable cost.

Charlotte: You could put in this $9,000 engine. But that was

Charlotte: Something that we would prefer not

Charlotte: The cheaper option that we're now going for is still about 40,000 to 30

Charlotte: But that's, that's just the nature of racing. This

Charlotte: There's nothing

Charlotte: Yeah.

Charlotte: Areas where there were trade offs to be made for instance.

Charlotte: Electric Power was, it was, was one of those, you know, whenever you have

Charlotte: Common resources that are shared among multiple subsystems. Always have important trade offs that needs to be considered electric power in this case was one of those

Charlotte: The alternator on the vehicle that normally provides electric power was not sufficient.

Charlotte: The pirated provided is not sufficient to

Charlotte: Power all of the electronics that need to be on board for it to be eponymous

Charlotte: To the engine. So we needed to resize the alternator and that became actually the big issue because, you know, you can just put a huge alternator on these cars and still make it work for a packaging perspective.

Charlotte: So we're or our solution at this point is to

Charlotte: Get a pretty fancy alternator commingle McLaren.

Charlotte: The race car company in the UK and it costs a lot of money. We basically that's it can produce around 50 amps.

Charlotte: So yeah, that that is the power and

Charlotte: It's

Charlotte: It's expensive. It's expensive alternator. Let's buy

Charlotte: But yeah

Charlotte: So anyway.

Charlotte: But that becomes an issue then because you know every team is asking for more power. We need more power to you know we want to be your computer or

Charlotte: Your computer was basically the main drain on power and it has additional constraints in terms of it's not just how much power with the quality of the power and be

Charlotte: carefully controlled, because if it, if the voltage drops, even for a split second that the computer will reset them use the car. So we need to be really careful about the trade offs.

Charlotte: Second trade off always is the green power and vehicle dynamics.

Charlotte: Because you can change the chassis slightly by changing the angles on the wings.

Charlotte: Changing the tires, potentially, and those that trade off as soon as you change the angle on the wing in order to give you more downforce and better traction though,

Charlotte: Even more horsepower in order to get up to the desired speed. And so those kinds of trade offs are have been have been discussed by the speakers.

Charlotte: Throughout in our country.

Charlotte: Is very nonlinear process. Right. So it's not so the reason. Okay, let's come up with the requirements and then we

Charlotte: Once we have decided on service level requirements we will go to the component level and you're done it.

Charlotte: Is in constant flux

Charlotte: And in the case of of this project is extremely challenging because

Charlotte: One of the driving constraint is keep the cost low as low as possible. If we, as the car will be used by universities to race against each other.

Charlotte: And we call these universities.

Charlotte: You can participate in the race as long as you buy this $850,000 car.

Charlotte: That's not broken.

Charlotte: It's not, not the way it's going to

Charlotte: It's going to work.

Charlotte: So we need to bring the cost of the car down and

Charlotte: That that the result is then that

Charlotte: Even though we made it a choice. We nailed it down.

Charlotte: Maybe back in April or May already you're revisiting some of these choices because it turns out that the epic that that there's cost implications left and right or suddenly a sponsor goes forward and say, oh, this computer that you're using. Previously, we have a similar computer

Charlotte: That we will give to you for free if you make us an official sponsor of this competition.

Charlotte: Then of course,

Charlotte: You know, are the people who are running this competition, say, oh, yes, by all means Clemson. Can you make it work and

Charlotte: We need to go back to the drawing board and look at it from a cooling perspective, from a packaging perspective from electric power perspective air all of these things need to then be revisited

Charlotte: To make sure that we can accommodate this new component that we were previously not counting

Charlotte: Yeah.

Charlotte: Okay.

Charlotte: Just to keep an eye on the clock. I have a hard stop at noon.

Charlotte: Okay, all my sponsors.

Interviewer: Gotcha. I think that's about what had you give me some good information.

Charlotte: What's, what's your background.

Charlotte: And experience with requirements

Interviewer: I did my undergrad in Mechanical Engineering here at Clemson

Interviewer: Yeah, so

Interviewer: I have a little bit of the

Interviewer: Design side experience from that and then

Interviewer: Just a couple of internships. So I'm still learning a lot about requirements as I go.

Charlotte: Before before before your mechanical engineering capstone project.

Charlotte: How formal. Were you there in in your arms.

Interviewer: Ours, I

Interviewer: It's hard to say because I was really didn't change very much. We had a fairly simple problem. I think

Interviewer: Our sponsors, were pretty flexible about what they wanted out of it. So,

Interviewer: We didn't have to do with a ton of changes, but we we tried to keep it fairly formal we had a spreadsheet with a big long list or PDF and that's where thing.

Interviewer: For the updated as we went and strike through and dates and

Charlotte: Yeah, I mean, ideally, this

Charlotte: We would definitely love to use an approach that is more formal than what

Charlotte: I recognized or probably doing. It's not working.

Charlotte: But a spreadsheet has the problem that we have

Charlotte: 41 students on the project right now at the faculty due to that think take on the order of 40 to 50 people involved in the project.

Charlotte: And we need to make sure that there's visibility across the project in

Charlotte: The in the into these requirements.

Charlotte: And typically

Charlotte: Yeah, number of requirements.

Charlotte: We're definitely in the hundreds

Charlotte: Typically you know by the time we get to level three individual component level. I mean, it would be thousands of requirements. And so that's that's something scalability is

Charlotte: It's very different to do requirements management and you have a project with two or three people versus 40 or 50 people

Charlotte: And so any any improvement that we can come up with in order to help support that.

Charlotte: To me that so scalability is is a challenge.

Charlotte: Combined with

Charlotte: I think

Charlotte: If requirements management.

Charlotte: Becomes

Charlotte: A full time job.

Charlotte: In and of itself, then that'll was a problem.

Charlotte: I know that in then in a large organization that a large project. Yes, you will have multiple people probably don't do anything but

Charlotte: Managing your requirements and updating the requirements in the database and making sure that everybody's familiar with them and making sure that they're consistent and separate separate

Charlotte: But it will be hard for us to find students who are willing to do that make their deep born to experience to manage requirements throughout the project so that I think this is going to be

Charlotte: Yeah.

Charlotte: Probably the biggest obstacle that we need to work around

Charlotte: So,

Charlotte: I think ideally would be that all students who some requirements management.

Charlotte: And the number of students or do the amount of time that we spend on

Charlotte: managing their requirements and the consistency of these programs across the project.

Charlotte: Will have to be limited. Otherwise, I think Google fall flat.

Interviewer: Yeah. Gotcha. Alright.

Interviewer: I appreciate your time.

Charlotte: No problem now.

Interviewer: Got some good information for me.

Charlotte: I look forward to working with you on them on improving what we do within the four inch, and I hope that mean that the orange can also be a resource for you in helping to evaluate your research and helping you.

Charlotte: Advance your research. Yes.

Interviewer: Thank you.

Interviewer: Good. Okay.

Charlotte: Start to and

Charlotte: Don't hesitate to reach out to you.

Interviewer: Absolutely.

Interviewer: So can you I guess just to start off with. Can you give me a little bit of background Interviewer: How you see requirements and how you use them.

Carmen: Um, so I was very involved in deep orange two through seven.

Carmen: And then I've helped a little bit with one sense, so you know that saying of how you cook a frog, as you put it in the water and then you slowly turn up the heat. Yeah.

Carmen: Nothing happened to me.

Carmen: So with deep orange to the first project.

Carmen: I would say they were probably about a year into it and it just completely fell apart.

Carmen: So then I was

Carmen: So I work in the automotive engineering department and

Carmen: I was talking to the guy who is the head of his name is Paul veenhoven and just to kind of brainstorm with them about what they could do. And then I I guess it was my fault because I suggested a topic.

Carmen: And then that's the direction we went so

Carmen: It was really

Carmen: Kind of from that one. So I would say deep orange two is very different than the other ones.

Carmen: Just because the the first plan for deep orange to just fell apart.

Carmen: But other than that, or deep orange three to deep orange seven we always started off with like a

Carmen: Some kind of a grand vision.

Carmen: So different for each one of them.

Carmen: So for like

Carmen: Five. For example, it was how to rebuild

Carmen: Are not even it you know so frequently. It didn't start with a question of the vehicle is charged with a question of the need, so you know how it is General Motors provide an option for

Carmen: Young people that is more than just a car of getting them from point A to point B. But what is that experience like

Carmen: So there are so many times when it was about the user experience and what could be offered to the user, rather than like I need a car that does this. So make sense.

Carmen: Um, so we would always start off with some kind of a grand vision.

Carmen: And then after that we would do a ton of research and how we did that changed for different projects we usually used auto Pacific

Carmen: And familiar with auto Pacific

Interviewer: I don't think so.

Carmen: Auto Pacific is one of the there's a couple of different surveys that can be used, but their surveys that are offered to new vehicle owners.

Carmen: And then it collects data about what do they like about their car. What do they not like about their car, but it asked, like a bazillion questions so it's

Carmen: You know specifically about

Carmen: Storage and about

Carmen: How you open the doors and is there enough space for your legs and so it's kind of anything and everything.

Carmen: But then in the last several years, auto Pacific is offer also asked data about what are the kind of products that you use, and what are the kind of products that you don't use. So then that way we can really take a deep dive and find out, like, you know what a GM customer is

Carmen: And what the

Carmen: Customer is not and what are the demographics and psycho graphics about where their customers typically live what their salaries were, how many kids, they have their ages and from that it would it would allow us to get a really good feel of

Carmen: Like the customer characteristics and what they currently have versus maybe what they wish they had. Okay.

Carmen: So we would spend a couple of months doing that and frequently Paul and I would work on that before the students ever started so

Carmen: One of the things that we would do too is we would be called it our sandbox, but it's like you. What is the sandbox that we allow the students to play in because giving them complete free rein is just, it's too much.

Carmen: And so it's like, how do you, how do you develop a sandbox that's reasonable. So I would say out of that kind of a research, we usually end up with 100 slides of information.

Carmen: Maybe about, you know, like, who is the company who are the characteristics of these customers. What are they not and it was always completely different for every single deep orange product.

Carmen: And then from there, we would start to develop like user personas.

Carmen: And we would like to have a good draft of those before we ever gave them to the students. And then with the students that they would definitely evolve as far as again like what are the what are the needs and what are the goals of a particular vehicle.

Carmen: But we would

Carmen: Change those every year. So like the personas that we had for deep orange five verses deep orange six verse deep orange seven are completely different.

Carmen: So when I say these, I was kind of like I have a lecture on every one of these topics and there are 870 automotive engineering class.

Carmen: So that's the class that I teach. I teach in the fall.

Carmen: So this is definitely like very high level description of of how we would do it.

Interviewer: Okay.

Carmen: So then getting to the requirements.

Carmen: Some of the other things that we would go through with the students as we would go over, like the brand.

Carmen: And

Carmen: What is the brand mean. And what's the history of the brand and what is the brand and what is not the brand. What are the goals of the company. So the goals of GM versus the goals of Toyota versus the goals of BMW are completely different.

Carmen: So we would spend a lot of time taking a deep dive into what is the company and what is the company, not

Carmen: That way they could understand, like, how are they really making a vehicle that's for Toyota and with Dearborn six we made a it was sponsored by Toyota, but then they spend a lot of time of looking at what is science. What is Toyota. What is Lexus. How are there how are there.

Carmen: Are those different from one another.

Carmen: So to make sure that what we were making that the right

Carmen: corporate logo and corporate fit.

Carmen: We would usually have for all of those, we would have the arm.

Carmen: Program Manager for the company.

Carmen: Come in and talk to the students really get a feel of what is the culture of each one of those companies. So like at Toyota for deep orange six. They're very into the five whys process. So asking the why questions to really deep. Dig deep down to find like that golden nugget of

Carmen: Why our decisions being made, or what is the ground truth that that users are having difficulty with our difficulty with manufacturing

Carmen: So then we would

Carmen: Change our strategies of how we interacted with the students to whatever the sponsoring company was really have a good feel of that company's corporate culture.

Okay.

Carmen: I'm

Carmen: With deep orange seven it was a little bit different because we did the same thing from auto Pacific like we spent a ton of time looking at that, but then that one was developing a new version of like a mini for the premium US market.

Carmen: And we went in and we found all of the information about like

Carmen: The sizes and the sizes of the of the many is and how they had changed over the decades and really focused on some of their

Carmen: Their design. So like minis have circular elements and they have toggle switches and they have creative uses of space and they have like a floating roof line and

Carmen: So then we would go through and make sure that the students understood. Like, what are those kind of heritage things that always really kind of differentiate a mini from another car that stuff size.

Carmen: To see what would make sense for us to carry over into a future generation and what doesn't make sense.

Interviewer: Gotcha. Okay.

Carmen: And then with our personas, we would how we would do that as we usually find

Carmen: Over the years, we realized that it was a lot easier for the students. If we could have pictures for them, of a real person rather than like hypothetical people

Carmen: Oh, if you know say Susie was going to be our persona having pictures that always picture the same person was easier to think about, then if it was like Susie always look different, you know, one time she had short

Carmen: Hair. She had long hair, one time she's

Carmen: You know,

Carmen: a size eight and the next time she's a size 14 so it's just kind of

Interviewer: Like

Carmen: How do we do that. So what we what we would typically do is we would find somebody that you know Paul or I know that we would loosely very, very, very loosely based off of

Carmen: And then we would get their permission to get pictures like off of Facebook.

Carmen: And so we can have kind of pictures of one person and then we would we would loosely based upon that person.

Carmen: But it was nice, too, because then we had like a base reference to go back to every once in a while.

Carmen: And we would do like a start off with, like, a two hour interview with them of know what did they like when they were growing up and

Carmen: What are their hobbies now and what are their hobbies not and so we can have it very, very, very loosely based off of someone but that worked really well to

Interviewer: Okay, that's a good idea.

Carmen: And then after we would do.

Carmen: All of that. So it was really, you know, that was probably a good six to nine months of background research.

Carmen: Okay, then we would start to develop

Carmen: Our sandbox and our sandbox was what is the vehicle and what is the vehicle, not so we would always try to give like based dimensions.

Carmen: I wouldn't say it was necessarily like around a power train configuration or anything like that. But if we could start with just some basics. Then it at least give them a starting point.

Carmen: And then in our, our class that we taught in the fall, you know, we went through the whole process of how do you go from a user's needs and transform those into your requirements.

Carmen: And so we would have a big list of, kind of, you know, what are the must haves and what are the what are the needs and what are the wants of the different users and then from that we would that really help drive a lot of our requirements.

Interviewer: Okay.

Carmen: I feel like I just mumbled a lot

Interviewer: I gotcha.

Interviewer: How did the when she when she sort of give it to the students. How did the students sort of develop requirements. What does that process look like

Carmen: Long transition because if we would start

Carmen: In the fall, preparing them and then in the fall. It was kind of like we had to download all of this information that they would need to know

Carmen: So I would say that it didn't start necessarily with like these are the requirements, because if we started with requirements then it forces you into a box.

Carmen: Right. And what we really needed was to push them on their creativity.

Carmen: So when the fall semester.

Carmen: And then the start of the spring semester. It was more of

Carmen: This is the kind of general idea of this vehicle and we were really careful to not give them specific requirements.

Carmen: And it was more about how you brainstorm and come up with all of these crazy cool ideas that you know are from something that could be implemented to something that you would see on the Jetsons

Carmen: Because if we started with their requirements too early, then it's it box them in

Interviewer: Right.

Carmen: And so we use the opposite approach where it was, you know, really a ton of brainstorming.

Carmen: Where you know so for like some of the things we had over the years where our deep born six vehicle one groups idea was to have a drone flies off of it.

Carmen: Some of the ideas were, how could you

Carmen: Could you put the vehicles and like a covered wagon kind of configurations

Interviewer: Or

Carmen: In a big circle and then it would turn into a big tent and then you can add like like each vehicle would have a attempt that would come off of it and then that way you can have like these little shared hippie communities where

Carmen: People would go camping.

Carmen: But it would be part of it would be covered. You could use your car for sleeping, if you wanted to, but then you can have your camp fire in the middle.

Carmen: You know, it was how can your car. See the clothes that you have on so like you have a blue shirt. So you're you're all of your interior elements would be blue. I have on a great sweat shirt, so all of my interior elements would be gray.

Carmen: So it was

Carmen: Like we didn't really push requirements or even discuss requirements until like the end of

Carmen: Their first fall semester.

Carmen: Because it's like the soon as you start talking about requirements. It's like that whole engineering brain takes over.

Carmen: And you

Carmen: focus so much on the requirements that creativity goes out the door.

Interviewer: Gotcha.

Carmen: Does that make sense so it was more, I think.

Carmen: We push creativity as much as we could.

Carmen: We would have creativity workshops

Carmen: We'd have brainstorming workshops we have, how do you sketch workshops we have

Carmen: You know, we'd have those kinds of things rather than goes straight to the requirements.

Interviewer: Gotcha.

Interviewer: Okay.

Carmen: We would have

Carmen: We would group, the students into teams.

Carmen: And they would

Carmen: Say compete against each other, but at the same point. It was compete against each other.

Carmen: It's like

Carmen: They would work in isolation.

Carmen: And then they would present their creative ideas in front of the entire class.

Carmen: So that really helped people like

Carmen: Think even more outside of the

Carmen: Box, because in the beginning it was more like

Carmen: Okay, I want to have cars, instead of having a window that rolls down from a button. I want it to be a gesture that goes down.

Carmen: Like we wouldn't have to really

Carmen: Really work to praise the creativity and the goofy ideas. I'm comfortable knowing that they needed to get goofy or and goofy here.

Carmen: Because it's like you gotta have a little crazy. So bring it back something that's a new reality.

Interviewer: Right, absolutely.

Carmen: Yeah, so I would say it worked more that way than saying we need requirements right away.

Carmen: And then in the spring semester.

Carmen: We worked with the Art Center and Pasadena, California.

Carmen: So Paul and I would rotate going out there. Probably we each one out once a month. So one of us was out there every two weeks, which is a total pain in the butt, but

Carmen: It kind of kept things going

Carmen: And then we would partner one design student with our engineering students

Carmen: And then that would kind of

Carmen: Get the creative juices flowing in a different direction because the designers would take some of their ideas and just run with them.

Carmen: But it also kind of started to keep them all grounded. Because at that point, then it's like, Okay, well, we can't have a car with square wheels so you can't have a car with doors that are this big or windows that are this big

Carmen: But it was kind of through that partnership.

Carmen: That

Carmen: That they would get

Carmen: more creative, but also start to kind of bring it down to planet Earth.

Carmen: If that makes sense.

Carmen: And then it was there that we would start slowly introducing some of their requirements. So we would give them like

Carmen: You know, what's your real base. And what's your

Carmen: What's your and we we also gave them things like constraints of obviously they had a time constraint and they would have a weight constraint.

Carmen: And they would have a budget constraint that they wouldn't need to work in

Carmen: The budget constraint really came to a lot later when they knew what they were going to do and then having to make choices about what can be produced. And what couldn't be produced, and we would have design reviews virtual designer reviews with

Carmen: Project managers from the company's

Carmen: Some of their feedback, but it was, it was really that we would have like these.

Carmen: Team.

Carmen: Battles isn't the right word, but it was like these team competitions against each other to kind of see which ideas made the most sense.

Carmen: It was at the end of the first year when like a concept would be picked to go forward.

Carmen: And that's at that point, I would say that's when reality hit about what what is in Dreamland versus what can we actually start to think about making

Carmen: So up until that time, they would do things like have tubular structures and they would have just kind of boxes in general for, like, where would a power train go or where would a battery pack go or how many occupants. Do you want to have

Carmen: We had them build a lot of books so out of cardboard and sometimes they would be really small. So it might be like their entire car would be like the size of a book.

Carmen: And they would make them out of like aluminum foil and cardboard so they could just kind of change them. But then we also had like tons of seats and we would, we would have them then practice like

Carmen: What's the space within the vehicle and can you put. Everybody's legs in there.

Carmen: So it was kind of taking it from

Carmen: This abstract to start to go to reality.

Carmen: So I can't say it's like because we had some requirements from day one.

Carmen: Like you had to have four wheels or you had to have like this kind of general dimensions but

Carmen: We really tried to not give them a lot of requirements until

Carmen: The end of their first like so they would have a fall semester and spring semester.

Carmen: And

Carmen: End of that spring semester when it was we would kind of cherry pick the best ideas from all the different teams.

Carmen: And pick one designed to move forward with and then that's really like when the requirements started hitting hard

Interviewer: Gotcha.

Interviewer: Okay.

Carmen: I don't think that that's the process that they use now.

Carmen: But when I was involved. That was the process that we done

Interviewer: Gotcha. Okay.

Carmen: Then how we introduce the students to the requirements that we had

Carmen: When we went through our class. It was, I was very different now than it is to so our class was. It was a three credit hour course. But it was really

Carmen: It was we had like a lab section.

Carmen: So much of it was like, I don't know, they were

Carmen: It was like

Carmen: Downloading car into human

Carmen: So we had some things that were on like. So the things I taught were more about how do you work in a team.

Carmen: How do you think about your user experiences. How do you think about basic human factors we would have exercises where we would bring in, like, if we're doing a project with Toyota. We worked with Toyota and we had

Carmen: Maybe 15 Toyota vehicles and our and our building.

Carmen: And we would have the students do like little usability studies where they would focus on ingress, egress. But then we would also dress them up as

Carmen: Pregnant women or older people, or we would have them put pool noodles under their feet and wrap, saran wrap around their legs. So it's like if you are getting in and out of a car and mini skirt. What is it like

Carmen: As our population is so very male

Carmen: We made them think about boobs and tummies and high heels and skirts and, you know, just like the, the things that they wouldn't normally think about

Carmen: It that way they can really seeing like, what is it like to have

Carmen: A chest

Carmen: With a seat belt versus

Carmen: You know, I've got it.

Carmen: Doesn't matter.

Interviewer: Right.

Carmen: And we would have we would group them so there would be a tall person in a short person in each group.

Carmen: So they could really then see the difference of, like, what are the strengths and weaknesses of this particular type of the car for a shorter person versus a taller person for a thinner person versus a fluffier person so

Carmen: A lot of that first year too is like really getting an understanding of what a car is like for not them.

Carmen: So having them think not about what they want as a as an engineer and what they want. As a consumer,

Carmen: Customer wants. So I would say that was probably

Carmen: One of the hardest things for them to wrap their heads around

Carmen: Because, you know, when we have our students come in.

Carmen: They've all dreamed about building their own race car or their own sports car. And that's what

Carmen: They want to build and they don't dream about building a minivan or

Interviewer: Anything.

Carmen: So it was just kind of going through that process. So we did that.

Carmen: We talked a lot about like the brands and what what are the different attributes that go into the brands and

Carmen: Looking at brands that worked well and brands that didn't work well and how brands make their tag lines and what that means and what it means from within the company to what it means from the public perspective.

Carmen: We would look at, like how you start to set targets we look at the design lifecycle of building a vehicle of what goes into the research versus the pre DEVELOPMENT VERSUS THE the kind of concept development stage.

Carmen: We look at it from the perspective of what is the market need, what is the consumer need, what is the manufacturer need, what is the order the legislative rules.

Carmen: We would talk about like what brands are and what brands are not. We talked about psycho graphics and demographics and talk about trends and like world trends. So 30 year trends 10 year five year trends and where that's going to fit for that vehicle.

Carmen: We would talk about things like

Carmen: So that we definitely spent a lot of time talking about that we would talk about like what a brand images versus what a brand identity is

Carmen: The attributes behaviors circumstances of brands. Again, a lot of time on the auto Pacific data. We will go through maybe 20 different companies have like Ford and GM and opal and BMW of how that works for them and what they've looked at over time.

Carmen: retention rates was always helpful for them to look at

Carmen: The brand development and then we talk about target markets so like

Carmen: With either economic so the how much money people have to spend, but then also like the variability of what are the kinds of vehicles people in the Midwest by versus people in the south for people in the north and why that's important to consider.

Carmen: We think about, again, a lot of what people like to do versus what they don't like to do was really helpful for thinking about packaging.

Carmen: We got your customer vehicle criteria like

Carmen: Let's say more JD power data. Both are emerging and mature markets.

Carmen: Then we go through your what it's like to. How do you make your value proposition for your vehicle.

Carmen: We spend a lot of time talking about

Carmen: sustainable mobility.

Carmen: So we always had a couple of lectures about that they talked about like a SWOT analysis and how you look at, you know, what are the strengths and weaknesses of the kind of vehicle kind of technologies that you're looking at what people are satisfied with they're not satisfied with

Carmen: And then we would go through like for the brand that we were making of like

Carmen: For a particular kind of for a vehicle that was close. Like, what were the key features that were important. What was strategic overkill. What were the low priorities. What were the shortfalls of that vehicle.

Carmen: That really helped him to start to get an idea of with an each one of those, we would go through, like, what are the features that fit with those. And that would lead us into being able to kind of lay the groundwork or

Carmen: Different markets.

Carmen: And then from there, we usually talk about the different cohorts to. So what are different generations warrant. Was whole

Carmen: Data like synthesize all of that data. So once you have all of that. How in the world do you start to put it together. So then you can start to make your requirements from there.

Interviewer: Right.

Carmen: We would give them case studies of some of our previous vehicles that we would make

Carmen: Then we start talking about like the engineering targets.

Carmen: And and then it would be, you know, how do you go from

Carmen: For each one of those again, what is the, what are the corporate targets, whether the legislative targets. What are the customer value attributes that we wanted to look at

Carmen: And how would you start with what is the voice of the customer and how would you start to put that then into metrics and targets.

Carmen: Sometimes we use QFD for that. That would really be based upon like what did the particular OEM what

Carmen: Really would go through like four phases of the QFD of how do you make the targets.

Carmen: So it would start off with like the what's in the house for the product planning.

Carmen: We talked about like how do you have the voice of the customer. And then how do you start to put those into engineering terms.

Carmen: And if it was like a strong some relationship or a weak relationship.

Carmen: And then from there we'll talk about how do you put those and take cascading targets. So what's the most important to what's the least important. And then how do you come up with what you're going to rate it upon. So a lot of those would come from the OEM

Carmen: Some of my come just from legislative targets, so

Carmen: Like all of the crash standards would be from

Carmen: Obviously what the the requirements of the vehicle and we would we would typically do this only for US market. So we would focus on us requirements, but not necessarily European requirements.

Carmen: For many there were some of the European requirements that all of the BMW vehicles must meet to

Carmen: The so we would kind of pick up what was what was

Carmen: More important from them. And then from there, we would start adding like what are the objective measures and how can we think about

Carmen: The different levels. So

Carmen: And then the different levels would be like if I was going to talk about like the design the look and feel.

Carmen: Then that would go divided into interior and exterior and then starting to develop the targets. So for the exterior and might be proportions and might be overhangs that might be

Carmen: What kind of surface. Do we want does it need to be a class a surface or is it going to be something different.

Carmen: We would talk about like the aesthetic issues of what are the design features we want to have with talk about

Carmen: What color the vehicles are going to be and the different colors that different OEM typically use for the interior would be things like

Carmen: You know, what is the, what is your panoramic view are going to be like, because so much of that is set with your eight pillars and your be pillars and we are cowl as

Carmen: We would talk about what are the visual appearance.

Carmen: So is there going to be a center stack. Is it going to be like Chevy where there's the bow tie that goes throughout. Is it going to be more like a mini whether it needs to be some circular elements. Is it going to be, you know, how are you going to creatively put those

Carmen: How many seats are you going to have. So we would, you know, just talk about like our cascading targets that way.

Carmen: And then reused a book with the class that is called H point

Carmen: And that is that was written by there's two guys Stuart Macy, and Jeff wartell and Jeff Bordeaux was one of the designers that we always worked with the Art Center.

Carmen: So it was nice that the one of the books that we used was, you know, but one of the people they were interacting with pretty frequently

Carmen: But that does a nice job of kind of walking me through like all of the subsystems, and the order that you should think about them. And then Paul would talk about, you know, and an engineering level of detail of, you know, the suspension and the engines and it was going to be an ice or

Carmen: Be EV and go through all of the battery chemistries. And so I don't know. It was just an insane amount of data.

Interviewer: Sounds like it.

Carmen: But then we would use all of that for our target catalog and our target catalog was just a huge spreadsheet.

Carmen: And a lot of times that we will also use that to frame like our Bill of materials.

Interviewer: Okay.

Carmen: But both of those documents, then would have all of our

Carmen: Kind of all of our targets and all of our requirements on them.

Carmen: Okay.

Carmen: But such a huge part of it was knowing like your competitors.

Carmen: And what your others do, because it's like, you gotta understand your competitors to know the space that you're going to play with.

Carmen: Right, understand your competitors to make sure that you're not making something that already exists.

Interviewer: So when you talk about like the targets and requirements, that sort of thing.

Interviewer: When you would write them how how kind of was that written, is it more just like a plain text sort of thing, or did you sort of delve into the more parts of speech type definitions for requirements.

Interviewer: You give me an example.

Interviewer: I top of my head. It's not a very good example, but I guess.

Interviewer: There's some

Interviewer: I guess definitions that are like yet have this verb and subject and the modifier and that sort of thing. And

Interviewer: Each piece has to be there to really be a full complete requirement, but a lot of people will just sort of write it in plain text or just the vehicle must have four wheels, that sort of thing.

Interviewer: There was there like a specific process.

Carmen: He may get to I can share my screen. And I'll show you some of these

Interviewer: Try

Carmen: So with the share screen button down on the bottom.

Carmen: Right on the side of that button is almost like if you touch on the there it goes. Yep.

Carmen: Okay, so how we would start

Carmen: Is we would have

Carmen: So we would have our different kind of phases.

Carmen: We would start with voice of the customer. So if we had something like a smooth ride.

Carmen: And then we would look at it from the vibrations of the steering wheel vibrations of the seat interior noise interior noise at highway speed interior noise at full throttle road noise when noise, noise from an auxiliary equipment.

Carmen: And then from there, we would just say kind of what our expectations were going to be for this particular vehicle.

Interviewer: Okay.

Carmen: And then we would have our benchmarking would come from all over the research that we have already done and we would definitely involve the students with us, of seeing like, what is the industry standard and what is the brand standard

Interviewer: Okay.

Carmen: And then when it comes to. So then we spent a lot of time looking at, like, what is our target vehicle and what are the vehicles that are all the way around it and we would do this for a million different dimensions. So, like this one is for tire radius wheel base.

Carmen: And then

Carmen: We would have

Carmen: Like our different level of targets. So the way it would look in their

Carmen: Target catalog. It would be like a gigantic Excel spreadsheet that you could kind of pop these out or bring them back in.

Carmen: So at the highest level it have design look and feel performance comfort and convenience safety and security cost of ownership and quality.

Carmen: And then you would break them out and you would have more and then you would break this out again and then you would start to have all of these

Carmen: And then you would break this out again and then you would have even more. So kind of going through at the second level then for each one of these, we would have, like, what are the industry standards.

Carmen: For performance.

Carmen: And then for comfort and convenience.

Carmen: And we were just kind of keep going through it that way. So these were things that were built over time and not that we would necessarily have a target for every single one of these

Carmen: We would at least have these listed and think about which ones are the most important

Carmen: And then for, you know, passive safety and active safety, it would really depend so I most of the time we didn't, we would use the IHS ratings.

Carmen: So that was the one that was the the clearest understand for our students, but

Carmen: We would list all of these, just to know that if they were going to actually build a vehicle for production that they would not only have to meet all of these

Carmen: And then this would pop out for you know a bunch of other tests, but they would have to take into consideration all of the other ones too. For the other countries.

Interviewer: Gotcha.

Carmen: And then we have our

Carmen: Cost of Ownership targets and our quality targets with quality targets. Obviously we

Carmen: We never met these because it didn't make sense to meet these we aren't going to crash, one of our one and only vehicle, but depending upon which product or which which team. It was our vehicles were never watertight

Carmen: As there they were hand built and and built vehicles. They just don't

Carmen: It doesn't make sense. You know, you need like an extra million bucks to have that

Carmen: You would when they were doing their design. They at least had to think about. I would say for deep horn seven and for deep on sex. It was the the

Carmen: Sponsors really wanted them to think about, okay, what would it take to have this be watertight

Carmen: And what would it take to have it be dust tight so the deep on sex was like an SUV.

Carmen: So that one. They definitely wanted to think about, you know, how are you going to keep

Carmen: All of the dust and small debris out

Carmen: There were some things that we never built like we never built an HBA see system in any of our vehicles.

Carmen: Or in seven that they had to do the engineering and show like

Carmen: How the airflow was going to be and where should they had to

Carmen: They had to think about it from an engineering perspective, even though we never did that from a functional perspective.

Interviewer: Okay. Gotcha.

Interviewer: Can you tell me a little bit about

Interviewer: Sort of your

Interviewer: Requirement change management process because I'm sure that over the course of project, some of the requirements involved in that sort of thing. How did you manage that and work through that.

Carmen: Those were always handled at design reviews.

Carmen: So we had design reviews every couple of months. And the first when we had our first target catalog.

Carmen: Then the program manager. Again, this is my experience. I'm not sure how they're doing it now.

Carmen: But my experience is that

Carmen: Paul and I would put together.

Carmen: The target catalog. The first draft, and then the students would add to that. And then, um,

Carmen: So since I'm not an engineer.

Carmen: A lot of times I would go through and I would do like the BS check first

Carmen: So if I knew it was complete BS then

Carmen: And that's definitely something I got better with over time. And then as like I was a I was a good kind of first read

Carmen: Right. And I could I could find the BS and then we would send it back. And they're like, Okay, this makes no sense, try something else. And he obviously had to do.

Carmen: The more in depth analysis of it since he came from the auto industry, he had done that for so many vehicles that he'd actually built went into production and

Carmen: It was just, you know, part of who he was.

Carmen: But then once we had that kind of lockdown then anytime the students wanted to change a target. They had to propose that at the designer view and the company had to agree to it.

Carmen: And sometimes they did. And sometimes they didn't so

Carmen: And sometimes that company added new targets or more or stricter targets. So, for example,

Carmen: On deep born sex, instead of having four standard doors, there's

Carmen: There's

Carmen: Like that the double open doors like the suicide doors on one side and then there's a driver's door on the other side.

Carmen: So when we went from having four doors.

Carmen: To that kind of a configuration then Toyota added new targets. So they wanted to make sure that we would

Carmen: Be able to meet the pole test.

Carmen: I don't know, there was like three or four of them. But then it it forced the body and white team to go back in and to make some of the structures more robust

Carmen: And so it was, you know, so it's kind of a it was a little bit different with each team.

Carmen: And then some of them were they would be removed. So with deep orange seven

Carmen: We have this windscreen that goes basically from the cow, all the way down to the nose of the car. And so that was one of the innovations that BMW really liked and they wanted to try it out.

Carmen: But because of that, then a lot of our front impact.

Carmen: Standards were lifted.

Carmen: Because it just, you know, like it. It just, you couldn't try something that revolutionary

Carmen: And still have the standards that are designed for a windshield. That goes straight down.

Interviewer: Gotcha.

Carmen: But they most definitely then they looked at, okay, so you have to be able to think about like a pedestrian so if if you had a pedestrian

Carmen: You know, how is that going to work. So it was they would. It would evolve as the

Carmen: Design evolved and as the engineering evolved.

Carmen: And there was frequently standards that the students weren't lifted that either. Paul would not lift or the company would not left

Carmen: And so it was kind of like we were there first voice of yeah seems reasonable to lift this one, but then there would be times where the company would come back and say, absolutely not.

Interviewer: Gotcha.

Interviewer: Okay.

Carmen: And then in our target catalog. Our last tab of the of the document.

Carmen: Is Tad, you know, like those changes. So it was basically like who proposed the change. What was the justification for the change which designer, it was

Carmen: Did the AICAR faculty buy off on it, and if so, then it's which design review. Did it go on to and then was that was that approved or not approved.

Interviewer: Okay.

Interviewer: Looks like some good record keeping.

Carmen: Yeah, because otherwise, you know, things were just kind of Evan flow.

Carmen: And yeah.

Carmen: But it was always like one slide to at each design reveal that was kind of like these are the specific changes that we're asking for in terms of the target catalog.

Interviewer: Catch up

Carmen: But they also had to do the same thing like once they set up their budget.

Carmen: If they wanted to move money from, like, I don't know.

Carmen: Say we got a donation for an engine.

Carmen: And seating concept was going to be really expensive. We have to ask permission to have

Carmen: Like big chunks of their budget to be moved from one to another. And again, that's just because something that happens in industry and we wanted to have them have that experience of of having to ask

Carmen: Ask because of the justifications.

Interviewer: Okay.

Interviewer: What sort of what were the student

Interviewer: I guess attitudes towards requirements, because I know in my own experience. I've seen that some people tend to buy into the whole

Interviewer: Idea of requirements, a lot more and they want to stick to it. Some people do it really wholeheartedly and other people sort of just it's there because it's there. So, what, what sort of where was your experience with the student attitudes towards

Interviewer: Requirements and targets and that sort of thing.

Carmen: I think because it was a vehicle.

Carmen: Like

Carmen: You've got to have them.

Carmen: And if you don't have them. It's just going to be a mass

Carmen: So,

Carmen: And I think to the fact that we we went through and we spent so much time talking about them. And so many of them were about, you know, crash standards. And we gave them case study after case study of of what went wrong and how much recalls cost if you don't meet

Carmen: Standards that

Carmen: I don't think it was ever really an issue. I mean, there were some of them that, for it was almost like they there were ones that we all hated for different cars are four different deep orange projects as

Carmen: If it was one that we ended up hating

Carmen: Because we couldn't build

Carmen: What we wanted to. It ended up being good because it forced us and it forced them to find engineering solutions around it. And I think in the auto industry as

Carmen: Requirements or requirements you have them you live with them.

Carmen: So it's, I don't know, it wasn't

Interviewer: wasn't really an option to not

Carmen: It wasn't an option to to not

Carmen: Deal with them.

Interviewer: Mm hmm.

Interviewer: Okay.

Carmen: And and i think too is we use them is kind of like these, these gates along the way.

Carmen: You had to find a way to make it work within the requirements or else you didn't progress.

Carmen: So,

Carmen: Necessary reality is I guess.

Carmen: I think the way that they were introduced was good too, because we

Carmen: Had a lot of like horrible crash videos. Older cars and then we say, okay, and then this requirement was added and then you could like, you know, see some of those differences.

Carmen: I think the ones that were the hardest were a lot of the things that are out of date now because technology has evolved so much

Carmen: And standards haven't kept up with them.

Interviewer: Okay.

Carmen: But again, it's a made it. I think it kind of helps the students really realize like

Carmen: Why vehicles are the way that they are

Carmen: So it's just

Carmen: No necessary reality.

Interviewer: Gotcha.

Interviewer: Engine that just want to talk through like the target catalog that sort of thing at

Interviewer: The design reviews.

Carmen: Mm hmm.

Interviewer: Who all is involved in the design reviews, which if there's like the company, product manager and the students and the faculty. Is there anybody else.

Carmen: I'm

Carmen: For deforms one

Carmen: I remember that it was like, because

Carmen: I went to a few of them.

Carmen: But it's more like I was in an outside observer. First one, they didn't have an industry sponsor.

Carmen: And so it was like the design reviews were with all of the faculty I car.

Carmen: And that was neat because

Carmen: The faculty were involved.

Carmen: And I would say after that one I think because it was just so much work that the only faculty who are involved are the people who are part of the project that nobody else ever comes

Interviewer: gotcha.

Carmen: So it would be the people who are involved in the project. And then, and then the sponsors and then sometimes we would also have depending upon who the industry partners that we were working with the industry partners would join to

Interviewer: Okay.

Carmen: And each OEM was different, of you know what they were like, so with BMW, they were

Carmen: Intense. And they were long and the questions they asked were exhausting.

Interviewer: Jeff.

Carmen: And with Toyota. It was almost like it was this light hearted fun presentation until I got

Carmen: To the questions and it was like the sick, the devil and he had an angel mask on when it came to the questions, then it's like the angel ripped off.

Carmen: Feared and but it was great because they were all program managers within OEM

Carmen: And they asked hard frickin questions and some of the things that they did to is a lot of sponsors. I was a BMW was different because of the language barrier.

Interviewer: Uh huh.

Carmen: But other than that, they always ask that different students would present

Carmen: Is everybody had the chance to present to industry.

Carmen: And thrilled with industry.

Carmen: And then, but I think the way they did questions was, was reasonable because it's like the presenter had to try first

Carmen: And then it's like you could, you know, tag, a friend of anybody on your team and they can speak to

Interviewer: That is good.

Interviewer: Okay.

Interviewer: I think that's the bulk of my questions.

Carmen: Okay.

Interviewer: Thank you.

Carmen: It's my

Carmen: Talks. I have to run

Carmen: My next thing.

Interviewer: But absolutely, yeah.

Carmen: Hopefully this helped

Interviewer: Absolutely. I think it did. Thank you so much for your time.

Carmen: Yeah. Appreciate it. Absolutely. Okay. All right. Bye bye.

Interviewer: Okay.

Interviewer: Yes, yeah.

Interviewer: So I guess to get started. Can you sort of give me a little bit of

Interviewer: Background on

Interviewer: I understand a little bit of background on how

Interviewer: You interact with requirements and sort of how

Interviewer: Like in your position.

Interviewer: They actually use requirements.

Catherine: Sure, so

Catherine: When it comes to Deep Orange. It's a completely different ballgame compared to what you see in a research project.

Catherine: Now department, you have the vehicle level requirements.

Catherine: That you boil down to each and every subsystem.

Catherine: And then, then the subsystems keeping the requirements in consideration, they're trying to develop the relevant concepts of technologies to meet them, but

Catherine: Even to build the latest level requirements, you need to have a

Catherine: Larger objective or a view.

Interviewer: Right.

Catherine: I think I was one of the key faculty members in the deep orange 11

Catherine: Program. And for that, we actually have a theme sustainable by design concept. And then we went around, you know, within that theme so

Catherine: There was not like specifically saying that this vehicle has to need this much of crashworthiness and all those things, but

Catherine: Those are eventually came up in a sense that when they are sustainable by design concept we were looking at everything from

Catherine: From the building up from the breadth of the vehicle to the running of the vehicle. How can we make it more efficient. How can we make it more economical because all these words, we can talk about economical efficiency everything adds up to the sustainability.

Catherine: So that is basically. So the sustainable by design has been on the back radar, but it has constantly got into each and every thing that we make a decision on so I was primarily focusing on

Catherine: Body in white structures and materials.

Catherine: Interiors, but if you look into any of these things right.

Catherine: When you wanted to advocate sustainability, even in the interiors, then the seats have to be more durable enough so they can last

Catherine: Long on

Catherine: One side, we were making a

Catherine: A a consumer vehicle, not for personal

Catherine: Ownership but for a fleet ownership.

Interviewer: Okay.

Catherine: And it will be

Catherine: It's a big deal that the people can just rent it. You know, we're about and all those things. So

Catherine: When the usage of the vehicle is almost

Catherine: 18 to 19 hours or 20 hours in front

Interviewer: Well,

Catherine: So it could. So I mean to to maximize the utilization

Catherine: Because that's how you can get more economic investment make the make the most efficient, you know,

Catherine: more economical and all those things.

Catherine: So when you're running a vehicle for such a long duration obviously a

Catherine: Lot of different people step in step out in the usage is very vast so you need to make sure the do fabrics that also durable enough

Catherine: So what is the durability mean a condition is a metrics for it. So understand, sustainable by design was the theme. But when it boils down to each one is small systems. You see how we brought her down. Right.

Catherine: So that's kind of how we're looking at and

Catherine: If you think about a typical vehicle usage.

Catherine: You drive. They come to

Catherine: Office and then you're parked in the parking garage.

Catherine: Right, and until evening, you won't even touch it. You go home. We'll put it in a garage. Or you go to groceries and come back and put it so

Catherine: In a four hour cycle.

Catherine: You use vehicle probably for less than an hour. Right.

Interviewer: Right.

Catherine: If you're using from an hour. That means you're wasting a lot of time, that's kind of how it is conceived. Right. Oh.

Catherine: Our key idea has been in the deep orange 11 is to maximize the utilization to your vehicle. So you drive it, you come to the office after it drops you, it goes to pick up other people. It runs like a fleet.

Catherine: And then whenever you need it. Again it comes back. Right.

Catherine: So that's, that's the key idea. So, too, I to maximize the utilization. We felt that is one of the sustainable by design con think sustainability to advocate sustainability.

Catherine: And

Catherine: After people usage. For example, if you even book a cab.

Interviewer: I think

Catherine: You can book a cab until two or three o'clock in the night, but after that it stops right i mean typically cab services are not there.

Interviewer: Right.

Catherine: So what we felt it is the same vehicle once the passenger traffic is done can be used to transport goods, for example, a restaurant may need. And if you look at typical restaurant to delivery things. It gets all the packages food and everything like the packages.

Catherine: In the morning times, four five, you know, that kind of time so

Catherine: This vehicle can also be used for those applications.

Interviewer: Wow.

Catherine: So when you want to use it for that particular service or even during daytime it can it can go for picking up people dropping off people or it can even be used for delivering the Amazon packages, you know, Amazon, these

Catherine: Two. You can do it for private right

Catherine: Right. But when people are not there when you're transporting packages, the seats have to fold and then packages have to go in right

Catherine: The design what we call a certain concept of the configuration.

Catherine: reconfigure ability of the interior was one of the metric that we have

Catherine: And what we need to do the reconfigure ability

Catherine: Because we wanted to accommodate passengers plus packages. Right.

Catherine: So this time sustainability.

Catherine: You maximization of the utilization.

Catherine: Plus, but then you have reconfigureability that evolved out of these things.

Catherine: And

Catherine: Then comes easier durability. Then let's say the floor fabric because when you put packages, you take it off this lot of things right. So your fabrics, your carpet, the materials and

Catherine: Everything that the US has to be durable enough to ensure that this longevity for all of these things to last. Right.

Interviewer: Right.

Catherine: So I perceive metrics aiming for do 13 which is probably where you are.

Catherine: In all of this. I'm also part of deep orange 13, by the way.

Catherine: Okay, so for the deep orange 13 also we were discussing yesterday, we need to have a vehicle level targets to meet but requirements. Vehicle level requirements for targets, but even to get that

Catherine: What we understood is we need to have mission level packets

Catherine: So the mission requirements.

Catherine: Should be provided to us or should be generated by us and presented to GV SC so that they can bless us in that yes, these are the ones and

Catherine: If things are okay then, then fine, but once we have the mission requirements then we all sit together and start putting together vehicle requirements, because if the mission requirements as I'm just throwing up something here. Make

Catherine: It the mission requirements says this off-road vehicle has to

Catherine: Go in northern part of Canada. Right.

Catherine: That's not a mission requirement, that a vehicle requirement. A vehicle requirement - I don't know how it even looks like.

Catherine: But I am

Catherine: Suspecting maybe

Catherine: It may have to do more with.

Catherine: Using the vehicle to battle in combat in in cold, cold regions, right.

Catherine: Something like that. Okay.

Catherine: Okay, then scale requirements down. Is it has to be

Catherine: Minus 30 minus 40 those kind of temperatures. Right.

Interviewer: Okay.

Catherine: And once that kind of thing comes up every material that select within that needs to be good enough to meet that particular outcome so then you can boil down to structures.

Catherine: And, you know, other kind of things. Again, I'm not an expert in powertrain. But as I'm talking more from a structural materials manufacturing standpoint.

Catherine: For the powertrain. So that's really important because you need to make sure

Catherine: If it is electric power train or a hybrid power train you to make sure everything that's there functions properly, they don't get jammed because the extreme cold or extreme hot conditions.

Catherine: Right.

Catherine: And if I answered your question, but that's how I perceive

Interviewer: I think you answered my question.

Interviewer: Um, so, what sort of is the

Interviewer: The process that has been used to develop requirements. So once you have your sort of mission level requirements, how do you then sort of start to tease out the, I guess, more vehicle level.

Catherine: Okay, I'm gonna take back again go back to the deep orange 11 example.

Catherine: The mission level requirements over there or the vehicle level requirements like the vehicle level requirements for

Catherine: What, let me put it this way, sustainable by design was the mission level requirements.

Catherine: And the data level requirements were more reconfigurable designs, high durable fabrics.

Catherine: high durable components right

Catherine: And

Catherine: Energy Efficient powertrain system.

Catherine: long lasting.

Catherine: Long Range battery this thing.

Catherine: Things I don't recall, but we have it.

Catherine: You know, so

Catherine: Basically the beta level requirements will be following the mission-level theme of the sustainable by design theme.

Catherine: But then the vehicle level requirements have their own individual definitions. Okay.

Catherine: And this is where expertise from different domains should come in, should step in

Catherine: Requirements cannot be just written by one person or one Expert. Expert Professor right

Catherine: Right. Whatever I perceive as made materials or manufacturing structures thing may not be perceived by others as it makes sense.

Catherine: Yeah, so I cannot say what the powertrain requirement could be

Interviewer: To meet this

Catherine: Goal, sustainability goal. Right, even autonomy. Deep Orange 11 was also an autonomous vehicle.

Catherine: Autonomous group was looking at a vehicle rental equipment with the vehicle maneuvers in the shortest possible path.

Catherine: Efficient path, something like that.

Catherine: So if you answer your question about how, what's the process. The process. At least I personally like to be and

Catherine: Looked at was there is a mission level theme or a requirement and then now all the domain, people come in and then we all flesh out concepts of how each and every subsystem puts together a requirement map. Okay.

Catherine: That that over sees this as a mission level theme or targets.

Catherine: Does it make sense.

Interviewer: Yes.

Interviewer: So you have the sort of the overarching team and each sub team. And then they all sort of feedback in and

Catherine: Yeah, I think it's a kind of a chicken and egg problem.

Interviewer: Because

Catherine: The way people perceive is your overarching thing and then you have available requirements and then subsystems work towards those make level requirement.

Interviewer: Okay.

Catherine: That could be one way of doing it.

Catherine: The other way is

Catherine: The overarching theme is there and all the subsystem experts come in they together, build the vehicle level requirements.

Catherine: And then they take the vehicle level requirements now focus purely on each and every subsystem and then start listing out individual requirements for that subsystem.

Catherine: You get the difference

Interviewer: Yeah.

Interviewer: So how do you write requirements, like is it just sort of like a plain text.

Interviewer: Just vehicle does or must meet this function or you have some sort of like automated system is sort of

Catherine: Sometimes it's qualitative. Sometimes it's more

Catherine: Defined quantitatively, for example, high durable fabrics. We didn't have any quantitative measurement there.

Catherine: Or the configure ability. We didn't have a quantitative measurement. What we qualitatively knew is that the seats can be either folded.

Catherine: To create space or to easily move to create more space. One of those two right

Catherine: There's no equation. There's no metric or anything for that right

Catherine: But when it comes to structures. Let's say we were meeting say this was an autonomous vehicle, Deep Orange 11. So one thing we completely eliminated or

Catherine: did not consider is crash. But this week.

Catherine: No one knew how autonomous vehicles, what led to the guidelines for autonomous vehicles in future.

Catherine: There are not meant to cash.

Interviewer: Right.

Catherine: If the vehicles in the world is connected and autonomous, they all know if anything is coming, there is no room for error.

Catherine: They are not meant to cash.

Catherine: So that's so when it comes to structures, for example.

Catherine: Carbon fiber tubes. Right.

Catherine: They have to meet certain static load that's a quantified metric

Catherine: Is a particular nose and load that it has to meet because of because they have to have this much amount of strength.

Catherine: So, it

Catherine: Makes us quantitative plus qualitative

Catherine: Measures

Catherine: OK, so the requirements are not all quantitative model qualitative its a mix. That's how I see it.

Catherine: Okay, and sometimes

Catherine: For example, hey long raging and highly efficient battery.

Interviewer: Pack near

Catherine: The available technologies we didn't say that we need to meet certain energy

Catherine: Capacity. That was not the intent because we are not researching anything

Catherine: They're not doing anything.

Catherine: We wanted to see how what

Catherine: What's available out there. So we had a A B C D, four different types of battery systems available or battery technologies available.

Catherine: One is best. Other one is lithium so financially or something of that, right, each and you pick which one has. What is the energy capacity of each of them.

Catherine: Was what's this

Catherine: What's this, the this thing. And as you capacity.

Catherine: Versus number of cycles.

Interviewer: You know,

Catherine: That particular information is available and we looked at all the four compared and we said, Okay, this is our best pick

Interviewer: Okay.

Catherine: So,

Catherine: That that's how I mean, sometimes it's qualitative and quantitative. Sometimes it's a mix of when I say makes basically, you start with the qualitative assessment of comparing for different batteries and then you have the data to compare applicants quantity. Right.

Interviewer: Okay.

Interviewer: How do you sort of, I guess, document the different departments like keep like a big spreadsheet or is there.

Interviewer: Yeah, I sort of

Catherine: Deep Orange. And I think we talked about Chris Paredis

Catherine: evidence books

Interviewer: Okay.

Catherine: And that's the requirement by all the students to start putting information in evidence books.

Catherine: standard protocol in there which will be given, and they can obviously for back to previous

Catherine: Deep Orange evidence books.

Interviewer: Okay.

Interviewer: So in the, I guess in the sort of design process. I'm sure you have areas where some of your requirements change.

Interviewer: Had to redefine them something like that. How do you sort of manage and track those changes or is that something you don't have to do

Interviewer: So sort of how if you I guess sort of like the battery thing is if you decide that you're going to go with battery a

Interviewer: You sort of design around that and then you can't get hold of that and you have to go with something that has different specs. How do you manage the requirements that that change around that.

Catherine: Yeah, that always happens.

Catherine: You know that

Catherine: Happened so

Catherine: I still remember.

Catherine: We had a very similar

Catherine: Thing for our generator

Catherine: We had a particular system that we originally designed but then that changed.

Catherine: Honestly, in that, in that scenario we look at the most possible

Catherine: Thing. So as long as it. So we probably prioritize okay this, These are the requirements for this particular system.

Catherine: Which, what are the ones which we cannot. Absolutely.

Catherine: Change. I mean we have to have. Let's see if I'm putting component come in this particular component has these metric requirements. I, my A meets all of them but is not available

Interviewer: Right.

Catherine: Now B meets five of them up - lets say we have 10 requirements.

Catherine: B meets five of them.

SCatherine: And those are the critical to make this functional may be geometric

Catherine: Tolerance, because most of the fence. When you start putting things together.

Catherine: It's the geometric tolerance assembly that makes it

Catherine: So,

Catherine: So you prioritize the metrics that are absolutely needed

Catherine: You start

Catherine: Ignoring or, not ignoring, but putting the other ones on the backseat.

Interviewer: Okay.

Pa: Does it make sense.

Catherine: To the end of the day, you only have two years to make this vehicle and

Catherine: All the luxury. So you have to make choices and this always happens is obviously

Interviewer: Okay.

Interviewer: And there's all of this thing, sort of changes, and that's where things that also recorded in the evidence books.

Catherine: Should be

Catherine: An ideal situation. I don't know if the students didn't but

Catherine: Everything should be recorded in the evidence books.

Interviewer: Okay.

Interviewer: Do you, do you ever do I sort of like requirement reviews. Is it part of like a design review.

Catherine: So that's what we do every week

Catherine: So we have faculty participating in the equal

Catherine: Of course, Chris and I used to sit in all meetings.

Catherine: All the subsystem meetings, I have knowledge in a few of the subsystem information, but I don't have nearly enough knowledge in the other ones, but I used to say to just gain some understanding. But there are other professors who used to participate. For example, Dr. Gia is to oversee the autonomous

Catherine: He used to participate and

Catherine: He, he basically

Catherine: Used to sit in on guide and work. He was only confined to the autonomous group

Catherine: And we used to go to initially used to go through requirements and concepts to what are the concepts to meet those requirements. Right.

Catherine: Once the concept is finalized, then we don't look at the requirement anymore because we know that this concept needs that

Catherine: Then we look at how we implement the concept, but the process of implementation, we again go back to the requirement and say, okay, and are you checking to make sure this meets, this meets, this meets that

Catherine: To answer your question, we do keep a check on it every time.

Interviewer: Okay.

Interviewer: What are sort of like the student attitudes towards requirements. I know some of the design projects that I've done in the past it.

Interviewer: Some people seem to really

Interviewer: Use them like to bounce solutions, and then others sort of just, I guess, don't really buy into the need for requirements. What is, what is it the student attitude towards it. As you've seen,

Catherine: I'm actually seen in Deep Orange seen students do follow it, majority

Catherine: Be one of them.

Catherine: But majority of them I have seen following the requirements map

Catherine: You have to overlook them to

Catherine: make things work out but

Interviewer: But

Catherine: Before they do, they don't do that in silence there. Obviously, you know,

Catherine: Take to make everyone aware of things, but majority of them followed those strict requirements.

Interviewer: Okay.

Catherine: Or at least that we asked them.

Interviewer: Gotcha.

Catherine: I think that's part of the original

Catherine: Meeting and you know we tell them what to do, what

Interviewer: My list of questions, make sure I've got

Interviewer: Everything we need

Interviewer: Can you walk me through. I guess just the process. One more time for, I guess, for deep orange 11 I'm just sort of how

Interviewer: You start from the mission level and sort of like the smaller pieces, like a do you use

Interviewer: Like a Q F D or something like that to sort of drive like smaller pieces of requirements.

Catherine: What is to

Interviewer: Quality function deployment.

Catherine: Design terminology

Catherine: Yeah, okay.

Catherine: See the good thing is we have

Catherine: When I was getting Deep Orange 11, Chris Paredis was part of it.

Catherine: Okay, Chris is the design guy.

Catherine: So he actually

Catherine: Knows

Catherine: What you're talking about QFD system level design requirements and so

Catherine: I'm a domain guy, I have

Catherine: Local domain knowledge in the materials and manufacturing

Catherine: Model composite structures like that. So that's my

Catherine: information.

Catherine: So my, my thing is when it comes to process, they said before, we do have a mission level requirements and we say, guys. You have to meet reconfigurability, but we don't simply go into the students, you have to be confident, doesn't matter.

Catherine: The reason for it. Right.

Catherine: Right. Reconfigurability because of

Catherine: This reason. But overall, what we tell them is sustainable, by design is what you have as a theme.

Catherine: And ins, which I was talking about in

Catherine: Terms of energy efficiency long-ranging engine and all these things.

Catherine: Evolve out of lot of discussions from the students

Catherine: Will not always tell them what to do.

Catherine: Four or five months for students to do a lot of study and mood. I was talking about package delivery at nighttime that is something students found out.

Catherine: Okay, and how long we can run, you know what, and

Catherine: Delivering Amazon things delivering packages.

Catherine: Folding SEATS. THOSE LITTLE BIT details and all

Catherine: That for everything they have to tie back to

Catherine: The

Catherine: theme, which is the sustainable by design. And once you have that, we say that high durable structures, efficient powertrains, these are subsystem requirements.

Catherine: And system. They put together all the matrix and they basically Oh by the way, I forgot. We need to also personas in deep orange eleven

Catherine: Basically, let it go for certain personas right

Catherine: That's, that's something we have to have. I don't know if that is will be followed in this one to in the importance that in because deep orange 13 is a difference maker. I don't know if it's probably going to be a man.

Catherine: Autonomous thing very

Catherine: No riders, they be in there.

Catherine: But in deep orange 11

Catherine: There are people who ride

Catherine: And we wanted to develop the vehicle for people who try it. Right.

Catherine: So that is that that the people who ride are called

Catherine: Personas and

Catherine: We need to define those personas for to those personal as to how does a day in the life of of that particular person looks like.

Catherine: For example, if you say

Catherine: Family with three small kids and one up doing drives. The vehicle you need to provide them the car seat and you know they bring their car seat if you need to have enough

Catherine: Things inside to harness the carseat, right. But if you completely eliminate that then you don't need to worry about. So

Interviewer: They go, but

Catherine: But, but how much population of people you're eliminating by just eliminating kids. Right.

Catherine: So those are the things so defining the persona and let's say you define a person record Elizabeth, who's a working professional

Catherine: What is the professional do?

Catherine: The day she typically spends and how she uses the vehicle.

Catherine: And the parents living also had another key thing that I wanted to tell us when we said sustainable by design. We have to meet certain sectors.

Interviewer: Okay.

Catherine: And those sectors, we have defined it as care share and deliver

Catherine: It means that we should be able to take older people for care services.

Interviewer: Okay.

Catherine: Share is basically ride sharing.

Catherine: Delivery Sterling of packages ourselves, parcels is right.

Catherine: So the vehicles, the sustainable by design, big vehicle should meet these three service sectors and when you're delivering for care of this it's older people. And what if the older people.

Catherine: Cannot use the mobile

Catherine: can export it to each other. So that means you're making should be able to take the wheelchair insight. So you should have

Catherine: You see how things are evolving now.

Catherine: And who can the wheelchair person go by himself for the they should be a personnel who are gay or

Catherine: Sometimes they can do by themselves. So sometimes they needed assistance. Right.

Catherine: And what is the typical VHS. size What is the length of it that they don't have an insurance. Those are quantifiable metrics, who are podcast in the world right

Catherine: So,

Catherine: They can flipping seats, how to fold, but it has to accommodate a teacher and mentor sipping for another person right

Catherine: You have to flip the space around it.

Catherine: And then the ramp has to meet

Catherine: Certain weight requirements.

Catherine: So that's a additional something else. And do we put

Catherine: Basically

Catherine: A mini bed more like an ambulance.

Interviewer: Well,

Catherine: That was one of the discussions that came up initially or at least it will be not so the vehicle will not be considered for an ambulance.

Catherine: Can only be considered for transporting person A to from person x from point A to point B. Point B to point B is the hospital and the clinic. That's it.

Catherine: Okay, so

Catherine: That's how things get involved and then sharing, ride sharing, do we eliminate families with smaller kids, because we have probably these additional things

Catherine: So you have to put money can I make available for that can satisfy every month. Right.

Catherine: Right, so that's that's how things evolve and this one happens all over the discussion, but the sustainable by design was the theme that

Catherine: It from the beginning before even the students started in that case share deliver was the service sector so we can get it, which was also there before the students started

Catherine: So before use. The students start on this project, you need to have a theme. You need to know what service sectors, you're looking at on what mission mission requirements and at least a few of the vehicle definition or requirements and

Catherine: Then the students will jump in.

Catherine: Stockton commodities and a lot of the students homesteading mean chair dimensions add that insurance adventures. These are all something that students have the will develop

Catherine: Of course faculty are there to guide them. But I'm telling students

Interviewer: Okay.

Interviewer: Gotcha. Yeah.

Interviewer: Okay.

Catherine: But if you don't tell the students anything and just give them a white sheet of paper.

Catherine: That confusion because they can write anything

Catherine: So you have to constrain that thinking process.

Catherine: Developing a boundary

Catherine: Because

Catherine: If you don't have limited time, then, be my guest. You can do whatever. Right.

Catherine: But if I have limited time you need to make sure we deliver it, you know

Interviewer: Absolutely.

Interviewer: I don't think so. I think that's all my questions.

Catherine: So,

Catherine: Good luck in putting this together.

Catherine: Any other questions. So you have any doubts and in future to speak with the name. Okay.

Interviewer: Okay. Absolutely. Thank you so much for your time. I appreciate it.

Interviewer: Nice me. Cheers.

Interviewer: Bye bye.

Interviewer: Okay.

Interviewer: So,

Interviewer: I guess to get started. Can you give me

Interviewer: Just walk me through

Interviewer: I guess their requirement generation process, the shot us for deep orange so far.

Claire: Okay. Um, so before I start telling you the process. If you could tell me for what are you trying to apply this requirement derivation. I can, but I can give you better examples.

Claire: Again,

Interviewer: So,

Interviewer: I guess for something more just sorted out the process so

Interviewer: How you start from the as the vehicle level or system level and then sort of

Interviewer: Build it down into smaller pieces.

Interviewer: I guess I don't know if that answers your

Claire: And that's it. This is for the deployments 13 project right

Claire: Yeah okay on it so far. So I think in many ways the points 13 and the difference to our project are similar, except for the

Claire: Locomotive being used.

Claire: So I'm

Claire: Both of these projects will be this will don't have to build a car.

Claire: They basically just have to make the already available car autonomous right

Interviewer: Mm hmm.

Claire: Yeah. So how do we start is that we already get a set of requirements that like very high level requirements that

Claire: This is what you're supposed to do.

Claire: From there, we try to break it down into smaller pieces. So basically systems thinking or systems engineering is making a complex problem.

Interviewer: A very simple problem.

Claire: I would say not just one problem, but like many multiple simple problems which you can solve and which build up to become the big, complex problem that you will looking at

Interviewer: Okay.

Claire: So when you're already given a car.

Claire: And you have to make it autonomous

Claire: So, so your high level goal would be

Claire: Making the car.

Claire: Autonomous capable or autonomous

Claire: So I think, in your case, it is making it automotive side.

Claire: And I guess it was making it autonomous capable. So, so when you have to make already available car autonomous. The first thing you you would look into is what other things do I need to put on it so that

Claire: The function that a driver performs. Again, we did not

Claire: Autonomously by the car.

Claire: Okay, so, so when you're given a goal that okay, you have to make a car out numbers, then you first look at what what are the things that can replace a driver for that you have to think, what are the functions that a driver performs

Claire: So we start from there. So what does the driver to the diversities. The driver.

Claire: Things plans in his mind and then he acts, he or she acts.

Claire: So for these three things, then you gather the necessary sensors are research about the sensors.

Claire: And then you put them on. But this is the acting part on our side as engineers, I think we need to so

Claire: So making the car autonomous is a concept.

Claire: After that,

Claire: We need to go into the definition of the concept. What does it mean to make the car autonomous. So there is strategy. So there is concept strategy sorry concept definition of the concept and strategy.

Claire: After which you do concept development.

Claire: But between the definition and concept development, you need

Claire: To do a lot of research and development.

Claire: So in this research is where you will look up

Claire: As you will try to learn what the driver does the driver functions. What are the sensors, you need to replace a driver that can do the functions that the drivers.

Claire: And then

Claire: In pre-development you try to figure out

Claire: How many sensors. Suppose you need on what are that accurate as you need or what are the components you need and how you're going to bring them all together.

Claire: And then you go into concept development where

Claire: You try to define the scope for the people on your team.

Claire: So what are the things that you need to divide the people for like all of you kind of look

Interviewer: All

Claire: If there are 20 people on the team. Not all 20 will sit and look at one sense.

Claire: So in concept development, then you define the scope for the team.

Claire: And then you start working on it. So it's kind of divided into

Claire: Four, the research part.

Claire: Okay. OK, and also in the concept development, you

Claire: So you try to define the small smaller projects. So you have gone by now you have already breaking down the complexity.

Claire: So, you know,

Claire: What the, I'm sure they see this word, though the big, complex problem is made of. So it is obviously made of the smaller problems. So you take all these smaller problems divide them into team and start working on them.

Interviewer: Okay, and

Claire: And this is when you start working on the smaller problems that is CDs.

Claire: Development.

Interviewer: Okay, okay.

Claire: Do you have any questions, I know I said a lot of things.

Interviewer: So you start with sort of the general

Claire: This is what we're trying to get into

Interviewer: And then you sort of like a functional decomposition. Yeah, sort of start to develop some concepts and sort of split that up into teams.

Claire: Hmm, you try to define them as smaller

Interviewer: Problems. Right. Okay. Yes.

Claire: And then

Claire: The team, the invite is lifting management. I just

Interviewer: threw that in

Claire: But you try to define them as smaller teams, I

Claire: Think

Claire: That would be a better way of saying it.

Interviewer: Okay, gotcha.

Interviewer: That makes sense.

Claire: And generally, we follow a V model process of development. Are you familiar with the V model?

Interviewer: I think so. I've seen a few times.

Claire: Yeah, so it yeah use basically start with the system and you break it down to the component level and then you start. So that is the one side of the Wii and the side that goes up, it is you start with component development and you go up to the system development.

Claire: And within all these steps, you always go back and verify, you always go back and tested.

Claire: So it is not just like you develop the entire system and then you start testing.

Claire: So when

Claire: You when you start with the component development. So once you think this component is the lab you tested you verified. Then you move on to the subsystem.

Claire: Development. So you develop the subsystem you you test it, you verified and then you move on to integrated. So you integrate. So suppose there are

Claire: Four subsystems. And you want test and verify all four of them together. You will first test like to do two of them, then three of them, and four of them. And then that is how you get like the entire framework working

Claire: And then you put that framework on the car

Claire: Okay, sounds

Claire: Good, so

Claire: Hmm.

Claire: That is it. I guess I had to see

Claire: So where are you in your project phase, like, what are you doing

Interviewer: For me, I'm sort of like we're, we're looking at

Interviewer: Developing different systems and processes to actually like sort of help with the energy of requirements.

Interviewer: And that sort of thing.

Claire: Okay, so you

Claire: You don't have a defined scope right now is it

Claire: No. Okay. Um,

Claire: Alright.

Claire: So have they given you a high

Claire: Level.

Claire: Goal for the project.

Interviewer: Actually not work. I'm not working on it. I'm on deep orange.

Interviewer: Working on another project that's sort of, I guess, studying for how you do it.

Claire: Yeah, just told me

Interviewer: Yeah yeah yeah

Interviewer: But I guess sort of the, the scope is were

Interviewer: Explained it very well, but

Interviewer: We're looking at developing a system like some sort of actual computer to an app or something like that. That would help with sort of automating the requirements management process into how they are requirements are coded in those sort of things you can track things a little easier.

Claire: Oh, OK.

Interviewer: So the more sort of background information. I guess I can get on

Interviewer: How you do it now. Maybe we can find some ways to

Interviewer: incorporate that in there and make it a little more customized and then any find some opportunities for improvement. That's the thing.

Claire: Okay, so let me get this right. So you are working on some sort of tool.

Claire: That would help in like requirements derivation and definition.

Claire: Yeah. Oh, OK. OK, so you're not directly working on the project.

Claire: Right. Oh, OK. OK. OK. I get it, I get it.

Interviewer: Yeah, I should explain that better before we got started, but

Claire: No, that's okay. I just thought that you were working on the project side I jumped into how the defining.

Claire: Is done

Claire: So,

Claire: Let me, let me think. What can I give you for too long.

Claire: So, so do you want that like the tool will be like automated like you would

Claire: Put in

Claire: The high level.

Claire: Scope and it will automatically derive all the requirements. Is that what you're doing, trying to do.

Interviewer: Not necessarily. I think, I think the looking more sort of a way to guide. So if you

Interviewer: If you're writing a requirement and

Interviewer: Making sure things are well written and

Interviewer: Oh, like you don't have any sort of conflicts in them or

Interviewer: Okay. Each requirement corresponds to a specific function. That's one thing.

Claire: Ok ok ok ok.

Claire: So in the

Claire: Definition and the pre deployment phase.

Claire: We do a lot of systems thinking

Claire: Okay, so we spend almost

Claire: Like since our project was accelerated we spent less time but the other different projects spent almost a semester on function definition and and breaking down the requirements into l one, l one, l three

Claire: So three levels.

Claire: So we do that for we did that for almost two months where we were only defining what the driver does and how we are going to replace it.

Claire: So understanding the functions of a racecar driver was very crucial for us because we were all we are also going at a very high speed.

Claire: So, um, once we deny those

Claire: Functions.

Claire: Of the driver, then we

Claire: We went back and checked, which of these do we beat actually because the driver does a lot of many things.

Claire: But which of these do we need in a race car.

Claire: So after defining those then we went into the research phase where we try to find how we can

Claire: What function of the driver can be replaced with what centers.

Claire: Okay.

Claire: And after that was the challenge of how to put it on the car because the car is like pretty small than a passenger car.

Claire: And so you didn't have like the luggage compartment where you can put in your computer and stuff like that. We only had the space where the drivers, that's

Claire: Okay, and really narrow spaces on the car as well.

Claire: So then we went me check.

Claire: How

Claire: To put it on the car.

S Okay.

Claire: So now we're done with that.

Claire: And we are done with

Claire: component level development. So now we are into the verification phase. So where we are.

Claire: Dying to see the different subsystems. I'm communicating with each other or not.

Claire: Yeah I touched her take time to explain but it was pretty cool.

Interviewer: That's great.

Claire: So,

Claire: Um, what is the tell me something you like. Tell me something about you. I guess so.

Claire: I would like to know you better.

Interviewer: I guess.

Interviewer: I'm, I, I'm working on my master's in mechanical engineering. So I'm focusing on design research and that sort of thing.

Interviewer: I'm just this sort of

Interviewer: I guess change management and how requirement changes refactoring two things and how you find changes in components and how all of that sort of plays out throughout the whole web design process.

Claire: Oh, that's interesting.

Claire: Okay.

Interviewer: Y'all have to do with any of that sort of thing.

Claire: Um, no.

Claire: Not really. So we do have to deal with it. But we don't have like system in place for that.

Claire: So even now when we are like trying to validate and verify all our

Claire: Components and subsystems that has so many changes, left and right. But then we're not really tracking them.

Claire: They're just like being communicated like when we meet or when over emails or phone calls. That's all. So we don't have a system in place for that.

Interviewer: Gotcha. Mm hmm.

Claire: Yeah, I do have any more questions.

Interviewer: I guess when you when you actually write requirements, that sort of thing. How does, how do you do that. Does it just sit down like living group and everyone just sort of writes, things like plain text based on that your functions are like a formal system or process for

Claire: Yeah, so we tried to try to do it in a couple of ways. So we made like a big excel sheet where we first defined what the column should be because that is how the new end up breaking up the requirement.

Claire: So we did that as a group.

Claire: And then we thought that, okay, let us individually fill in what we feel are the

Claire: Requirements and then let us discuss them, but that did

Claire: Not work out really well because everyone has a different view of looking at the system. So everyone has a different perception of the system and what what what is the complexity and how to break down the complexity. So it is very subjective.

Claire: So that didn't work out so we sat as a big group.

Claire: We sat together in a room and display the excel sheet.

Claire: On a projector and then we brainstormed actually it was that

Claire: Was fruitful because then

Claire: There were people who, who had really good perception of what it should be, and were able to break it down really well. But then there were some who who are misguided then

Claire: They also understood what it actually should be. So as a big group we guess we sat together and we didn't. And that was really fruitful

Interviewer: Okay that's good to know.

Interviewer: Okay, yeah.

Claire: So we have one

Claire: We have a requirements sheet. It is a huge sheet for a passenger car.

Claire: Just when I'm, I'm not sure if I'm like a lot to share it with you but

Claire: I think you can ask to practice if

Claire: If you want to take a look at how we

Claire: Let me try to find it and show it to. I think we have signed all the MBAs and stuff. Right.

Interviewer: Yeah.

Claire: Yeah, it would just bring it up for you.

Claire: Just a moment.

Claire: Oh, you have to enable screen sharing

Claire: So this is like a big I'm good target catalog.

Claire: So we do

Claire: So the first click the green column, the full way call targets. It's like the like the system level targets.

Claire: Then we break them down to subsystem requirements and then we go into components specification

Interviewer: Okay.

Claire: So this is how the process for the passenger car car is centrally, and this is really helpful. So when you define the subsystem level requirements that helps you in selecting the components and then you, you can easily go into components specification

Interviewer: OK. OK.

Claire: So, so if you see, let's take the first the prototype week the cost or the power in the subsystem requirement for it so

Claire: The first full color so far in chassis born in white. So they contribute a lot to the entire car's cost

Interviewer: Okay.

Claire: So from that. If so, if you from that you define the target value.

Claire: Then you break it down to. Okay.

Claire: This can be the budget or whatever for the subsystem.

Claire: So if you now define that part and should be $75,000

Claire: Then you can. That gives you some kind of a ballpark figure for selecting your components. Then you go into components specification. So when this catalog was made it was derived by the cost, not every project is derived by cost. So some projects.

Claire: Are derived by a function or the some capability to do it and they don't really have

Claire: Like any constraints for costs.

Claire: But in case of, like, for example, our project, we have the constraint of cost that's functionality. So the car, we should be able to do this, this, but it should be within this list, and that becomes tricky because you know you need certain sensor which is really expensive.

Claire: But you can't take by it because it is expensive.

Interviewer: Gotcha.

Claire: So,

Claire: Yeah, I'm not sure if I can share this with you. But this is really helpful. We use this

Claire: In a system thinking class.

Claire: Did I have the requirements.

Meredith Sutton: Okay. Looks really helpful.

Meredith Sutton: Yeah.

Claire: Let me check with Dr. Burgess like that.

Claire: If I can share this with you. Okay. Okay.

Claire: Anything is

Interviewer: I guess once you once you sort of have the requirements developed. Do you go back and sort of review them to make sure that they're still valid or

Interviewer: Any sort of review on them at all.

Interviewer: Yes, like a

Interviewer: design reviews or something like that.

Claire: Yes, so the requirements.

Claire: So once we actually start with the development, the requirements don't really change.

Claire: Not that much.

Claire: A few do but not

Claire: Like they don't not in a way that they would affect the entire definition.

Claire: So yes, we do go back and we check

Claire: How it affects other things.

Interviewer: Okay.

Claire: So, but we don't have like a design review for that. So we use our design reviews for showing the work that we're doing, and the development of the requirements that we had

Claire: Published before

Claire: Right. They

Claire: I guess there is no project that where the requirements don't change over time.

Claire: So you'd have to go back and you'd have to revise them.

Claire: If they are interdependent or something like that.

Interviewer: Yeah.

Interviewer: You don't really

Interviewer: Need to

Claire: Know we don't at least in our project. We didn't have to

Claire: Yeah, because our approach like our scope was fixed. We just had to define

Claire: How we are going to do.

Claire: It. So for that, for the how part we had to break it down our scope never really shifted so because of that our requirements didn't really shift because at the end they were replacing the driver and that's what we had to do.

Interviewer: Okay, that makes sense. Yeah.

Claire: Yeah.

Claire: I think this was like a good introduction. So even going down. If you have any questions you can get in touch with me. So I don't want to put you on the spot and say,

Claire: Any more questions.

Interviewer: No, I gotcha.

Interviewer: Um, I guess the only other thing I'm sort of

Interviewer: I guess in the way the gel have done requirements so far have you noticed any sort of issues or like trouble with anything that maybe you can see as a way to improve the process. Yeah.

Claire: I think definitely, definitely.

Claire: I think the language. Um, are the

Claire: Norman, not the nomenclature noted the language of defining the requirement makes a huge difference.

Claire: So,

Claire: So initially, when we were defined the requirements.

Claire: To people had the same thing in their minds. But the way they wrote it was different. And that created huge confusion.

Claire: So let me think of an example, um,

Claire: Um, okay. So, G, placing the driver.

Claire: Was like

Claire: A requirement. Right. Okay.

Claire: But for some people.

Claire: So that was a requirement. But that wasn't the highest level of requirement, the highest level was making the car autonomous. So the car should

Claire: Run autonomously.

Claire: That can be broken down one step below as replacing the driver.

Claire: So I know it just, it is that I think I said it in the wrong way. So making the car autonomous and replacing the driver. I think these two things mean the same thing.

Claire: Right. But since they were written that way. People started clicking in doubt differently. So when you say, making the god autonomous people directly went into

Claire: Components specification hasn't. We need the sensors, the sensitivities answers, but the people who defined it as replacing the driver.

Claire: They started breaking it down.

Claire: Into driver functions.

Interviewer: Okay.

Claire: Yeah, so the meaning was the same like that end goal was the same, but since they defined it differently.

Claire: They broke down the complexity in different ways. And that leads to a lot of confusion.

Interviewer: I wouldn't have thought of that.

Interviewer: Yeah, really good point, yeah.

Claire: Yes. Next, there was confusion in

Claire: Two requirements. And

Claire: Eliminate to functional requirements so functional requirements are different and just the level one requirements are different.

Claire: So that is often confusion of what is a functional requirement. And what is a

Claire: System requirement or a subsystem requirement.

Claire: So when you say functional requirement. It is what this thing is supposed to do.

Claire: And

Claire: When you say like a subsystem level requirement or element requirement. It is

Claire: Harder.

Claire: Okay, wait, I think I got myself confused. I'm

Claire: So element is supposed to be.

Claire: System requirement.

Claire: And we're supposed to be subsystem requirement and L three is component level requirement. Right.

Claire: But when we see a level one.

Claire: Requirement. I think it creates confusion as in

Claire: Because generally the system level requirement is one or two.

Interviewer: Right.

Claire: But then people start breaking it down there itself.

Interviewer: Okay.

Claire: So some confusion.

Claire: Confusion is that about the levels.

Claire: And how do we should you go because even in like subsystem. There are like one subsystem can can consists of three or four subsystems. So what is the level of those

Interviewer: Okay.

Interviewer: Okay.

Interviewer: Yeah.

Interviewer: Okay.

Interviewer: Any other issues or anything.

Claire: Huh.

Claire: Yeah, I'm trying to think of there were plenty of

Claire: Like because we spent many, many long hours on this.

Claire: Yeah, I guess, but these were like two major issues because even went to, uh, to two different groups sat independently and came up with.

Claire: Like their

Claire: Requirement derivation having the same sub and having the same system level requirement when they broke it down. It was different.

Claire: Is

Claire: It is helpful and counterproductive and

Claire: At the same time,

Claire: Because you have to

Claire: It is very difficult to think from all the aspects and from someone else's perspective.

Claire: So I think if there was like a standard or

Claire: Something where this is how it is like, well, it is not really well defined. So it is very subjective.

Claire: So if network, it was well defined that this is how you have to break it or if there was like a big example of something

Claire: Then I think

Claire: People will start thinking in the same way.

Interviewer: It's a good point.

Claire: Yeah. Did you get it too. I, I think I confuse

Interviewer: Things like if there's a way to sort of show

Interviewer: Yeah, deep to break things down or

Claire: Yes, right, and how to break them down.

Interviewer: Okay.

Interviewer: One of the ideas that we sort of had for this sort of app system program tool thing, whatever you want to call it.

Interviewer: Is just sort of a way to visualize requirements and just sort of see how they're connected, that sort of thing. Maybe like a graph or something where there

Interviewer: can sort of see the links between things. Would that be helpful at all or

Claire: Yeah. Uh huh.

Claire: Yes, yes, yes. This will definitely be helpful because

Claire: I think that is how you will start

Claire: So it will not only help you in defining and developing the things, but with this will really help you when you're trying to verify and validate because

Claire: When you are done with your development.

Claire: So you only have the functions in mind.

Claire: That you had defined before starting the development

Claire: But once you're done with it, you own and you only check to those functions that you have defined but you you forget about the entire debit enter dependability, it has on different subsystems or different requirements. So, yes.

Claire: Definitely, if there is a graph, we can trace it back and see. Okay.

Claire: This is what it depends on, and that is what I have to validate and that is how I check that this requirement is fulfilling all the requirements.

Interviewer: Okay, good to know. Yeah. Okay.

Interviewer: Cool.

Claire: Yeah, so I think, are you familiar with the fault tree analysis chart.

Interviewer: I think I've seen it a few times. Yeah.

Claire: Yeah, so something like that would be helpful.

Interviewer: Okay.

Claire: So that the child basically tells you, from where the fall generates and what all it is affecting

Claire: So, so instead of false if that was like a requirement like from where it generates and what all it affects

Interviewer: Think that's about all

Interviewer: The questions I had for you. This gets top of my head.

Interviewer: Yeah, okay. Yeah.

Claire: This was a good exercise for you. And I realized

Claire: That I should have

Claire: Yeah. If you have any further questions like never hesitate to reach out to me. I'm quick with emails also so,

Interviewer: I really appreciate this. This is can you some good information.

Claire: Thank you. My pleasure.

Interviewer: Thanks. Right.

Claire: Yes, yes, soon. Bye bye.

Interviewer: All right, bye.

Interviewer: Thanks.

Interviewer: So I guess.

Interviewer: We can start with sort of just how do you define requirements and how you've worked with them so far.

Candace: So I hate requirements.

Candace: I really do um.

Candace: So.

Candace: My understanding of what we're supposed to do is come up with.

Candace: An example of deep learning, you know high level.

Candace: mission level requirements that are.

Candace: Then fulfilled by vehicle level requirements so.

Candace: For example, like say the mission is 200 kilometers long that's a that's a mission level requirement and then the vehicle requirement would be.

Candace: needs to be able to travel 200 kilometers or whatever, without refueling or without breaking down or.

Candace: That sort of thing and.

Candace: When.

Candace: We start getting into like vehicle level things, then we can start at a very high level um so.

Candace: That would that example of 200 kilometers would be like a vehicle level requirement, but then you can start breaking it down into different subsystems so.

Candace: The power train, you know needs to be able to power, the vehicle for that long and then there's going to be a bunch of different requirements that fall out of that, based on the power train.

Candace: You know, maybe some other requirement in the mission level would be some type of terrain, that you have to traverse and then.

Candace: You would have.

Candace: You know other subsystems that may be your autonomous navigation needs to be able to recognize different features and the terrain or your your vehicle suspension system needs to be able to overcome any obstacles, you know that that you might encounter.

Candace: That.

Candace: help at all.

Candace: And I don't feel like I'm an expert on requirements.

Candace: So I just want to like.

Candace: Make sure I'm saying the right thing, but.

Candace: I don't want to confuse you.

Interviewer: No, any sort of information is good it's more about how you're practicing it and sort of your perspective on it, rather than any sort of right or wrong answers.

Interviewer: Okay, for sure.

Interviewer: But yeah no that makes sense.

Interviewer: So.

Interviewer: When you sort of start to develop them.

Interviewer: You got sort of an initial brief or you came up with the mission scenarios and then.

Candace: Yeah so we don't.

Candace: Worry about and there's times now.

Candace: I think we're finally.

Candace: Getting close to something that makes sense.

Candace: A little bit um.

Candace: Yeah so like the initial brief way back in October of last year, you know when we all signed up for Deep Orange was high speed autonomous offroad a vehicle that that aspect really hasn't changed too much.

Candace: And what we've been trying to define in our mission scenarios.

Candace: Is what exactly is this people need to do.

Candace: Because it is funded by the government, I think a lot of people had the idea of this being like a military vehicle, but I think you know we've been trying to not make it that.

Candace: So our missions have kind of shifted to be all domestic and really focused on like National Guard type activities.

Candace: National Guard, or like FEMA or something like this um.

Candace: The.

Candace: um.

Candace: And then the other aspect is like defining what is off road exactly and what is high speed.

Candace: Because in high speed on a road is different than high speed off road you know and off road can be.

Candace: A huge number of different terrains you know were typically like road is you, you don't have that many different types of road surfaces concrete and asphalt really uh so um.

Candace: Yeah so we've been trying to come up with like ways of defining these missions, so that we can be very descriptive about the type of terrain that we're.

Candace: Traversing and at what types of speeds, we would hope to traverse these terrains and and.

Candace: Yeah I mean that's, the main thing and then like in terms of the the actual mission accomplishment you know it's.

Candace: Like I said it's been much more focused on.

Candace: Like domestic like domestic National Guard type activities, rather than military.

Interviewer: Gotcha okay.

Interviewer: So.

Interviewer: Once you've got this news, then you sort of break down.

Interviewer: In the individual pieces of requirements.

Interviewer: How did you sort of can you talk me through that sort of breakdown.

Interviewer: Piece was that done in groups.

Interviewer: Well yeah like.

Candace: So the whole team, the whole Deep Orange team was split into.

Candace: Three sub teams and we each kind of initially we all came up with three different missions.

Candace: And then, a bunch of requirements and then we said well let's narrow it down to three total missions so then we came up with a, you know as a team we kind of sat down and came up with this will be our three missions and then we split them up among three some things to go out and.

Candace: Kind of further flush those out.

Candace: And then.

Candace: As each sub team well you know, once we fleshed out our mission, then we sort of looked at it.

Candace: From a vehicle level so like then we tried to assign requirements to each subsystem or or what the vehicle as a total would do.

Candace: To meet those mission level requirements and then.

Candace: Based on our understanding of what the subsystems would look like I guess.

Candace: That makes sense.

Candace: So we all kind of have a basic understanding of like you know how a suspension works and how a power train works and blah blah blah, so we would come up with a.

Candace: Vehicle level requirements to meet those mission requirements based on that understanding.

Interviewer: Excellent.

Interviewer: When you wrote requirements, did you just sort of write them as like a plain text sentence or did you.

Interviewer: Sort of go back to the I know there's definitions of requirements to say have these specific parts of speech and and sort of thing.

Candace: Yeah um we tried our best to put it into the way that it's supposed to be so they're supposed to be like shall statements.

Candace: The vehicle shall be able to do this.

Candace: I think well that's not the only aspect but that's like.

Candace: Sometimes it's hard to.

Candace: Say what you want to say so, like if you, if we look at the.

Candace: The requirements file I don't know if every single one is written as a shall statement because, like you know you want to be able to do something, but you're not really certain how to word it at least that's that's what we ran into um.

Candace: But in general yeah we tried to keep to the the shall type wording and then for the missions.

Candace: It's like will the mission will be 200 kilometers will have X terrain, it will be whatever.

Candace: And then I think if you go further down there's other types so like a.

Candace: Vehicle requirement will be a shall, but like a functional requirement.

Candace: Has another wording type and honestly I don't recall exactly what it is.

Candace: But basically yeah it, it has something to do with it being a function versus like a vehicle requirement so that's.

Candace: That's our sticking to the.

Candace: Specifics, what I was doing my best to for sure yeah.

Interviewer: Okay.

Interviewer: Once you've gotten the requirements written, how do y'all sort of review them, why do you review them.

Candace: Chris reviews them and tells us.

Candace: to rewrite them.

Candace: I mean so we've been for this we've been using MATLAB requirements editor, which is a new thing I don't think that prior Deep Orange projects have done that so that's been another like learning curve it's like trying to figure out how that works.

Candace: But it.

Candace: Allows you to.

Candace: Generate a really pretty easy to read report it's kind of like an outline style format.

Candace: And it will show you which vehicle requirements go back to which mission requirements.

Candace: And so as a like as our sub team that's just how we looked at them, but in terms of getting feedback that's that's come from like Nafiseh or Chris or other people.

Candace: VIPR or what's the other one called the GVSC.

Candace: And so.

Candace: I think we actually got feedback on Friday that we need to.

Candace: Make a couple of changes but yeah it's it's mostly been us doing the writing and then getting feedback from.

Candace: The advisors.

Interviewer: Okay gotcha.

Interviewer: The next sort of set of questions I have may not have had to deal with yet, but sort of looking at requirement changes.

Interviewer: So, not necessarily just rewriting them, but maybe you're adding new requirements or.

Interviewer: Sort of modifying or deleting existing ones.

Interviewer: Have you all had to deal with that, and if you have, how do you sort of manage these requirement changes.

Candace: You haven't yet, but I do anticipate that yeah we're gonna I really think that as we get further along we're going to realize that we need more requirements to define everything.

Candace: Um.

Candace: It's.

Candace: I don't imagine it's going to be a lot of work but it's it's interesting because, like I said we're using this MATLAB requirements editor.

Candace: And we're.

Candace: All doing this through Github.

Candace: which turns out is not a supported feature.

Candace: From MATLAB so.

Candace: I think there was a lot of frustration coming from the requirements phases, because we were under the impression that we could.

Candace: All work on this file collectively and everyone would be able to see the change and what turned out with that's not the case and basically everyone was overriding everyone else's work.

Candace: Oh God so.

Candace: In terms of making changes to.

Candace: That particular file it's going to have to be very.

Candace: Kind of locked down, I guess, so that only a few people are kind of responsible for that.

Candace: In terms of more broadly, just like.

Candace: Adding or editing requirements.

Candace: We haven't we haven't done it yet, but I don't anticipate that that it's really going to be an issue.

Candace: Does that answer your question, or I don't really know if that's like.

Candace: Yeah i'm not really certain I understand.

Candace: The root of like where you're going with that.

Interviewer: No, I think you're I think you you sort of answering it is it's hard to obviously talk about something that hasn't happened yet.

Interviewer: But yeah I I sort of driving towards how the.

Interviewer: sort of plan to manage the changes that sort of thing. Is there sort of a plan in place and just sort of making sure that it's updated in the document and that everyone's aware that there's been a change to the document or something.

Candace: So what we're hoping.

Candace: We can do and we're still exploring this in in terms of like meeting those requirements.

Candace: Is there's also built in MATLAB testing.

Candace: Harnesses that you can build into your model.

Candace: And what we're wanting to do is build a link from that model back to the requirements model.

Candace: Meaning.

Candace: Like I said, maybe we'll have two or three people on the team that are responsible for making sure that requirements model is up to date with the latest changes.

Candace: Is assuming that work is done, and done correctly, then the testing harnesses should automatically be updated to reflect those changes and.

Candace: Just running you know your test simulation should tell you whether or not those new requirements have been met, now I guess what I should say is those changed apartments new requirements, obviously, are going to require.

Candace: A new test to prove that they're correct or whatnot.

Candace: But I guess the idea in my mind and we haven't discussed this at great length as a team yet.

Candace: Is that, because the because of the way the files.

Candace: Are not supported by get in MATLAB, we need to distribute who's who has access among a few people and so you'll have.

Candace: A few people update requirements, a few people updating test models.

Candace: And assuming that's all done correctly, it should be pretty easy to track.

Candace: New new requirements change requirements and make sure that we're we're meeting those goals.

Candace: This is all hypothetical no idea this actually going to work but.

Interviewer: It's good to have a plan in place at least yeah.

Candace: We'll see if we can get there, anyway.

Candace: I think, being able to link back to an actual value in the requirements file.

Candace: And access it from like a test model would be huge and then it's just a matter of doing the work so.

Candace: Hopefully we'll be able to figure that out in the next couple of weeks and that's actually realistic.

Interviewer: She mentioned that the MATLAB file output thing sort of has a way to sort of link between different subsystem requirements backup to the overarching requirements, as you just got like a little bit of traceability there.

Interviewer: Is that are you considering that, like the relationships between them when you're writing requirements you looking at sort of how they're interconnected.

Interviewer: And that sort of thing how they might influence each other.

Candace: I know we definitely are supposed to be.

Candace: I don't know that.

Candace: It's happened yet on the level, maybe that it should I guess the best answer that I have.

Candace: I yeah I mean.

Candace: There's like this idea that we're going to go 80 miles an hour across like a wildly rough terrain, you know and we're going to do it with a really good fuel economy and whatnot and, like those are two completely.

Candace: Non-realistic goals right.

Candace: But.

Candace: At least from my perspective, and this is just me.

Candace: Talking I don't think that this I'm speaking for the entire team.

Candace: On this.

Candace: I think I view the requirements, a little bit as like being aspirational goals and you start to design and see how close, you can get to that and then we'll adjust the requirements down as we learn more.

Candace: But I think that, like setting requirements based on what's.

Candace: Currently available in the market is kind of like why would you do that, because now, I mean you could just go out and buy that right.

Candace: So.

Candace: I don't think that's exactly the right approach, but I have a hard time myself like getting past that like I wanted to do all of these things let's say that it will and then let's prove that it won't sort of things.

Candace: And then figure out how close we can actually get to all of those things.

Candace: But I'm.

Candace: As far as like the interconnectedness um.

Candace: I don't think it's been it's been a.

Candace: Really addressed at great length, yet.

Interviewer: Okay.

Candace: Hold hopefully.

Candace: Us putting this this structure in place.

Candace: We should be able to catch that.

Candace: Those issues, and I think that's really the root of why we're doing all of this is being able to to look at all of those things.

Candace: You know, coherently and be able to to see like okay, this is affecting us and so we'll need to if we make a change here it's going to affect that and.

Candace: Can we eliminate that that connection somehow by you know designing around it or is that is that definitely like a hard constraint so.

Interviewer: Gotcha.

Interviewer: Okay.

Interviewer: I'm going to shift gears a little bit as part of our project we're also looking at.

Interviewer: Some sort of software, maybe app development sort of ideas just sort of help with requirements generation solicitation everyone call it.

Interviewer: So I’ve got a couple of like hypothetical features that you might see in an app and see if they would be useful.

Interviewer: And then.

Interviewer: Maybe give me some ideas about what's gone wrong and how you think it, it could be better but.

Interviewer: Just to.

Interviewer: Get started, maybe.

Interviewer: If you have like a search feature, for your requirements, what sort of.

Interviewer: Things would you like to search for or organize your requirements with like filters or something like that.

Interviewer: Is there anything in particular.

Interviewer: So that'd be useful for.

Candace: Well, this one one thing came up just last week in that.

Candace: So in this MATLAB requirements editor Chris can go through and lead comments, but there's no way for us to view requirements that have been commented so like there's.

Candace: It we would still have to review every single one to find where a change has been made, so I mean just just that you know, like being able to filter on you know comment was added or modified date or something my bat.

Candace: And maybe that feature exists and we just don't understand how to access it I don't know.

Candace: But that was the first thing that came to mind when you said that.

Candace: Other than that.

Candace: At least our system, I think, allows or I mean just because of the way that we built them in.

Candace: Can pretty easily filter on like what subsystem it's related to over or what.

Candace: Mission scenario it's related to because you can basically each requirement will show all of its relations um.

Candace: That's a tough question I haven't really thought about like how I would want to search through them and what would be helpful and.

Candace: At some point, I guess, a.

Candace: Flagging requirements that are at odds with each other, would be.

Candace: A great feature.

Interviewer: That's funny because that's actually a question that's another question, I had would it be useful to be able to just see requirements that are in conflict.

Interviewer: Yes, so okay.

Interviewer: Cool cool.

Candace: Having having a feature built in that suggested a new requirement, so that they were not.

Candace: At odds would be even better, but I don't know that seems like it's it's quite advanced.

Interviewer: Sort of along those lines, would having some sort of way to to recognize the parts of your requirements like as you're writing it and sort of give back a, this is a well written requirement, you need to change something here and there's.

Candace: Like a like a paperclip.

Candace: Guy.

Candace: Yeah I think that would be excellent.

Candace: You know, maybe you have some sort of maybe it recognizes exactly what you're trying to say, but like you could tell it if it's a functional requirement or a mission requirement or a vehicle requirement, and it would suggest.

Candace: A format or yeah word changes that fit within.

Candace: The different parameters, I think that would be super helpful.

Candace: At least for me like.

Candace: I mean my my first experience even hearing about these was you know, last fall and I like okay.

Candace: I didn't understand it then I'm beginning to understand it now, but like it like I feel like I haven't seen really good, clear cut examples of like what.

Candace: What makes a good requirement, what makes a bad requirement, you know.

Candace: So, having something that was.

Candace: Yeah giving you a live suggestion as you're typing but definitely be I think helpful.

Interviewer: Would it be useful to have like a way to sort of visualize the connection between requirements, I don't know that some functionality you already have, but like to sort of maybe graphically show these ones are linked here here and here.

Candace: I don't like don't like flow.

Candace: Chart of requirements.

Candace: yeah I'm I I do think so um it could get quite messy quite fast, with all the interconnectedness of our simulate project that we're building this in does show a file hierarchy, so it shows this file is linked to this file because of the way we built our files.

Candace: It doesn't show a lot.

Candace: But, presumably, and this is, I brought this up with Chris.

Candace: There's kind of two approaches that you can do, and I think what we chose was having all of our requirements in one file makes it easy so to keep track of where they are right.

Candace: And link back to them, because we always know we got to go in this file and link back here.

Candace: I think some people use this where.

Candace: Maybe each file is a requirement and then it has sub requirements within it.

Candace: And in that sense.

Candace: You know, assuming, you did you're linking right, then the the file file tree should reflect that but because of the way we built it it doesn't exactly so maybe having.

Candace: You know, based on the contents of the file showing that would be a great.

Candace: Thing to do, yeah.

Interviewer: Do you ever have any issues with maybe requirement redundancy, so you have two requirements that are saying the same thing, where did differently.

Candace: Yeah i'm particularly I think we've worked through most of those issues, but like when we all had our separate meetings and then brought all of our stuff together, of course, there was a lot of overlap in that.

Candace: But yeah like I think there's still a little bit of work to be done in terms of.

Candace: Cleaning up and making sure that everything.

Candace: Is a non-redundant and be going back to like we said non-conflicting.

Candace: You know.

Candace: But then also making sure you provide enough detail there's like these there's there was these two there was one that was like the acceleration.

Candace: Of the vehicle and one was a burst speed, which is like a term that the GVSC uses and I think it's it's it's not something that's common, at least in passenger vehicles, I was not familiar with it, but basically it's the ability to go from zero to 200 yards in some amount of time.

Candace: Where acceleration is from zero to some velocity and some amount of time, those are very, very closely related, but.

Candace: Like the same thing I don't I'm not really certain.

Candace: I mean you have definitely a function of time in there is a difference, but it's.

Candace: Yeah it's like I think they could, depending on how you write it you could work them out to be the exact same requirement and so.

Candace: Sometimes there's like little subtleties like that that.

Candace: Are at least, such as one one particular art project where I'm not quite certain, I understand why we have both right now but.

Candace: Right now they're both in there and I guess, maybe, as we.

Candace: Begin testing we'll see why we need or don't need them.

Interviewer: So having a way to maybe capture or predict that, along with the conflicting requirements so redundancy and conflicting requirements, and that would highlight that both of those together might be useful.

Candace: Huh yeah.

Interviewer: Do you usually write machine requirements sort of separate by nature, or do they end up sort of coupled together so one relies on the other, or have you tried to sort of separate them so that each one of exists on its own.

Candace: Um.

Candace: As far as mission requirements.

Candace: I think.

Candace: In general, at least the way our team approach, it is they're very separate some are are somewhat related like maybe the types of terrain that we're traversing or.

Candace: That sort of thing or like there was submission requirements based around navigation that were like must be able to navigate at night or in inclement weather or.

Candace: You know, some other.

Candace: In in frigid temperatures, everything must still be functioning properly blah blah blah.

Candace: When you go to start linking back the vehicle requirements to these things, a lot of times they do come in.

Candace: Kind of groups are not always but.

Candace: Again, like looking at acceleration and velocity you know, like we have.

Candace: A set of requirements that kind of fall together that are like it must be able to accelerate this fast and must have a burst speed.

Candace: This this amount, it must be able to attain a top speed of this amount and those kind of all get grouped together does, that is, that what you mean or or is this something different.

Interviewer: yeah I think I have a slightly different picture in mind for sort of couple of requirements.

Interviewer: Because it sounds like you've got them pretty pretty separate for me I didn't think a couple of requirements is that one requirement that has multiple different pieces in it, so it should be.

Interviewer: It should accelerate to the speed.

Interviewer: And do it within like a certain.

Interviewer: Something that has two pieces that.

Interviewer: Could be so that maybe are in the same.

Interviewer: Sentence or the same like requirement.

Candace: In general, yes, we try to keep them very separate, there are a couple.

Candace: That I.

Candace: Got like the traversing of the types of terrain um.

Candace: I don't remember exactly how we worded them, but it was like must be able to traverse X terrain, you know snow terrain up to like point three meters in depth that velocity or whatever you know.

Candace: And then.

Candace: It was getting those getting messy.

Candace: And and and and you don't want to have that.

Candace: And I think at least.

Candace: For this I'm.

Candace: I think, because we're we're looking at so many different types of possible driving scenarios versus like on our road.

Candace: Like we're trying to.

Candace: Without adding 1000 different scenarios which are totally possible you know, an off road driving situation.

Candace: Cover as much ground as possible and so yeah there's like a fine line so like we tried writing some in the form of like must be able to reverse and then would have like a vector of.

Candace: Scenarios and then a vector of velocities or something.

Candace: But then like that's not really doing anything other than.

Candace: You know, saving and writing out each one individually, but.

Candace: Yeah there's definitely were some that were combined, and I think dealing with those.

Candace: Is probably still something that we're going to have to do.

Candace: Because because ideally.

Candace: You want a singular.

Candace: Requirement for statement because it's much easier to test that.

Interviewer: Absolutely, yes.

Interviewer: Okay.

Interviewer: I think that's most of my sort of hypothetical questions are there any other issues that you've seen sort of come up.

Interviewer: That are sort of areas for improvement along the way, anything like that interest.

Candace: Um.

Candace: I don't know if this is so much like an area of improvement thing or if it's just getting everybody on the same page but, like, I think that.

Candace: Some of us some of the teams have had different ideas of how to write these things.

Candace: Of course.

Candace: I want to say that our team was doing it, the correct way, but I don't know that that's necessarily true but I'm.

Candace: just getting.

Candace: Everyone to have everything in the exact same format, so that it read in a way that made sense, you know.

Candace: Our team tried this very like hierarchical like outline style approach, where you know you start at.

Candace: Some level and then each sub level below that level, you know meant something so if you have another top level item whatever is below that at the next level was the same style of.

Candace: Sub level as on the previous one, so like we did ours as.

Candace: Exactly it was like functional requirements function and then vehicle requirement or something.

Candace: So they all had to like.

Candace: Be similar styles of words and things.

Candace: And so that wasn't necessarily the case in each team's representation so just having some sort of consistency, like in that.

Candace: Again, like this is all this whole MATLAB requirements thing is new to everyone so each person was free to interpret I guess how to use it as they would and again like I said, I think our team is even using it much differently than like what I've seen online where most people will split.

Candace: Into separate files for each of their things and blah blah blah um.

Candace: There's definitely room for improvement and file management, but that's that's more of a MATLAB issue than it is a our teams issue.

Candace: So yeah I mean, I think that that type of functionality is coming, and you know, eventually, it just takes time to get it built in particularly with with a very.

Candace: It's all get prepared proprietary file type you know it's not a common just text document it's very convoluted with MATLAB isms so it's it's something that MATLAB itself is going to have to fix not it's not anything that we're doing wrong.

Candace: uh.

Candace: Yeah I don't know other than that I don't think there's a lot of other issues.

Candace: That come to mind yet.

Candace: To be perfectly honest, I kind of haven't really been thinking about the requirements for a couple of weeks I've been focused on other things so.

Candace: I know that's definitely something that will be a topic of this week's meeting so I'm hoping after my exams tomorrow, I will have some time to to review that and think about that um.

Candace: I don't know if you're going to be there, but we have our first design review of the vehicle coming up in like two weeks so.

Candace: There's.

Candace: A lot to do in regards to like cleaning up and presenting requirements for the actual thing.

Interviewer: Gotcha.

Candace: Hopefully, some more things become more clear as we put that together.

Interviewer: Okay.

Interviewer: Well, I believe that's all the questions I have for you.

Candace: Okay.

Interviewer: I appreciate your time. I'm going to

Interviewer: write up my notes and sort of based on the little transcript that I'll get from this sort of summary of what we talked about and I'll send it to you if that's okay, just so you can.

Interviewer: Make sure that I understood what you were saying correctly, and pulled up the important parts, right. I'll try to get that to you in a few days.

Candace: Okay. Sounds good, and if you have any other questions you think of or clarification feel free to reach out.

Candace: I'll do my best to answer them.

Interviewer: Okay.

Candace: Yeah.

Candace: Cool.

Candace: Sorry, I was late.

Interviewer: It's all good, I appreciate your time.

Candace: Yeah oh I'll talk to you later.

Interviewer: All right, thank you alright thanks.

Interviewer: Just to sort of get the ball rolling. Can you give me a little bit of background about I guess what your role is and what you do when I guess how that interacts with requirements.

Georgia: Sure, so

Georgia: Excuse me. So right now I am GVSC essentially their chief scientist so GVR is ground vehicle robotics.

Georgia: So technically, I'm the senior technical expert.

Georgia: And that role.

Georgia: splits between the you know grumpy ago robotics organization and customers.

Georgia: And so customers are people like

Georgia: The, the CEOs, the program executive offices and PM.

Georgia: But in some sense you know the customers. Also, the research community.

Georgia: Not in a direct sense

Georgia: But like

Georgia: But more indirectly, in the sense that, like the research community has some aspect of you know what what they're working on what they could be working on what their

Georgia: Expertise is and

Georgia: I'm not trying to necessarily facilitate that interaction with us, but I'm trying to understand it and I'm trying to direct it in a way that helps us right so

Georgia: For instance, routing problems like think of like traveling salesman, um, they can fit pretty well with, you know, traditional logistics like convoy. But there's actually an element of routing and vehicle management in combat operations as well. So helping

Georgia: You know, academics.

Georgia: Understand those nuances are those constraints, so that those problems can be generalized to other needs of the army as well.

Georgia: And so, like, in that sense, like, you know,

Georgia: It's like a customer relationship where you know I'm not just trying to help the projects that are helping me directly, that are funded through me, but I'm trying to help the field better understand our needs and

Georgia: So that's the academic side the organizational side is is something. It's not quite a management role. But it's more of like a strategic role.

Georgia: Trying to align our products, trying to align our future with what could be possibly down the pipe with what is coming down the pipe right thinking 510 15 years ahead.

Georgia: And seeing what we have now technologically

Georgia: Seeing what we where we need to be and understanding what might take to get there.

Georgia: And then that other pieces that you know the PTO and

Georgia: And that's more along the requirements piece. So it's like speaking three languages. Right, so like the the academic language.

Georgia: talks more about so routing problems, great example again. So the academic language. I'll say like, okay, are using a two stage optimization. And, you know, are you creating a directed graph.

Georgia: Of like where everything's going

Georgia: And then how do I use that graph so that I can improve it and then you know understand some transparency.

Georgia: Issues and then I go to the the technological side which is

Georgia: The like GV organizational I say, hey,

Georgia: The output of this. This work is is a graph.

Georgia: And we might be able to implement that into our interface or warfighter machine interface, but we also want to think about, you know, our world model.

Georgia: As well as our navigation stack. So like our world model doesn't necessarily need the graph, but if it could

Georgia: Pull some satellite information from other nodes in that graph, maybe pre populate those areas. Think of almost like a rendering engine. So like, it's actually pretty cool video. If you ever look at, like,

Georgia: How graphics cards render like a world

Georgia: Like it's pretty much just like it's like a triangle.

Georgia: So it's the viewpoint of the user. And then you see all these trees popping up and disappear because it doesn't need to render those right so world model connect in a similar way.

Georgia: In a world models like a 3D view of like the world.

Georgia: And maybe maybe taking what the output of those graphs and rendering. Some areas that I might be headed towards next

Georgia: Might be more efficient than just

Georgia: Doing pure reactive, things like that. And then I can go to the P O side and I can say like, listen.

Georgia: There's a requirement of, you know, needing to render ahead of time or to really take advantage of global planning, as well as local planning.

Georgia: And that requirement reflects on this type of computation.

Georgia: Right, so you can kind of see like the transition right so like a two stage optimization to create a graph with some transparency that transparency reflects into our products and then how we use

Georgia: That output to improve some aspect of our autonomy and then because we're doing it in that way, it translates to a requirement for the PM of, like, you know, what's required in order to enable these things.

Interviewer: Okay.

Georgia: So,

Georgia: It's that that's

Georgia: I I don't necessarily live in one domain, more than the other domains.

Georgia: For example,

Georgia: Right now I'm evaluating requirements for an existing request for proposal that a PM is about to put out

Georgia: On the other end, I'm helping build requirements for another side of another program. So like

Georgia: And by build I mean like not explicitly but more or less trying to provide my input trying to say like, you know, if I was building an experiment.

Georgia: I might want to adjust the I might want to evaluate the spatial acuity of the user and use something like a cube comparison test.

Georgia: So how do we build that as a requirement.

Georgia: And how do we relate that to like targeting and so like you know it's it's more or less like you know

Georgia: Bringing

Georgia: My background and knowledge to the PM to help them.

Georgia: Understand what are important about requirements or when I'm doing with this RFP is I'm basically saying like, you know, they have a requirement that says

Georgia: We want the vendor to understand that an open architecture is important, not just for data, but for information that's being shared across the network to do things like AI.

Georgia: And so, like, I'll be like, Okay, well then that's, that's something that we can adjust in our growth section that's something we can adjust in our interoperability section of our piece back and things like that so

Georgia: So the requirements are more my involvement with requirements are.

Georgia: Kind of like an advisory role, I guess.

Interviewer: Okay.

Georgia: I know that was a really long explanation, but you kind of see like how you know how it all fits together.

Interviewer: Yeah, absolutely.

Interviewer: Make sense. Yeah.

Interviewer: Okay.

Interviewer: So I guess when

Interviewer: If you don't do a ton of requirement development, per se, I guess, how would you, how do you see requirement development being done, or how do you do it yourself sort of two prong question, I guess.

Georgia: So how I see it being done is usually top down, basically.

Georgia: We want some output.

Georgia: You know, and we translate that output. So targeting is another example.

Georgia: You say, I want to hit something for far away.

Georgia: And then you start to break down will what as far away mean and how fast doesn't need to happen and things like that. Right. I need to, you know, slow to Q within so many seconds or milliseconds. I to, you know, track with so much

Georgia: lead time or things like that. Right.

Georgia: Things that are measurable.

Georgia: Right, so you take something that's not measurable and you start making it measurable.

Georgia: And that's a top down.

Georgia: And what was the second facet.

Georgia: I guess.

Interviewer: If you, if it's yourself sort of developing requirements.

Georgia: Is awesome. I

Georgia: Bottom up

Georgia: Bottom up. Yeah.

Georgia: So I knew I, yeah, I forgot where I was going with this. So,

Georgia: A top down, is how I see it usually been done bottom up is usually how I tried to

Georgia: If I do it.

Georgia: And the bottom up is basically like it's more detailed about what I have versus what I need.

Georgia: And and I hate to say it that way. But so the requirements that I would be building would start from. Okay, I need GPUs. In order to do this thing right and

Georgia: I can't just say I want a GPU. I need to understand better if I need to have a specific architecture, because that works better. Right, so

Georgia: Right for this type of analysis like okay, I need a GPU with this architecture. So I'm trying to start at the most general

Georgia: Idea of needs and then build out. What are the core components of that that include that need. And so I'll say, like, in order to run autonomy, I need this type of computation with this type of framework that supports this much memory at least right like it's more like minimum

Georgia: Minimum constraints.

Georgia: Right, like

Georgia: I can't, I would want more than this, but this is that a minimum what you absolutely need and then like you gradually try to broaden that so like when I'm developing I guess it'd be more bottom up.

Georgia: And likes like another aspect of that with respect to the

Georgia: You know what I referred to earlier with like trying to have like an open architecture trying to think about what the end goal would be, you know, several phases down the line and what is some language. I can put in there now to help me get there.

Georgia: So, and that's not always quantitative right that's more qualitative. So I guess my experience in how its developed is quantitative my experience in developing is qualitative

Interviewer: Okay.

Interviewer: Is tends to be sort of involved in the, I guess the requirements generation or development process.

Georgia: Sorry. Um,

Georgia: That's a tough question because it's really dependent

Georgia: In terms of like actually taking these needs and writing them down into

Georgia: Some type of, like, again, a piece back

Georgia: Or an RFP, or something like that or

Georgia: Or even trying. So there's two aspects. Right. So there's the PM side which is creating those performance specifications.

Georgia: And then there's the

Georgia: The vendor who's usually creating a PDF or a preliminary design review.

Georgia: And a CDR. And then there's also us that generally create something like an ICD.

Georgia: Initial capability document or leave, it's, it's hard to keep track of all the acronyms. So, uh, there's usually kind of three different roles and building those requirements.

Georgia: So the vendor basically coming back and saying like, you know, this is what my preliminary design requires this is

Georgia: A PM basically saying, I need to have these types of this type of performance and whatever requirements, get me there. And then there's us that say like, Listen, if you want.

Georgia: Like a standardized by wire kit. This is your ICD right you should be doing at least this you should be doing it this way.

Georgia: Or be using these things.

Georgia: So it's kind of like a mishmash of all those things.

Georgia: So the lab, the vendor the P. O.

Interviewer: When you sort of sit down to write requirements.

Interviewer: Is that something that sort of done like

Interviewer: As a group, is it

Interviewer: Somebody like a designated person that sort of sits down and just sort of writes out like I guess plain text or something like that or is it automated computerized in some way.

Georgia: No, it's usually done as a group.

Georgia: I mean there might be one person that starts off.

Georgia: With something

Georgia: Basically throwing something at the wall.

Georgia: But ultimately, it's all done as a group.

Georgia: I'm not familiar with any automated requirement generation.

Georgia: And anything close to it would be the bottom of what I referred to earlier.

Georgia: Where you're basically collecting what already exists.

Georgia: To identify like what are the minimum designated you know

Georgia: Things that you have to have for the system to work. So a

Georgia: Good example would be basically saying like, you know, GPS requirements would basically say like, Oh, I want some level of precision. I want some, you know,

Georgia: Timing

Georgia: piece to it, but like, you know, the bottom up would be like

Georgia: You know, just taking a list of what GPS. I already have like the the items on it basically saying anything antenna with this type of game, it needs this right like

Georgia: And then using that as a starting point without having someone manually do that.

Interviewer: Okay.

Interviewer: Gotcha.

Interviewer: Once you sort of have the requirements. Is there like a review process in place. And if there is, what does that sort of look like and

Interviewer: Was involved in

Georgia: So I've not been involved in a review process because the requirements that the stage that I'm in. They're always kind of evolving.

Georgia: So, and I guess it would be more of an informal review process where it's like

Georgia: It's not an explicit event.

Georgia: It's more like

Georgia: We're learning more about how well the system can perform we're doing experiments were expanding or changing things and just updating as we go.

Georgia: Right.

Georgia: Like we'll do an experiment. And, you know, we'll find out. Dust as a bigger problem than we realize. So now we need some requirement for how we handle dust.

Interviewer: So,

Interviewer: When you sort of have this like I guess requirement changes or additions that sort of thing. How, how does that get managed. Do you have some sort of way of making sure that the information is

Interviewer: Disseminated properly, that sort of thing.

Georgia: That's something I'm working on.

Georgia: So knowledge management is really hard.

Georgia: It's a really fundamental problem and it's really

Georgia: Hard to get right.

Georgia: So right now things are kind of manually disseminated.

Georgia: But

Georgia: You know, obviously it's

Georgia: It's inefficient.

Georgia: Yeah.

Georgia: I can tell you that

Georgia: You know, our requirements at the lab end versus what the CMT the cross functional team manages aren't always in sync.

Georgia: And

Georgia: That's because again ours or bottom up. And there's our top down and we're both kind of adjusting in different directions and also their portfolio is a lot bigger. So like our requirements are very specific to our systems are our software.

Georgia: And their requirements are going to be more broad against like

Georgia: power and energy and cooling and sizes size, weight, you know, I mean like

Georgia: Well, well.

Georgia: Said like of course there's going to be top down because they don't have the the experience or energy to do a bottom up across that entire portfolio so they rely on each individual section to do the bottom up and find where they meet the middle

Interviewer: Do you have some sort of, I guess, requirement management system. I know there's a couple that exist out there like doors and that sort of thing is that

Georgia: Yeah, I'm familiar with doors, but we don't really use that

Georgia: Ours aren't as explicit like that, like, just because of the evolving nature of everything we're doing

Interviewer: Mm hmm.

Interviewer: A few of our meetings. I think it's, you know, we're sort of trying to develop this sort of software app sort of program.

Interviewer: Thing to sort of help with requirements.

Interviewer: Are there any sort of, I guess, maybe lessons learned, or something like that. You just from the way that you manage requirements or something that sort of built in functionality that way. Maybe some sticking points or something like that.

Georgia: So my understanding of your guys's project is that you're essentially trying to decompose and link.

Georgia: These different contextual expressions.

Georgia: My only

Georgia: So my concern. My first concern is that these are written by humans.

Georgia: So, and written by lots of different humans right so it's it's it's a hard problem and understand why there's research doing it. Um,

Georgia: It's not something that's easily semantically parsed

Georgia: Because, you know,

Georgia: One person writes the draft and then like, or maybe a small handful people write the draft and then it gets you know reviewed and edited and updated and small words change here and there.

Georgia: And then you don't really have the same voice across it. And while the requirements are are meant to

Georgia: Structurally convey intent.

Georgia: They can be still flawed. So I have a good example.

Georgia: Let me pull up something

Georgia: So,

Georgia: Excuse me. So, um, there was something called the

Georgia: Like the LRRDPP

Georgia: It was basically like what do we how do we identify what manned-unmanned teaming

Georgia: Capabilities we want

Georgia: That are relevant to the army and how do we understand where we should be in when what's the progression.

Georgia: And some of the these requirements are very specific right so basic obstacle detection and avoidance at less than 20 miles per hour.

Georgia: Okay, I can understand that. And I can kind of trace, I can discreetly trace what that means.

Georgia: Right. But then there's also stuff like limited teaming and basic tactical behaviors for on road operations that unpacking that statement means a lot.

Georgia: Right, like

Georgia: There's, there's a lot right so PNT so position navigation time, improved longer duration operation in the absence of GPS signals. I can translate that roughly to

Georgia: an eventual quantitative measure. Right, so I want

Georgia: The amount of time that I can operate without a GPS signal to increase

Interviewer: Okay.

Georgia: Uh,

Georgia: Supports operations in terrain and environments challenging to GPS. Okay, I, I definitely know where there are some definite challenges the GPS like canyons or concrete jungle to the city.

Georgia: But like

Georgia: And I definitely know where it's not challenging the GPS like open fields but like once you start getting into the middle like it's a lot fuzzy. It's really fuzzy right so

Georgia: What I'm getting at is, like, you know, some of these are very discreet and then others like take a little bit to unpack

Georgia: Right, and that that's that's my concern with like an automated system because

Georgia: It's almost like at a small scale that's easy for a user to kind of go in and update. But once at scale, like it's nearly impossible.

Georgia: Once you have this big interconnected tree or how things relate to other things and complex ways

Georgia: So,

Georgia: Is, you know, is my

Georgia: So I would expect that my improved longer duration operation in the absence of GPs would improve my limited teaming

Georgia: Capabilities. And the reason for that is like if I'm unable to position myself but I'm compensating for that. Then when I coordinate with another teammate because I'm

Georgia: Able to compensate for my

Georgia: My I'm not so I'm not so reliant or dependent on that positioning

Georgia: I'm more likely

Georgia: To be able to say, adjust my speed.

Georgia: And change formation with, you know, understanding them not going to hit each other because I understand my position better despite it being noisy.

Georgia: Same thing with like maneuver or basic obstacle detection avoidance sets that lower speeds like I can see how those requirements help build into this teaming

Georgia: But like, you know, what is teaming still has yet to be

Georgia: Defined so

Georgia: What I'm getting at is, like, you know, when I had mentioned earlier that I speak three languages academic integration and PM like

Georgia: I

Georgia: I'm not sold that like the like the context of those languages for requirements sake is still well understood, fundamentally, for you to decompose them.

Georgia: Does that make sense.

Georgia: So,

Georgia: And so like teaming

Georgia: From a

Georgia: Academic perspective means one thing or it means, actually a lot of things.

Georgia: Teaming from an integration perspective.

Georgia: Means usually like communications teaming from a PM Perspective.

Georgia: I mean that could mean. I mean, I'm still kind of unsure there. What that means like that could mean

Georgia: Teaming in a doctrinal

Georgia: Perspective.

Georgia: Where you know you guys are essentially just on my team and I have a call sign for you. And even though I don't interact with you or coordinate with you.

Georgia: I I'm doing something I'm either in a supporting role to someone else that's helping you, or I'm way over there doing something else, helping the broader mission.

Georgia: Right, so

Georgia: Right, so yeah.

Interviewer: So that's a really good point. Yeah, I think it's something that we may not be fully considering and

Georgia: I just think that

Interviewer: Look at

Georgia: I just think, like, you know, if you're gonna so it's one thing to be able to break apart the sentence and figure out how things relate to each other.

Georgia: But in order for that to actually work. You still need to fundamentally

Georgia: Extract the perspective and context of what that sentence was written for

Georgia: Right, right. So,

Georgia: Amazon like Alexa has some work relative to this and it's it's more in the much more basic realm. So like Amazon wants to do like long term conversations with Alexa

Georgia: So that you can say Alexa. What's the weather like today and the Alexa will have access to your calendar and see that you're doing something, and that something is probably outside

Georgia: I was using picnic in a previous like version of the story, but like, that's too on the nose, maybe, maybe you're going to the doctor, maybe, such as doctor's appointment and knows that you're going to have to go outside, you know,

Georgia: To travel to that doctor's appointment. Although now telework definitely screwed that up.

Georgia: But

Georgia: But in any case for the story sake. Right, so like it. It looks into your calendar and says it's supposed to rain today, remember to take an umbrella. When you go to the doctors at noon. Right.

Interviewer: Mm hmm.

Georgia: Or if they also want you to be able to ask lots of questions. So, you know, you can be with your kid and say, like,

Georgia: Alexa, tell me about the Ankylosaurus and I'll say like the angular source was a dinosaur that was during this, you know, period. And then you can say something like, well, how does that compare to the Cretaceous period and then like, you know,

Georgia: It'll be able to you know link the previous question to this question.

Georgia: Anyway, so

Georgia: That's at a very, very, very basic level that long term context.

Georgia: And and I think your guys's work is going to be a lot more challenging than that because that sequential context.

Georgia: Or at least you know directly

Georgia: Correlated context. And you guys are going to have some you're going to have to find that direct correlation

Georgia: Right, so you're going to take teaming in this perspective and you're going to have to look at across other documents or other requirements to see if t mean is referenced again and make it hopefully in the same way.

Georgia: In order to build some understanding of what teaming might mean and how you can apply it to build the tree across these other requirements.

Georgia: Least that's my perspective.

Interviewer: Yeah, no, I think that's a really good point.

Interviewer: I think that's something that we may not be fully considering is the context. I think it's really good that you brought that up because that is a good point.

Interviewer: Other any other sort of any issues with the way that you like. Y'all do things or something like that, that maybe we could

Interviewer: Take some inspiration from that way.

Georgia: So something that we're investing heavily in is system modeling like system L type

Georgia: Under so building out our system models relating them to some reference architecture.

Georgia: And then trying to link those things together so that we can better understand constraints. So like all the whole purpose of all of this is to reduce complexity. Right.

Georgia: These are all really complex things and your head starts to kind of spin a little when, again, you look at the scale at how much you have to abide by.

Georgia: It's like if you're given like a 400 page contract.

Georgia: And you're like, you have to abide by this the most actually even the best example. The best example of this is Terms of Service, no one reads Terms of Service. Why, because they're too complex there too long, and it's it's not tenable for one person to break all this down individually.

Georgia: Right, you need teams of people to do that.

Georgia: And you know, that's what we have. So, reducing complexity, even for the team is a step in the right direction.

Georgia: So a

Georgia: System modeling is just a way of kind of like structurally writing down these things, such that you can apply structural processes to them.

Georgia: Like evaluating constraints.

Georgia: Evaluating very, very basic stuff so like a understanding that here. I haven't. I have a good example. Here I'm just full of examples.

Interviewer: It's good.

Georgia: Understanding that like

Georgia: You know that like attributes like yaw

Georgia: means the same thing across the system. So like

Georgia: yaw can mean crab angle.

Georgia: It could mean

Georgia: You know rotation around the z axis or side slip, like so. Like there's

Georgia: Like that. That's a good example of like managing expectations and constraints were

Georgia: System model is going to do that much more systematically at scale than a human.

Interviewer: Right and

Georgia: Now you can get around this with good knowledge management.

Georgia: Basically

Georgia: You know, coming to the table with a set of standards and say, just like just please meet these standards. Right.

Georgia: This standards as ER is rotation around the z access. Right. And if we're all following the standard and we have some conformance tool.

Georgia: Then, you know, we've already reduced

Georgia: Some complexity that the system model might have to to explicitly define

Georgia: So, doing, doing things like that where we develop standards or we developed performance tools where we, you know, have some reference architecture or some authoritative source of information about the subject area.

Georgia: So that we can you know model these goals and constraints to help reduce complexity.

Georgia: Not just between what we're supposed to be doing. But what we actually are doing

Georgia: That's kind of how we're doing it now.

Georgia: And it's still a work in progress.

Georgia: We're still not there yet.

Georgia: Basically

Georgia: So a system model isn't going to represent all aspects of your system is going to represent the intent of the modeler right so

Georgia: The it's what I'm getting at there is like even if I have a really good system system model. I'm not necessarily going to help reduce my understanding or help improve sorry help improve my understanding of teaming

Georgia: And how I'm accomplishing it what it's going to do is it's going to help understand that I I have the dependencies in my system to help do obstacle detection and avoidance.

Georgia: Right that I've defined yaw correctly.

Georgia: That I've

Georgia: I have systematic

Georgia: Structures that allow me to not only understand what isn't isn't an option, what is and isn't an obstacle, but I can populate that information across my system in such a way that activation changes.

Georgia: Based on that definition right so that's what a system model is going to do, but it's not going to tell me, like, you know, in the aspect of understanding obstacles. I'm properly coordinating with my teammates to

Georgia: You know, so that they can drive in front of me without us hitting each other.

Georgia: So,

Interviewer: Okay.

Interviewer: You mentioned, I guess sort of issues with knowledge management, I guess sort of from a change management point of view.

Georgia: Configuration Management. Yeah.

Interviewer: Yeah. Uh huh.

Interviewer: What, what can you tell me a little bit more. And I guess sort of the issues with that. Maybe there's a way to

Georgia: So,

Georgia: And that's that's related to complexity as well. So knowledge management is about

Georgia: Taking something that's evolving.

Georgia: And reducing the complexity or the overhead for the average person to follow that evolution.

Georgia: And you're right, it's, it's actually a config, so it's it's both a I'm calling it knowledge management because that's a very broad approach to how you can to the problem.

Georgia: In the sense that, like, it doesn't have

Georgia: A configuration management usually applies to a specific system.

Georgia: Where you're just watching how it changes and everyone understands where the changes are occurring and how that affects them.

Georgia: The issues that we have with it are that like it's just

Georgia: It good knowledge management requires and good configuration management requires dedicated personnel.

Georgia: To produce those artifacts.

Georgia: To update those changes to

Georgia: Distribute and

Georgia: Populate whatever databases or models or whatever, right, like like it knowledge management is a central role and configure manage configuration management is a central role with distributed benefits.

Georgia: Without someone acting as that central role we have distributed not knowledge management, which is supposed to asynchronously update

Georgia: And that's difficult

Georgia: So that's, that's the best way I can put it

Interviewer: Gotcha.

Interviewer: Okay.

Interviewer: So some way to sort of

Georgia: How do you think about

Georgia: Well, no. So

Georgia: I guess I'm of the belief that it doesn't have to be centralized that we can do things asynchronously and distributed and still have enough knowledge and 80% solution right

Georgia: I just I just still haven't figured that out yet.

Interviewer: That's no that's a tricky one.

Georgia: And so if even just think about like autonomous vehicles coordinating so

Georgia: An example I like to use here is imagine you and a friend are searching through the woods to find something that someone lost

Georgia: Okay, and

Georgia: Let's just pretend it's like

Georgia: That like okay this is good. This is easy. So you're on a commute. You're on a canoe trip with some friends.

Georgia: And someone has like their phone. And one of those protective cases.

Georgia: So there are new gets flipped.

Georgia: And the phone is somewhere down the river right and so you guys spread out to search for this phone. And it's in the protective case.

Georgia: You're going one way friends going another way, and you're kind of like

Georgia: Searching across the river beds and stuff like that.

Georgia: And you get to some aspect.

Georgia: Of this river bed where it's like, it's kind of dammed up and it doesn't look like the phone is there.

Georgia: But like any other case, like you, you probably don't need your friends to come over here and help you if they're done looking over there.

Georgia: So what you can do is you yell and you say, hey, it's all dammed up here. I don't see the phone. Keep going that way, say, the river splits.

Georgia: But then, like, you know, you're waiting for them to yell back at you saying you know Roger. Sure. Okay. We don't hear anything.

Georgia: Right, so your mental model of what they're going to perceive next determines whether or not you're going to yell again. So you look around.

Georgia: And then you look you look a little further down, you're like, Hey, actually, even though that splits way over there like it's going to come back around and we're going to see each other.

Georgia: So even if they're following the other path, they'll see me. I don't need to hear the word Roger

Georgia: They'll eventually find this

Georgia: Right, so that's distributed knowledge management that's asynchronously updated.

Georgia: You didn't need to have to go backwards and confirm instead your understanding of what they know and how they're going to get there means that you know they're likely to get to that distributed knowledge.

Georgia: Later, and you know that

Interviewer: Gotcha. Okay.

Georgia: Right.

Georgia: Yeah, so that's distributed knowledge management.

Georgia: That can be asynchronously updated.

Interviewer: Okay.

Georgia: So if it's possible for humans to do it.

Georgia: I think it's possible for for us to figure out how to get machines to do it.

Interviewer: Right.

Interviewer: Okay.

Interviewer: Yeah.

Georgia: I know it's kind of a very contrived example but I'm just trying to give you something that like that makes sense. Like,

Interviewer: Yeah.

Interviewer: It definitely good.

Interviewer: Yeah.

Interviewer: I think that's most of the questions I have for you.

Interviewer: Okay, you give me some some good things to think about and bounce off the team. Hopefully we can

Interviewer: Yeah.

Interviewer: I think, for sure.

Interviewer: There's more stuff to consider.

Georgia: And I think there's probably some prior work and extracting context.

Georgia: So like, if you think about it, just like

Georgia: I'm kind of riffing but like you know 20 years ago topic modeling LD a PSA.

Georgia: Like, those are all basically saying like, I want to take words and I want to group them into similar topics, religion, politics, whatever.

Georgia: And then, you know, we've come a long way since then, in like

Georgia: Breaking down sentence structure and kind of reading between the lines.

Georgia: To figure out some of those long term context or that that long term care long term that that long range.

Georgia: Relationships between you know sentences and paragraphs and previous sentences and paragraphs.

Georgia: So I imagine there is some prior work out there that can help.

Georgia: I guess not group, but not group or cluster, but

Georgia: Better understand those dependencies.

Georgia: And and the way I describe it like that is because in my mind. It is a graph. And when you're building a dependency structure, you're building a graph.

Georgia: I don't know. I'm just not. I'm not too familiar in the language domain.

Georgia: As I am in the image domain.

Interviewer: I guess the last thing I will ask you, are there any other people you think might be a good source of information for me to talk to you.

Georgia: Um,

Georgia: Let me think about that. I'll

Georgia: Maybe

Interviewer: Uh huh.

Georgia: Maybe a. So there's a guy named Sam on my team that might be good. But let me ask them first.

Interviewer: Okay. Yeah, absolutely.

Interviewer: Yeah yeah

Interviewer: Okay.

Interviewer: Yeah, I'm just trying to get

Interviewer: As much. Yeah.

Georgia: I know

Interviewer: Yeah.

Georgia: Yeah yeah

Interviewer: Yeah, okay.

Interviewer: Well, I think that what does it for me. I think that's all the questions I had so

Georgia: All right.

Georgia: Appreciate your time.

Georgia: Yeah, you feel free to email if you have a few follow ups.

Interviewer: Absolutely. Okay.

Georgia: All right. Take it easy.

Interviewer: Bye.

Interviewer: Okay, and so to sort of I guess kick us off, can you start me out with a little bit of like your understanding of requirements and maybe, how do you define it and sort of how how have you interacted with them, so far, the difference process.

Colleen: yeah um so like before going into this restricts like the difference harden the objective of it is to get a feel of how the Olympic village and rate.

Colleen: And the very first very first step if you talk about the Viagra is coming to coming up with the functional objects functional objectives and victory comments.

Interviewer: So the.

Colleen: way we started off.

Colleen: was like we knew the vehicle would be autonomous, it could be fast can do it would be offered.

Colleen: So that.

Colleen: The things we started off with.

Colleen: And the first step was.

Colleen: To create missions scenarios think about where this vehicle we know it's it's sponsored by the military so like come up with scenarios.

Colleen: Where this would be a potential best product.

Colleen: So thank you what mason's not yet added a few comments now so once like we had thought about the missions like we are a team of 2021 people so like we came up with different missions widely varying missions came up with in total nine missions and then sat down together and.

Colleen: selected, some of them, which had.

Colleen: You know, sufficient variety, but not like one is, it is in desert and one is in colder not not like that, I mean one way, you cannot do that right so sat down and.

Colleen: wrote together two to three missions and then started thinking about in technical terms like what what will be the functional object so.

Colleen: When like one or two weeks on that.

Colleen: And from there, we didn't have a killer comments on the functional requirements.

Colleen: And then some level of system records so i'm i'm in the overall objective was yeah we're building a vehicle, this is the first step, we need to know this and, like get it in our head that.

Colleen: Every everything that will follow will link to this weekly requirement list for making I mean the overarching agenda was not to come up with.

Colleen: An exhaustive vehicle your comments by the books.

Colleen: Saying that.

Colleen: We, like our end end objective was not to make the make the.

Colleen: wiki look comments in the most in the in the best way possible, but to fall upon or to start with, when you are building a model and.

Colleen: So we revisited quite a lot of times from the regular comments, because it was not very refined and.

Colleen: We kind of struggled a little bit and getting the hang of how do we start from nothing and still be specific and not so, not so specific that we're limiting ourselves on the vehicle are building so that was.

Colleen: Really confusing and

Colleen: I, to be honest, it was not the most enjoyable part of do yet, but.

Colleen: I mean, the more you spend time, the more you realize that it's inevitable, I mean just one of the most critical parts of building anything.

Colleen: So yeah so that had been my interpretation and experience with building up requirements into you.

Interviewer: So.

Interviewer: let's go into a little bit more details for the how exactly did you develop that you said that it was sort of a maybe a cyclical process should have went back to it a few times, but you walk me through that little process a little bit more in detail.

Colleen: Yes, yeah um so.

Colleen: We started off with yeah function and objectives right um.

Colleen: Since we're dealing with.

Colleen: Different TEAM members are some of them were like too broad and some of them are two specific.

Colleen: um we talked about drone compatibility and now.

Colleen: You can write down like the nitty gritty of how this will happen um what what exactly the systems should be in place so that this can happen, some of us did that, and it was, oh no, we should not be taught in.

Colleen: The synopsis sipping the mass of the room, how many drones like we should be keeping in general yeah there should be a number, we should keep in mind, which will later finalize that here, this is the payload of the drones were going to carry.

Colleen: And not say how much right now, but have a placeholder so.

Colleen: Some songwriters to plot some hurdles to specific and.

Colleen: When I say that we went back to it quite a lot of times, it was.

Colleen: Mostly getting everybody on the same level of detail and also we kind of mesh.

Colleen: How many how many people, we have to work with some of the requirements were to I mean so much that obviously team of 20 people cannot handle that.

Colleen: approach that will be focusing on building the vehicle and.

Colleen: Not focusing mostly on drone compatibility, because that necessarily not necessarily in automotive portrait so was it more than Barton more on the grill dynamics and yeah so this would come up as a feature.

Colleen: So when you talk in mission contexts.

Colleen: I mean it's a given that the vehicle will run and maybe the most.

Colleen: talked about, we talked about detail, are the features this what it can do what that can do and kind of went somewhat in the wrong direction, focusing mostly on that.

Colleen: It.

Colleen: took some rounds of discussing to get us right in into the truck.

Colleen: So yeah like overly timeless spent learning how to do the requirements.

Colleen: Like 50% were were.

Colleen: course correcting and getting everybody on the same page and 50% were actually doing the work and putting down the requirements.

Interviewer: Okay.

Interviewer: When you when you're actually writing requirements, how did you how did you write them was it like a group everybody sat down and then, just like hand wrote out like plain text or did you sort of have in mind a specific way of constructing them.

Colleen: yeah well we had so initially we started off with an excel sheet so.

Colleen: Reasons descriptions on some logic active then data from the vehicle requirement and then for the regarding to system requirements can easily on nexus it then.

Colleen: We formalize that in simulating requirements in composer tool so like almost one and one and a half week was gone in learning that and bringing those requirements from excel to some link requirements and in the tool name is Emily requirements so.

Colleen: It has a couple of like.

Colleen: Interesting features, because you can really link different way cooler Comments like you can establish software link.

Colleen: Vehicle requirements to mission requirements are functional objectives, and you can export it into a table like.

Colleen: really visible so that was one that I will practice also you can link the individual vehicle your comments and also the system requirements to.

Colleen: test cases to do similar model for daily use, so I need this much amount of breaking distance, it will link up to the.

Colleen: baking model and from there, it will come back as a tech market is passed, or failed or it is, it has not yet been tested So these are a couple of the truck driving things why we chose some lingering comments, but.

Colleen: The way we put down was.

Colleen: excel to simulating the comments establishing all the links.

Colleen: doing all our revisits in the simulator common document.

Colleen: And, once we have a version one or beta version of requirements we export it out in the form of a table where like it's it's a summary with all the links established.

Colleen: to function objectives and requirements.

Colleen: And also, is an excel sheet, so that we can just discuss in a very exhaustive and comprehensive way you can read into all the details on this exact image with the faculties.

Colleen: There doesn't leave your comments to excellent backwards.

Interviewer: Okay.

Interviewer: When did you sort of review the requirements and when you did sort of what did that process look like.

Colleen: So it was.

Colleen: The going back to the requirement spot yeah.

Colleen: So it was all in the arts in the very first month of starting do so, we spent first couple of weeks on missing the comments, then we kill the comments.

Colleen: putting down demand excellence.

Colleen: And then immediately into signaling and then we went off into you know how the model should look what should be the are working direction.

Colleen: Not not talking about a comment that much and then, when Finally, we are talking about the technical stuff the architecture of the record Okay, then it.

Colleen: came back Okay, we need a decision on that this and it is clear that we should look into our requirements that sort actually guide us going for audit, but that that guidance was not coming from the way through the comments and.

Colleen: Then we thought yeah.

Colleen: This clearly stated that we should revisit and and the under 30% of time that I talked about that went in the learning experience was doing this, this thing.

Colleen: Okay, we have a starting point let's not discuss much more into it right now, because we are not the experts let's start with this, then we find an obstacle and.

Colleen: yeah we're not going ahead, so our requirement that we will describe requirements would be chance to come back and do the chance, take the next to next steps and again revisit i'm quite sure that we had our first video and we presented a set of requirements.

Colleen: And I will be doing that rates were 6% and some something will again come up and will will.

Colleen: will again figure out that this is not enough, we need to revisit define a bit more.

Colleen: So, like that's how returned to the revisiting part.

Interviewer: When you sort of start to see these sorts of changes to requirements may not have any sort of like formal changes, but it sort of addition or modification to a requirement, how are those sort of like managed and captured is there some sort of like formal process for that or.

Interviewer: Is that what does that look like.

Colleen: yeah so it's it's done in the same link read the comments so basically you have a list of objectives and.

Colleen: You have another list of a killer comments and there are hierarchal lower level structures, you can go on adding so.

Colleen: Basically, stating i'll take an example, so we had a functional ability of stealth right deviancy recommended, yes, health is a very tricky thing to describe and it will make your life so much harder, if you if you try to implement.

Colleen: It nice I laid it looked like yeah This makes sense we soon implement as a missionary comment.

Colleen: But when when this this comment came back, we went and remove delta and remove all the specific way cooler comments that was.

Colleen: linked to stealth, and it was easily possible because we actually worked on a hierarchical structure where all these links were established, and you can refine out, which is.

Colleen: I mean.

Colleen: A particular particular comment is linked to styles and it is also linked to something else right.

Interviewer: So we're not actually delete that requirement we just deleted the link.

Colleen: And will we said that we not think about.

Colleen: Health, while while dealing with the system requirement, so that that's how we did.

Interviewer: Okay.

Interviewer: So, so when you do that, is there, do you have to sort of present any sort of like change proposals sort of like hey we'd like to to make this change or is that something that sort of just.

Interviewer: done as you see fit or.

Colleen: So more like.

Colleen: Chris coming back from CBS is meeting and telling us that yeah So this has been the feedback.

Colleen: This is the point we need to address.

Colleen: So we discussed with him what.

Colleen: What it should look like without actually doing it in front of him and a couple of students who have all done that particular particular comment that in together removing it and developing next week, which is hey we have made that change.

Colleen: What are you thinking in this way or that is something some some other things that are missing.

Colleen: Missing so that, so the process.

Interviewer: yeah that's kind of what I was asking for yeah this is there some sort of oversight, or is it just sort of one person sees a change that needs to be made and it just does it and then yeah.

Interviewer: Okay okay that makes sense.

Interviewer: Okay.

Interviewer: let's see so you said you're using sort of excel and the matlab requirements editor is there any other sort of systems are tools that you're using sort of along the way.

Interviewer: Okay.

Colleen: When when we are working were mostly dealing with the matlab on the ceiling credit commentator.

Colleen: What we're talking to stakeholders than most lyrics in terms of excellent guys, if you want to send the exhaustive list, then it's the next or not.

Interviewer: OK.

Interviewer: So I guess i'll sort of shift gears from here, because it's part of part of our project and we're looking at.

Interviewer: Possibly developing some sort of software or program to actually help out with sort of requirements development.

Interviewer: And requirement management that sort of thing so i've got a few sort of hypothetical questions, maybe about like features, it could be implemented and see if they'd be beneficial or maybe some sort of food for thought and see this make you think about some potential ideas.

Interviewer: So just to kick that off, are there any sort of issues with with standardization of requirements.

Interviewer: Between sort of requirement writers or different sort of.

Interviewer: system teams or subsystem change something like that.

Colleen: And so the biggest challenge for us would be i'm not sure there was a recommendation or not, but biggest challenge was we had absolutely no idea from where we started.

Colleen: And we are like asking give give us a starting point Okay, if you say that massive the vehicle can be from 500 cases to 5000 kids we are large like, how do we, how do we cannot just the score at the absence rate.

Colleen: So if it's a 500 cases the outrun weekly requirements will be way different than input say 5000 cases so getting that initial idea if it is somehow possible from the beginning to.

Colleen: Get that started.

Colleen: With with like a skeleton of requirements.

Colleen: are doing that high level study that.

Colleen: This is a common way killer comments per subscriber, then I would say, it will speed up the process and a lot, especially when when.

Colleen: We are definitely not the expert for it, we are, we are beginners in writing weekly requirements and before coming here.

Colleen: Okay, we had we have to do this let's start off with the model so writing requirements and linking back to it was never that never in our heads.

Colleen: And now it has kind of sunk in like the backup our hands the year.

Colleen: We will link everything back to the regular comments of these need to be done properly.

Colleen: So when one an expert is not writing the requirements some kind of.

Colleen: Initial guideline and spill it on to fall back on video.

Interviewer: Okay.

Interviewer: What sort of information, do you find just the most important to turn a caption requirement, maybe, like the subject specific like target value or just sort of like the overall scope something like that or any other features that are critical to have and it requirements.

Colleen: some kind of.

Colleen: Alright, so.

Colleen: When when you say high speed autonomous, so I mean highspeed what does that mean it is, it is it 30 K peers, or is it a 130 mph so.

Colleen: some kind of ballpark because.

Colleen: Almost for a month or how or one and a half months we are thinking high speed means.

Colleen: Like 100 miles per hour and anything less than that.

Colleen: it's not good enough.

Colleen: So, at least if someone had said that yeah anything greater than 20 or 30 K pages price with a love.

Colleen: and your that lot of time.

Colleen: would have saved I mean not not in terms of progress of do, but the time you spend talking to each other over the week.

Colleen: hours of this presentation yeah that could have been saved a lot so some initial starting ballpark numbers would help.

Colleen: When whoever is.

Colleen: Like sponsoring other stakeholders, I mean they have something that definitely they have some rough idea.

Interviewer: And they're.

Colleen: Really really a high level and they might be having some amount of numbers attached to that.

Colleen: So those kind of starting points would would really help I mean there is a slight risk of limiting wonderful can be and what the solution can be to the statement, but in essence of time that should be balanced, you know some kind of tracking figures ballpark numbers.

Interviewer: Okay.

Interviewer: Do you ever have any issues with like requirement redundancy, so you have a couple of requirements that are saying the same thing, but in a different way, or the same target but different values or anything like that.

Colleen: yeah yeah that has been there, and so, for example.

Colleen: team, they have the same kind of requirements to mobile iterate they will have excellence and capacity and making capacity.

Colleen: And maybe we'll have a bit more of your lateral and vertical and dollars this part and mostly D will deal with longitudinal once.

Colleen: It has been there and.

Colleen: it's just.

Colleen: We decided okay let's not discuss too much of what the overlap could be let's just do our own thing and a new will be meeting all together and going going through all the requirements between two different subsystems.

Colleen: Open yeah we'll see what are the overlaps and we'll we'll discuss okay and does your makes sense, or does our makes sense, or some basic same or this will be different and then go over it from there.

Interviewer: Okay.

Interviewer: Would it be useful to have some sort of method for perhaps visualizing requirements, so you can sort of visually see like the links between them or sort of like clusters.

Colleen: to know all our guidance has been.

Colleen: text like look look into an electric material look into Google and interpret what is a system requirement, what is your functional requirement and how this will buildings, so the layer making of that pictorial representation in our head.

Colleen: And if there is a current structure that will visually tenders, then that would be good it's like you, are writing switches pseudo code and you have an algorithm skeleton American it so definitely the latter one is and goes studios.

Interviewer: Is there any sort of function in the matlab editor that actually like graphically show you the links, because I know you mentioned it, you can sort of create the links, but is there any way to sort of visualize that like a.

Interviewer: yeah or.

Interviewer: Something like that.

Colleen: That is, you cannot meet the exhaustive list from a visual perspective but.

Colleen: Like you can work on hierarchical structures so mobility, then it will have three more sub sections and, within that you can create.

Colleen: And then you can manually link those things to the functional object which unmet needs and requirements and after you're done, you can export it as a visual thing as a PDF but all the links on the direct ancestor.

Colleen: So that part is already there in matlab.

Interviewer: When you sort of look at your requirements are most of them sort of separate in nature, or are they sort of like coupled or related together or to the same topic.

Colleen: i'm mostly they're they're good but.

Colleen: In some of them will definitely be coupled but mostly they will be.

Colleen: yeah mostly they were separate i'm just thinking.

Colleen: No, no, mostly they're they're separate.

Interviewer: sort of again sort of the hypothetical having a way to sort of.

Interviewer: recognize what you're typing as a requirement.

Interviewer: And maybe giving suggestions for like phrasing or maybe highlighting like ambiguity or some sort of conflict would would that be helpful at all or.

Colleen: um.

Colleen: You mean if we put down something, then.

Colleen: The feedback will be this is this is ambiguous and not clear.

Interviewer: sorta so like if you were you were typing in a requirement and then.

Interviewer: It sort of gives you feedback as you're typing kind of like the clippy the paperclip thing on Microsoft word I was sort of like give you formatting helps a little bit with something like that be be useful.

Colleen: um.

Colleen: So one of the issues was.

Colleen: How do we, how are we specific enough.

Colleen: At the same time not not go into too much detail.

Interviewer: So that.

Colleen: fine line, and we really struggled finding that fine line so either would be like too broad, or two specific so if something can.

Colleen: Ls that yet di or you're not in the right area here, that would be good yeah.

Colleen: um but.

Colleen: yeah so, for example, if we're talking about a vehicle.

Colleen: Being operable in the snow.

Colleen: I mean you can phrase Okay, this will be deep snow.

Colleen: One other way to phrase Okay, this will be two feet of snow, I mean so devastating to fit we don't know it will be to fit, but at the same time for adjustments and deep snow and what is the snow so.

Colleen: How do, how do we reconcile this.

Colleen: So you something and come up and help us with that that would be great yeah.

Interviewer: Okay.

Interviewer: And would it be useful to have some sort of way to maybe highlight if requirements are conflicting or.

Colleen: Yes.

Interviewer: Okay.

Interviewer: And then, what other.

Interviewer: Maybe shortcomings or sort of areas for improvement, have you maybe identified from the the process, the requirement generation process that you've used so far.

Colleen: um.

Colleen: So.

Colleen: I think about all the issues we had faced one was this ambiguity and one was.

Colleen: Not having enough starting points.

Colleen: And one one was kind of a solution we which we fell on to like start with something.

Colleen: Do the work come back and I still do not know that's the way that would be the way it should be dealing, but if it is not the way then anything that will help us, you know start with an exhaustive requirement.

Interviewer: Oh, and.

Colleen: Not having to come back to refine it later so many times.

Colleen: That that and that would help a lot.

Interviewer: Is there anything else you can think of that maybe wasn't an issue, but something you'd like to see sort of in the future, some sort of additional functionality, that being useful or helpful in any way.

Colleen: i'm human species on mobile process of.

Interviewer: Either one.

Colleen: mean always I would if we're using simulation great comment I would.

Colleen: like to see version control implemented there.

Colleen: matlab doesn't support that right now.

Colleen: I mean.

Colleen: The the whole point of lingering comments, is that this hierarchy is established straight.

Colleen: And do whatever you want so different people from different subsystems they can actually work on different parts which are not linked, I can work important someone else can work on DVD requirements.

Colleen: And the thing is, we cannot work simultaneously, even if they are independent, we cannot work on them simultaneously because version control is not support supporting yeah like to my change he does make change he does he's seen this and they're most interested in.

Colleen: So that.

Colleen: creates some time penalties on core part of not being able to work on these things so that improvement I would definitely like to see.

Colleen: If we.

Colleen: can think of one more.

Interviewer: So.

Colleen: One thing we often lost track of is OK, we have 12 months or 18 months to complete the vehicle and we are, we are coming up to this comment in this features they look great, and this will be part of the week.

Colleen: But in our head not being the experts.

Colleen: We do not have that picture, how much time and effort, it will take.

Colleen: So any kind of indicator okay this looks great but it's going to take so much time, I mean it it's a very simple questions, anyone can ask when they're writing their requirements and we find ourselves, you know.

Colleen: i'm forgetting to ask that and it looks great and someone does some summer down the line, looks they will say that yeah.

Colleen: I mean this will this this will take a lot of time and definitely we cannot achieve that some kind of checker to you know steer us back to the right that kind of continuity will be will be here.

Interviewer: make sense.

Interviewer: it's very anything else that you're getting is, it would be good for me to know or.

Interviewer: anything like that.

Colleen: So, so you were creating some kind of guidance to write requirements or a tool, or what exactly yeah.

Interviewer: yeah so my my job is working for them so where i'm looking to to understand how requirements are written.

Interviewer: And the overall just sort of requirement lifecycle process so that we can then.

Interviewer: find ways to sort of improve that or or tools to implement that sort of thing.

Interviewer: So if there's anything that I didn't maybe.

Interviewer: touch on in the reform process that would be good for me to know about.

Interviewer: like that.

Colleen: The one I think we'll have to do is.

Colleen: More.

Colleen: More feedback systems.

Colleen: So there was one where Dr brooks and tequila they came in and there are a lot of feedback and that like we had to make a lot of changes I mean they all made sense we are not thinking about those things.

Colleen: We heard one system like that, and if we had like two or three at the or, at least if we had that one system.

Colleen: course the very beginning that might have felt.

Colleen: i'm not sure, but just speaking in hindsight, you consider this medical despite.

Colleen: Always on so you know some guidance.

Colleen: and

Colleen: I mean it's it's a dicey thing thing to say that.

Colleen: Some amount of prescription.

Colleen: And a little bit slight slight slight reduction in freedom of you know, writing the requirements.

Colleen: To speed up, I mean the I ch a nice thing to say, but that's that's that's what I.

Interviewer: To having more feedback earlier in the process, you.

Interviewer: cool.

Interviewer: With that that's all my questions and.

Interviewer: I think that that's pretty much everything I had and.

Interviewer: So I will write up my notes into a little summary.

Interviewer: And then also not to you that's all right that we can just sort of review it and make sure that I didn't miss anything there's no glaring errors that's really I'm getting the right sort of.

Interviewer: Important pieces out of it so I'll try to get that to you, within the next few days.

Interviewer: But other than that I, I thank you for your time and for me with me, I appreciate it it's good information.

Colleen: Thank you.

Interviewer: Thank you, bye.

Interviewer: Wonderful.

Interviewer: Already, then I guess just to get started.

Interviewer: Can you tell me a little bit about how you.

Interviewer: interact with requirements and sort of in your role.

Interviewer: How often like frequency that's one of things.

Interviewer: Just sort of a background understanding of.

Daisy: required oh yes okay um so, you know as a faculty.

Daisy: Member I there a critical part of kind of what we teach in the design classes that.

Daisy: You can design something until you kind of know the parameters of the feasible design space okay oh requirements ultimately represent those boundaries between what's feasible and what isn't feasible.

Interviewer: and

Daisy: They also provide a gradient to the design space that tells us what regions in the design space are more attractive than others.

Interviewer: mm hmm.

Okay.

Daisy: So largely what I do you know as a faculty members, I try to emphasize the importance of identifying good requirements early understanding what they really mean in terms of the design, space and then coming back and revisiting them continuously throughout the design.

Interviewer: Because you will always be.

Daisy: questioning whether or not this requirement is still valid, whether or not based on our current understanding of the project, whether or not this is the right requirement, or whether or not we've evolved our understanding of the design space in a different direction.

Daisy: One of the critical things I think students have a hard time.

Daisy: Doing is seeing those those requirements as dynamic living entities.

Daisy: They also seem to be a little challenge in terms of recognizing that all requirements are not equal, ultimately, you may have a project that has.

Daisy: hundreds or thousands of requirements, but you really spend your time agonizing over a few.

Interviewer: Okay.

Daisy: A lot of the requirements that you may put into boundless space, you know are actually relatively easy to meet it's the ones that you know are really kind of driving your decision that you really need to identify.

Daisy: So a lot of this comes from both you know my understanding, as you know, a student of this going on, but it also is colored.

Daisy: A lot by what I did department of.

Daisy: Energy, where we did some requirement, a lot of requirements work for the systems that I was involved with.

Daisy: Oh, I use a lot of the Department of Energy terminology and structure for trying to sort of monitor and trace the evolution of requirements throughout a project.

Daisy: In part of energy we talked about it with requirements traceability matrices.

Daisy: Which kind of captured a here's the requirement here's why it's important who originated it, how are we going to test it at the end.

Daisy: And ultimately we'd actually have that form the basis for building a requirements test plan and for then documenting the results of the test plan is you just finish filling out the matrix with the results.

Interviewer: Okay.

Interviewer: Actually answers my next kind of question sort of how did you define requirements and where the where the source of that sort of definition and terminology came from okay.

Daisy: yeah a lot of its colored by you know essentially is coming out of the nuclear industry and so there's definitely a lot of requirements driven engineering.

Daisy: In their.

Daisy: codes and herds and practices and so there's a lot of emphasis on making sure you have things documented.

Daisy: And the documentation, you know, is really a tool to pass along understanding to somebody who may not have been there for the decision making.

Daisy: And that's also something students don't like to do that I don't see the projects is going beyond their class.

Interviewer: So to sort of I guess back up a smidge.

Interviewer: When you when you teach requirements, how do you.

Interviewer: sort of teach like the development process who's.

Interviewer: How was that how a requirement should they be developed and sort of who should be involved in that process.

Daisy: Ah, well you know I teach the development as well, my favorite ways of doing it is first by breaking down kind of your understanding of the project into kind of here's the goals.

Daisy: Of the project, because those often lead to some of the criteria being.

Daisy: developed, but also some of the constraints that come from the specification.

Daisy: Those lead to some of the requirements to provide the boundaries um.

Daisy: So we usually start there and then i'm a fan of going in using checklists.

Daisy: And to start asking questions about well what have we missed okay uh you know I mean, I had a senior design team that yeah I got to use an example.

Daisy: Because they designed a system to go into a classroom.

Daisy: And when they came up with their first set of requirements that you know they had a bunch of requirements about what has to be stored in this volume and you know these are kind of the sizes of the tables that could go on, I asked a question how big are the doors to get into the classroom.

Daisy: As a specified is like a 42 wide system and or could be a 42 inch wide system and I asked him how big are the doors and there's or I don't know we didn't check that and so you think it might be a problem, going.

Daisy: Through you know the.

Daisy: system going through a 30 inch door.

Daisy: And that's kind of why I like checklists is they know it's very easy to overlook a requirement or say sort of obvious.

Daisy: But checklist.

Daisy: make you kind of go back and you know systematically go through, and say, are there any requirements related to the dynamics of the system or to the recyclability in the system or.

Daisy: You know, to the thermal aspects of the system they may be obvious, but you know I guarantee that if you ignore the obvious requirements someone's going to forget them along the way, and you may produce a design that violates one or more of those requirements.

Interviewer: mm hmm.

Interviewer: Okay.

Daisy: And then the other thing I do kind of with the evolution is I you know I tell the teams that someone is in charge of that requirement.

Daisy: there's always a person responsible and that person was responsible job is to keep asking throughout the project are we still meeting this requirement, do we still need to meet this requirement is this still the right requirements.

Daisy: kind of insist that there has to be someone in charge of that, because otherwise it's easy to kind of forget.

Daisy: Your requirements, and so I tried to divvy it up amongst the team to say, everyone should be asking this question throughout.

Interviewer: Okay.

Interviewer: All right, so.

Interviewer: When you teach.

Interviewer: requirement writing.

Interviewer: Is there, like a formula and foremost I want the right word but sort of like a.

Interviewer: Specific format for it, or they just wanted.

Interviewer: Like plain text.

Interviewer: or specific elements that have either.

Daisy: encouraged complete sentences I don't necessarily require it.

Daisy: I do, encourage them to differentiate between some words like.

Daisy: Should and shall.

Daisy: We go through some of the examples from the NASA systems engineering sort of requirements pitfalls.

Daisy: about writing clear requirements about yeah well what system needs to do this.

Daisy: You know, for instance, you know writing a requirement that says, you know the satellite must be able to.

Daisy: control its.

Daisy: position in orientation and six degrees of freedom well it's not really the satellite it's the propulsion system that has to be able to do that.

Daisy: And the control aspect actually goes to the guidance system, and so you know you got to be careful about writing requirement.

Daisy: So that it's pointing at the right parts of the system.

Daisy: Writing requirements that kind of box you in unintentionally getting to what's the purpose of the requirement.

Daisy: NASA has an example where they talked about.

Daisy: You have to be able to.

Daisy: recover the system from a water landing within such and such amount of time and it's a well there was an assumption in there that it's a water landing.

Daisy: And, really, the question is, is that you know you don't want to leave the astronauts stranded in the capsule wherever it comes down longer than a certain amount of time you like to be able to get them out of the capsule promptly.

Interviewer: gotcha.

Interviewer: Okay.

Interviewer: You mentioned sort of going back over.

Interviewer: and

Interviewer: constantly reviewing requirements, what should that look like how frequent should that be sort of who should be involved in that.

Daisy: Well that's one of the reasons why I have kind of a you know designee assigned to each of the requirements is.

Daisy: That they should certainly be going back through the requirements at some regular pace.

Daisy: I mean, to some degree, it depends on what what's changing in the system, certainly anything you change anytime you make a change in the system that potentially affects requirement, you need to go back and revisit that requirement.

Daisy: But I also would advocate for kind of a periodic review of the requirements.

Daisy: What that term is I think is very project dependent.

Daisy: for something.

Daisy: Deep orange i'd probably say you know every you know, three weeks to a month it's probably worth spending some time kind of going through all the requirements and asking are these still the right requirements.

Daisy: For for senior design type project that operates on a semester basis it's probably something you're doing every week.

Daisy: And that doesn't mean things change, you may come back and say nope these are still good and that that's fine, but the point is do the review, you know ask yourself, the question is this still right.

Interviewer: gotcha.

Interviewer: Okay.

Interviewer: When you sort of get these if you do the review and you come back.

Interviewer: And you have to make a change.

Interviewer: How, how should those changes be managed.

Daisy: Regarding requirements traceability matrix we manage those.

Daisy: Changes by keeping the original requirement in there.

Daisy: Okay, we may deactivate it or you know cross it out or use a color coding to delineate the fact this is no longer the requirement, but then we then we show the new version of the requirement.

Daisy: One of the things I like about requirements traceability matrix is it's a hierarchical.

Daisy: it's just like an outline, and so a lot of times you see changes to a requirement being that we break a requirement down from a single statement into multiple statements.

Daisy: So those multiple statements can become subsets of the original requirement it's about you know we kind of we have a deeper understanding of the system, and now I understand really it's got to do X, Y and Z.

Daisy: In order to meet the first the original requirement, and so we can put those sub requirements in underneath the original The other thing that was nice about it in terms of the Department of Energy was a lot of times you had.

Daisy: sort of very high level requirements that really meant a number of conditions had to be met, and you could when we're doing the testing, we could roll up the testing by saying hey if I can do if I pass tests 6364 and 65 That means that the requirement that.

Daisy: oversaw the sub requirements were tested by 6364 65 is met.

Daisy: Okay, so yeah.

Daisy: level requirements.

Daisy: Like robots, robot needed to you know needs to move a container from position to position be well that involved the robot had to go to position, a it had to grab the container.

Daisy: And then had to move in or from A to B had to release the container than the robot had to pull away from position be.

Daisy: And we could.

Daisy: Have kind of this overall requirements say yeah this whole task is done, but then we can have the sub requirements saying all five of these steps have to be mad.

Daisy: And that led to developing our testing plan and became kind of a way for us to get a deeper understanding of all little things that had to happen.

Interviewer: gotcha i'm.

Interviewer: going on with that is there some sort of like formalized like process did you have to.

Interviewer: Do when you'd actually make a change the requirement would you have to maybe submitted for approval and discussion and that sort of thing.

Daisy: depended on the subsystem.

Daisy: Okay.

Daisy: So.

Daisy: In apartment energy and we had certain subsystems that had to go through a formal process another subset did not.

Daisy: And so we were allowed to make changes internally those requirements.

Daisy: So, so that that was part of what was laid out, we would we would prepare requirements we'd actually generate for Doc key events is participating the garments traceability matrix we would have a.

Daisy: project.

Daisy: Requirements document, which would kind of overall describe the project at a high level.

Daisy: And a lot of senior design teams would say that's all we need, but then we would have a project a design and specifications document that would take those requirements down to another level of detail okay.

Daisy: That you would do things like break down, you know the robot has to move the container for me to be into all the constituent steps okay.

Daisy: Then we'd have a third document, it was called the project design document that actually took the requirements down another level.

Daisy: And would say things like if it was an automatically activated actuator we'd have requirements on.

Daisy: You know the pressure that the actuator had to work at the number cycles, the actuator had to operate for the forces the actuator had to generate open and close.

Daisy: The time of response you know all your very detailed requirements that are now very much specific to individual hardware components.

Daisy: So we're kind of going down from the system level to the subsystem to the components, as we write these events, and so the requirements matrix is developing increasing levels of detail.

Daisy: And then the last document.

Daisy: Right, would be the the project test plan.

Daisy: which would be a how are we going to test all these requirements we've now generated in these three previous documents.

Interviewer: Oh okay.

Daisy: And that's obviously that that's far more formal than what I do in capstone design.

Daisy: Students would lynch me for suggesting, they have to write all those documents.

Daisy: Knowing that fundamental its kind of the practice of yo iterating through the requirements developed the them in details, you understand more and more specifically what has to be done.

Interviewer: Absolutely.

Interviewer: Okay.

Interviewer: So in I guess in the capstone design projects sort of what.

Interviewer: tools or documents or strategies, would you recommend for maybe managing his requirement changes or have you seen used.

Daisy: I do some to the requirements traceability matrix I do, I give them a template of that document.

Interviewer: And I.

Daisy: Know here's how it's kind of used in Department of Energy and I point out that you know many companies will use something like this, they probably won't call the requirements traceability matrix.

Daisy: In fact i'll see you they'll probably have their own name for it but they'll have something that's effectively doing, many of these same things allows you to capture monitor update.

Daisy: or revise and ultimately test against your requirements.

Daisy: So I tried to get them behind the idea of here's the information we need to kind of track.

Interviewer: As we go through this.

Daisy: And so that's kind of how I approach it and capstone is trying to get them behind the idea, and you know, frankly, whether they use in our team they use, you know, a typical PDF form or any of the other terms that are out there you're capturing things stuff who cares what it's called.

Daisy: The point, are you are you tracking your requirements are you questioning your requirements throughout and, ultimately, are you developing your insight into what the limits really are on the project.

Interviewer: make sense.

Interviewer: Okay.

Interviewer: i'm jumping around my questions, a little bit.

Daisy: you're adapting your requirements.

Interviewer: Exactly.

Interviewer: I guess.

Interviewer: A part of something else that i'm looking at is sort of the.

Interviewer: Role of like I guess requirement networks.

Interviewer: And, just like sort of the hypothetical.

Interviewer: hypothetical use cases for those sort of things.

Interviewer: In if you have like some sort of requirement network or the students constructed one.

Interviewer: Do you think it would have.

Interviewer: Would it would it would be beneficial, perhaps.

Interviewer: Because you could maybe display some conflicts or.

Interviewer: Maybe make more visual the.

Interviewer: The traceability and the hierarchy.

Interviewer: That sort of thing it's for visual requirement network.

Daisy: I think it's important to kind of track where you have requirements interacting and the requirements traceability matrix access have a column where you're supposed to reference requirements that are connected to this requirement.

Daisy: Whether or not visualizing it is beneficial I don't know i've never really tried to do that myself uh I mean for some people, the visual understanding of kind of how things relate is probably useful.

Daisy: From a copy El standpoint there's almost certainly a benefit in there, where you can have a you know computer assistant on your requirements flagging you when hey this requirements been updated by this team or this group does it affect our requirement.

Daisy: Knowing the.

Daisy: relationship and.

Daisy: Whether or not the visual representation of that graph is useful i'm not sure.

Interviewer: gotcha okay.

Daisy: The Informations us.

Interviewer: hmm definitely okay.

Daisy: and understanding when you have a requirements it's tied to lots of different things I mentioned, you know finding those driving requirements.

Interviewer: And those requirements that are.

Daisy: angled with each other 10.

Daisy: sort of driving requirements.

Interviewer: Right.

Daisy: So so there's valuable information to be extracted in there.

Daisy: You know visually I don't know if that comes through very well, I think that, I think, with a lot of real projects it just becomes so complex that people can visualize it like the computation to be very useful.

Daisy: Okay.

Daisy: That makes sense.

Interviewer: Okay.

Interviewer: See I.

Interviewer: sort of answered.

Interviewer: I asked you like three questions in one.

Interviewer: And figure out.

Interviewer: What else I need answers, for I guess.

Daisy: Often the students have issues with like redundancy, so they write multiple.

Daisy: requirements that are sort of addressing the same thing from a different perspective.

Daisy: and

Daisy: I think that actually pretty common.

Daisy: I think it's also pretty common in most projects that it's easy to write requirements it's harder to figure out when they're clearly redundant.

Daisy: Particularly early on in a project, I mean you know the requirements you right at the beginning of a project are so high level it's almost guaranteed you're going to have redundant requirements.

Daisy: The requirements, I think the bother that I worry about more necessarily then sort of testing or having requirement represents the same thing more than once.

Daisy: We have a requirement.

Daisy: it's never really a bounding requirement.

Interviewer: Okay.

Daisy: So requirement is just useless because you're never you know the requirements, basically, make it effective.

Interviewer: uh huh.

Daisy: And those are very hard to identify, but they can also be requirements that you actually I think you spend a lot of time, sometimes worrying about requirement that's actually never going to be bounding on your system.

Daisy: From the optimization world, so if we intake requirements, he talked about him, you know, in a numerical context, there are actually some approaches that you can use an optimization.

Daisy: To understand when you have requirements of that nature.

Daisy: But i've never seen anyone try to take those into the kind of the design world, probably because the mathematical basis to do it doesn't exist.

Daisy: But yeah I mean it's clearly a problem you see it an optimization.

Daisy: You know, an optimization the cost of of a truly redundant requirement is computation cycles and frankly computation cycles are usually cheap.

Daisy: The challenge is much more having requirements that are totally superfluous.

Daisy: to it and so yeah we're done in nature, but you spend you can spend a lot of time trying to use those requirements to guide the design and it doesn't help you.

Interviewer: Right.

Interviewer: Okay.

Interviewer: I guess what.

Interviewer: i'm sure there's something I haven't covered about the the requirements process but is there anything that.

Interviewer: The students tend to have trouble with or that you yourself have experienced sort of like issues with.

Interviewer: As part of the overall requirement process.

Daisy: and

Interviewer: you're sticking points or.

Daisy: requirements is tough to get students to do.

Daisy: In the scope of a one semester type course.

Daisy: They kind of there's a level of frustration that kind of ensues with you know coming back and trying to get them just right.

Daisy: In.

Daisy: A sense of I know what this really means you know why do I have to get the language just right, and I think that's largely a kind of an experience thing, and the fact that we're working on small teams and short duration projects.

Daisy: you're.

Daisy: Something up that's been worked on for 10 years and it really is kind of important because the person that started is three jobs away from this project now.

Daisy: So I think that's very hard to kind of teach students in a classroom setting get them to write really, really good requirements, because they don't see the imminent need for that in the course of the class.

Daisy: I think that's something that hopefully if you introduce it to them, they will develop it as their career goes on, it becomes more apparent to them why this is important.

Daisy: So I think that's one of the biggest things I struggle students to you know kind of get them to try to at least move in that direction, trying to put the effort in there.

Daisy: And so, a lot of times i'll focus more on we get the big picture stuff going understand there's so many constraints in the criteria.

Daisy: In.

Daisy: one or the other.

Daisy: Including I tell students, you know that you can have a requirement that you express is both.

Daisy: Okay, it may have a limiting value that's a kid straight I can't have it way more than 10 pounds by like it to be a fighter.

Interviewer: mm hmm so it's.

Daisy: A requirement one that's a constraint in one that's a criterion that says hey you know if I can, if I can get it at nine pounds that's better than 9.2 pounds.

Daisy: So you know some of that nuance is sometimes lost upon the students.

Interviewer: Right.

Daisy: So I think you know a lot of it is you know we don't have them for long enough, and the projects don't run long enough.

Daisy: For them to kind of see the value in really developing good requirements.

Interviewer: mm hmm.

Interviewer: That makes sense.

Daisy: or it will be an interesting experience i've never worked with them on their requirements, but since they got almost years you're starting to approach a totally different paradigm, where it's long enough that they're going to forget some of what they knew early on.

Interviewer: That hopefully is captured.

Interviewer: firewalls mm hmm yeah some to face a lot of similar challenges.

Interviewer: Similar attitude, yes mm hmm.

Daisy: I mean there's a lot of pressure on them to get something done get it out.

Daisy: In the document some of this project is kind of foreign to them.

Daisy: it's.

Daisy: Something we teach them through school.

Daisy: You know I mean, I had the experience in in Los Alamos where I had to go back and revisit a design decision that had actually literally been made 50 years before.

Daisy: wow and.

Daisy: ended design notebook there's 50 years old and I had to kind of follow through how, why did this person designed it this way.

Daisy: And I that I figure out unfortunately they did a good job with their notebook.

Daisy: I was able to.

Daisy: Design process in their decision making process and understand, well, I put this requirement on it, and you know, so I ended up making these decisions, as a result of that.

Daisy: I had.

Daisy: But you know just looking at their design without their notebook there's no way I would have known that.

Interviewer: Right.

Daisy: And there's no way for me to call them up obviously 50 years ago, you know I mean you know they're definitely retired, if not dead.

Daisy: The idea that hey wait a minute, they did a good enough job as an engineer, I can track down what they did, and why they did it.

Daisy: that's important but you know how many of the systems that you know, a typical engineering students experience exposed to it really has that type of a pedigree to it.

Interviewer: yeah.

Daisy: me, you know technology changes so fast it's pretty rare to actually run into that and so a lot of times we can just go reinvent the wheel.

Interviewer: mm hmm.

Interviewer: very good point.

Daisy: So the biggest challenge is getting them to buy in.

Daisy: Why is.

Daisy: Why is not just busy work you're asking me to do, I mean I think they understand the idea requirements, help us figure out how to solve the problem, but why are we, this time documenting it.

Interviewer: Right.

Daisy: and tracing it and worrying about kind of the the analysis behind it, and then the answer is really that it ultimately helps you you just may not see the payoff.

Daisy: In time for.

Daisy: These projects exactly.

Daisy: Okay.

Interviewer: I think.

Interviewer: That that's all the questions I had for you.

Daisy: Okay.

Interviewer: This has been helpful for sure.

Interviewer: I really appreciate it, and thank you for your time.

Daisy: Oh no problem have a good day have a good weekend.

Interviewer: Thank you, same to you.

Daisy: All right.

Daisy: All right.

Interviewer: All right.

Interviewer: Okay, I guess, just to to get started, and to give me a little bit of background and understanding of what your role is, can you tell me a little bit about.

Interviewer: What your role is with regards to requirements and that sort of thing.

Daphne: Sure sure Okay, I was.

Daphne: I got my PhD at Clemson the doctor sometimes Okay, and my research was not in requirements.

Daphne: But I came to the University of Maryland as a research educator.

Daphne: to supervise.

Daphne: Students with researches design and those are the undergraduate students I work with them and they solve a design problem and that part and then.

Daphne: They work on the research part after that.

Daphne: And for the design problem they use some online design challenges between available.

Daphne: and gave problem to ascendance a couple of them, they would be able to choose, and they will solve it through our 15 week semester, they are not they don't have to build the prototype or they just the body concepts sign in.

Daphne: You know, and they taught them the different concepts of requirements that generates requirements and this kind of stuff.

Interviewer: Okay.

Daphne: I hope that this is useful for you, I think my information because yeah I didn't want to say I don't want to meet you because that I raced for the last couple of years, I have not supervised capstone.

Daphne: Design projects but.

Daphne: I work with freshmen students and software on design design Problem Solving the problem and I thought my va canton some information is going to be useful for you.

Interviewer: Yes, absolutely.

Interviewer: So when you're sort of getting students started, how do you really define requirements, what sort of goes into that definition.

Daphne: yeah the requirements definition as I remember, we talked about the care.

Daphne: Of a need or a demand that a customer or stakeholder or the marketing team needs.

Daphne: From.

Daphne: The product.

Daphne: Something that they are looking for that they need to meet by the product.

Interviewer: sort of how can you talk me through the maybe the requirement development process or how you guide students to do that.

Daphne: vbrick.

Daphne: copula let's see it was two years ago now, please send me.

Daphne: let's can I open my documents, because i'm sure I have them.

Daphne: Absolutely yeah Instituto you're trying to remember, I remember, we have what he had the lecture and requirements to see what a disgusted by students in the picture.

Daphne: Okay, for requirements, I remember, I might make sure I asked about them okay.

Daphne: What are their illnesses expectations are vicious.

Daphne: That they.

Daphne: think they are expecting from that product or services or whatever is that.

Daphne: and

Daphne: They need to talk about the specific constraint that defeat is existed within that problem.

Daphne: Okay okay and let's see what our.

Daphne: I asked them to think about it what's that design is going to do for them, because that's going to help them to think about Okay, which type of requirements is needed to work harder.

Daphne: And home.

Daphne: and obviously I asked him about.

Daphne: about the objectives.

Daphne: That they.

Daphne: Are the things the solution is expected to meet.

Daphne: me think about okay What objective what's the.

Daphne: expected product is gonna satisfy or meet okay.

Daphne: Well then, maybe think about the objective is going to help them to come up with the requirements for that.

Interviewer: Okay.

Daphne: And the type of the properties at the expecting that product has.

Daphne: And what type of many properties, we don't want that product has maybe that's going to affect the decision, maybe the first step is going to be at the better understand the problem okay what trying to solve.

Daphne: Okay, I can courage to do that at the first step.

Daphne: Then what I knew they asked me to think about it a stir up the notes and they organize it they one of the tools, I told them to use that was the Objective three.

Daphne: To maybe summarize them in or organizer object to try to be hot group them as a sub sub groups okay that doesn't need to requirements or objectives.

Interviewer: Okay.

Daphne: Okay.

Interviewer: So when it comes down to to actually like writing requirements are like requirement.

Interviewer: Liz is there, like a formula that students would use, you know you have specific words that need to go here in here.

Interviewer: Or is it just sort of plain text just this is what we need.

Daphne: It was played takes by needs to a specific.

Daphne: Okay, if if we can quantify it something that they can quantify the expected to have those numbers there.

Daphne: Are what they asked him to be as specific as a full sentence to be clear for once, someone else's read it understand what is that requirement about.

Interviewer: Okay.

Interviewer: Once once really short I had a requirement list, did you just didn't really go back in and review the requirements or do they sort of just keep the same list not really making any changes to it.

Daphne: Ah, but in my case, of course, mine is the capsule design for it wasn't my CDs are freshman's right yeah but, in my case, I remember that when they come up with the requirements media there one time at the end of the Semester.

Daphne: I told them to check the requirements.

Daphne: And the middle of the Semester, when we come up with the solutions okay some concept of solutions through brainstorming and other methods, I told them, we can now check it, how many of these requirements are meeting why these concepts each.

Daphne: And it's sometimes when they talked about that they see Okay, is that something that was a requirement it devastated me this phone windy discuss about the data to the father, maybe this requirement is immediately swap or they don't need it, for example.

Daphne: Right and yeah they live in would if ya doing the consideration.

Daphne: And there.

Daphne: After that, did you did change it in my class.

Interviewer: Okay.

Daphne: You did a concert site selection of consideration human concept selection.

Daphne: Okay, modify add or delete requirements.

Interviewer: Okay.

Interviewer: That makes sense.

Interviewer: Maybe a difficult question if you don't you didn't see too many examples of these requirement changes but.

Interviewer: If you if you had to maybe prescribe a requirement change process.

Interviewer: What would be like an ideal state.

Interviewer: for students to sort of to go through to do that and then sort of follow through a process.

Interviewer: to actually make this requirement changes.

Daphne: I, to be honest, I didn't have to.

Daphne: Just as long as the students can justified it, why do you need to change something.

Daphne: If you want to add a requirement changes have.

Daphne: to remember, I don't recall that we haven't a specific process.

Interviewer: Okay.

Interviewer: So you just had to sort of propose a change to their group and then just have it justified with it reason.

Interviewer: Yes, okay.

Interviewer: And who would be involved in sort of these requirement reviews that sort of thing is that just the students or did they.

Interviewer: sort of get input from other maybe faculty or if they had any stakeholders.

Daphne: In my class there were.

Daphne: Students they always instructor and there was another faculty who attended the really.

Daphne: twice during the Semester.

Daphne: Just one factor to students, the instructor and another faculty as a guest.

Interviewer: Did the students use any sort of document or any sort of like tools or systems to help them in their.

Interviewer: I guess requirement management at all, or just keep like a running list or anything.

Daphne: No, they did not have my class students did not have those kind of.

Daphne: Mechanisms they write it down on the paper or a they of course they had their assignments on that.

Daphne: You have a presentation on that to present Thank you enter and then.

Daphne: The way.

Interviewer: These next couple of questions, maybe you're a little bit.

Interviewer: outside the scope of the projects for your students.

Interviewer: But maybe just taking this hypothetical.

Daphne: Sure sure.

Interviewer: But, would it be didn't ever really consider how requirements related to other requirements.

Interviewer: And if it did, would it be useful to have this sort of relationships demonstrated some sort of like a network or something like that.

Daphne: Be yeah yeah we had an exercise that we use.

Daphne: What we call that was the objective tree Okay, I told them.

Daphne: To cluster the related requirements together.

Daphne: Okay, and that was one thing to see the relation between them didn't go very deep with that, but I told them to do that and to make sure the requirements are not conflicting with each other.

Daphne: Oh, that wasn't what we do in my goodness.

Interviewer: Okay.

Interviewer: Okay.

Interviewer: And when you'd have a change that will be made to requirements.

Interviewer: hey I noticed, you said that you would justify the change, but would there be any sort of.

Interviewer: documentation of that justification, so they would have a record of why they made the change, and if they could I guess on do it.

Interviewer: In the future, is that ever something that was considered.

Daphne: I don't remember that one.

Daphne: Okay, maybe in the reports, the pretense somewhere, but it was not me can, is there a requirement to do so.

Daphne: You know, we did this unit discussions in the class.

Daphne: That you're doing those weekly meetings we discuss about that.

Interviewer: Okay.

Interviewer: Do the students ever have issues with maybe requirement redundancy where, if you have a group that is sort of approaching requirements from the same from different perspectives and sort of getting the same requirement that written differently or something like that.

Daphne: could easily be review the requirements when they generate the requirements to make sure he has a specific, what are the meeting of the justification why they needed will discuss the requirements, but specifically talk about that I don't remember that specifically.

Daphne: Oh, we investigate if they are.

Daphne: So how.

Daphne: How, what was the question sorry, but that.

Interviewer: sort of about requirement redundancy.

Daphne: redundancy yeah we didn't do they didn't dictate documents that that redundancy yeah we didn't talk about that the details.

Interviewer: You mentioned that you use this sort of objective tree.

Interviewer: disorder group and cluster requirements.

Interviewer: Was that.

Interviewer: Would it be useful to have some sort of way to to visualize those linkages between requirements, maybe.

Interviewer: I mean a slightly different way, like if you have some sort of graph based.

Interviewer: Something that would show like links it may be outside of the scope of the project.

Daphne: But yeah yeah yeah we.

Daphne: yeah we didn't just try just told them to maybe somewhere in this cluster together.

Daphne: They put it like a simple three right Okay, they try to summarize those ones for related Okay, for example, find a keyboard to keywords to.

Daphne: Talk about those four is that cluster.

Daphne: And the something.

Daphne: The relation between the requirements that you're going to show the.

Daphne: Cluster that, as a group.

Daphne: And then put a name for that team, for example, safety and reliability for exam requirements or what was that let's see, for example, or, for example, the.

Daphne: The ease of use, for example, or the safety, for example, and then, if we put all of the requirements related to safety under bets, for example, safety and reliability, for example.

Daphne: And that was the what we have not really.

Daphne: Advanced oh.

Daphne: yeah.

Interviewer: And then, I guess, this is more of like a general question.

Interviewer: But are there any what what would really be the maybe areas for improvement or some sticking points in the requirements process, are there any areas that students seem to have like a particular issue with.

Daphne: One thing which is important, I think the validation of the requirement to.

Daphne: Make sure, in the end, your design meeting or not meeting those requirements.

Daphne: This is one thing, which is important.

Daphne: yeah that's what i'm speaking about it right now.

Interviewer: Okay.

Interviewer: Are there any sort of methods or anything like that that you use to sort of help the students do that stuff or is that something that.

Interviewer: They took to easily like that.

Daphne: Ah, they do that.

Daphne: We need to go to the testing, or if we can do simulations or physical testing or prototype it to justify or to demonstrate that dirt design is going to meet those requirements or not.

Daphne: Or if they meet by how much we need that reason to the requirements needs to be a specific UK.

Daphne: To Durban and meet the requirements or they are not meeting the meeting but partially, they are meeting the requirements, how good they are and.

Daphne: That also is going to be.

Daphne: Another carrier.

Interviewer: Right okay.

Interviewer: OK, so the specificity of the requirements that actually makes them able to be tested.

Interviewer: be okay.

Interviewer: Okay.

Interviewer: make sense.

Interviewer: Is there anything that I, maybe haven't asked about that was part of your sort of requirements process.

Interviewer: That I need to know about I guess.

Daphne: think we covered everything.

Daphne: Okay yeah.

Interviewer: Okay, so sort of requirement generation and sort of talking about the.

Interviewer: initial objectives and grouping the requirements.

Interviewer: And then.

Interviewer: getting them as specific as possible reviewing them and then trying to verify them.

Daphne: yeah.

Interviewer: makes sense.

Interviewer: I think that's most of my questions.

Daphne: Sure sure.

Interviewer: Yes, this is this is good information.

Interviewer: Well, with that I won't take it too much more of your time.

Daphne: Sure sure sure I would be happy to help if you have any questions later on, just.

Daphne: send me an email and ask the question I will be happy to add.

Interviewer: Wonderful I really appreciate it.

Daphne: Sure sure.

Daphne: Well, thank you so much, have a nice day.

Interviewer: Okay, you too.

Interviewer: So I guess to take to get things started, can you give me a little bit of background on your role and sort of how that how you interact with requirements.

Interviewer: In.

Delilah: yeah so mostly I teach mostly teach the graduate design class.

Delilah: Okay, I mean when I teach.

Delilah: But I do also teach the capstone design at times.

Delilah: And the other one that's kind of for me to teach is our freshmen intro to engineering it's mostly a CAD class, but we do a little bit design work in there, there we don't deal with any requirements.

Delilah: For the capstone and then the graduate design class.

Interviewer: Okay.

Interviewer: And so, when you when you start to sort of teach requirements or or guide the students into developing requirements, how do you sort of start with like an actual requirement definition.

Interviewer: Or what do you.

Delilah: Usually start from customer needs gathering.

Delilah: Is the first place, then you get a whole list of customer needs typically I teach the students to map the customer needs into engineering requirements through quality QFD or the House equality.

Delilah: Okay that's usually how we do that.

Delilah: I don't know anything more sophisticated than that.

Interviewer: Okay.

Interviewer: When the students are development requirements didn't do it as a group.

Interviewer: individuals, and then they want to compare your lists How does that process work, I guess, from a personnel side.

Delilah: I don't know, because this is a graduate class I just kind of leave it to them.

Delilah: right to do it, however, they want.

Delilah: So no idea.

Interviewer: When they're when they're actually developing requirements are writing them.

Interviewer: Is that sort of done in plain text or are there is there, like a formula that pieces of.

Delilah: So.

Delilah: it's just the structure of the House equality.

Interviewer: Okay.

Interviewer: So nothing there's no specifics about like you shall statements here or will statements or HR specifics like that.

Interviewer: No okay.

Interviewer: Okay.

Interviewer: Do you teach the students to work through any sort of requirement review or anything like that.

Delilah: We I guess I review them as a faculty Member looking to make sure that the covered everything.

Delilah: i'm blanking on.

Delilah: The checklist I use to make sure they've actually made things more or less covered.

Delilah: It came out of one the dissertations and i'm blanking right now on oh I use a pro customer needs analysis I use Greens method for customer needs analysis produced by Matthew green.

Delilah: And part it's basically a checklist of customer needs, but I also use that when I start looking at requirements, just to make sure that they've got all the customer needs required.

Delilah: covered.

Delilah: yeah I don't use anything else.

Interviewer: March.

Interviewer: To the ever sort of go back and revise a list of requirements.

Interviewer: Maybe I should be making changes.

Delilah: We should, as they go through the process, they usually don't unless it for some to.

Delilah: suppress the time they don't some semesters we have done.

Delilah: In other experiments running where they were required to hand in their requirements every single you know quite frequently and they did change up some then not a whole lot really.

Interviewer: Okay.

Interviewer: When you saw requirement changes, even if they were infrequent was there any sort of.

Interviewer: management in place for that to make sure that that change was sort of communicated to the whole group or.

Interviewer: Now, nothing at all okay.

Delilah: No.

Interviewer: Okay.

Delilah: These are small teams and.

Delilah: You know.

Delilah: Not a big emphasis of the course.

Interviewer: Right, I understand okay.

Interviewer: Okay.

Interviewer: I guess, can you sort of walk me through.

Interviewer: Maybe the lifecycle of requirements.

Interviewer: That I guess i'd say, you said that you start with the customer needs, then you do QFD in the House of quality and then you check over them and then.

Delilah: I mean they hand them in as part of your homework assignment site glance.

Delilah: and make sure they're there.

Delilah: We got all the key aspects.

Interviewer: mm hmm OK.

Interviewer: and

Delilah: Then there's from there, they usually use them to guide the project and it's about.

Interviewer: Okay okay.

Interviewer: That makes sense okay.

Interviewer: Are there, aside from like the House of quality and.

Interviewer: The clarity, are there any sort of other tools or methods.

Delilah: That I can think of right off the top of my head.

Delilah: Okay, and that without glancing through my syllabus I mean specifically i'm crime and I don't do a whole lot.

Interviewer: Right okay.

Interviewer: And they're typically record requirements and excel or word document or a PowerPoint something like that.

Delilah: it's usually whatever they want to use.

Interviewer: Okay, so nothing in particular okay.

Delilah: And usually it's a combination of usually often a house quality excel with their PowerPoint or.

Delilah: word.

Interviewer: Okay.

Interviewer: Do you ever touch on it, maybe requirement relationships are sort of how things are interrelated or.

Interviewer: Effects another.

Delilah: No.

Delilah: Okay, are you talking more about requirements propagation and things have.

Delilah: changed one in it affects all of them.

Delilah: Not not formulating class, you know, sometimes you get projects where that happens on and, yes, the students don't get informal mentoring, or sometimes I spot cases where they've got requirements that are very.

Delilah: interdependent.

Interviewer: And I warned them about those types of things so much that that may happen.

Delilah: And that particular project.

Delilah: Occasionally i'll show up late in the game to happen before.

Interviewer: And the question is sort of if you see a change made to requirement.

Interviewer: Is there.

Interviewer: any sort of justification process or.

Interviewer: Something that has to be recorded, to make sure that it can be undone or something like that.

Delilah: No it's all kind of left up the teams, I mean lot of its very early phase was the capsules is very early phase innovation so one there's usually massive changes to a project as it goes to venue so early phase that there's.

Delilah: Really, no documentation that we do.

Delilah: Right now is.

Delilah: This a maybe a little bit you know in description implicitly us because they do write reports of the project, overall, and what they learn things like that might be buried somewhere in there, but there's no formal process.

Delilah: Okay, and I wouldn't, especially the capstone design course because the structure of it it's very early phase design, so it doesn't make sense to have that stringent requirements so she really shouldn't be there until later in the process.

Interviewer: Okay.

Delilah: And the capital capsule design when it's been a while a few years since i've last audit.

Delilah: But they're definitely wasn't anything that.

Delilah: That formal a capstone design process, the way, especially the way ahead and set up.

Interviewer: Do you ever have any issues with maybe requirement.

Interviewer: redundancy so they're.

Interviewer: approaching the same issue from different perspectives and with similar but not quite the same requirement.

Delilah: Definitely i'm not especially that really face designs now is a problem, though, because.

Delilah: it's sometimes two different ways of measuring a similar aspect and

Delilah: Then it just don't know exactly which Fisher you need at that point, nor do you know, sometimes it's one of those where each measure will cover the choir i'm about 60 70%.

Delilah: Fully describes it.

Delilah: So I wouldn't necessarily see that as a problem.

Interviewer: Okay.

Delilah: It also depends on if you're doing something else with the requirements in the process for what stuff I do it's usually really early phase and.

Delilah: wouldn't be a problem.

Interviewer: Okay.

Interviewer: What information, would you consider be the most important to capture and requirements.

Delilah: Totally depends on the project.

Interviewer: Okay.

Delilah: yeah it's really it's trying to quantify your customer needs.

Delilah: So you have something measurable to aim for.

Delilah: Good and what's most important then vary from project to project pretty dramatically.

Interviewer: sort of a similar question to the redundancy, do you often have conflicting requirements.

Interviewer: Yes, I don't issue.

Delilah: Lifting is definitely common.

Interviewer: mm hmm.

Delilah: It many most projects will have conflicting ones where you have to train them off or optimize them or things like that.

Interviewer: How do you sort of guide the students through that or How did the students tend to walk through that maybe trade off processing with that.

Delilah: One i'll have them use the theory of the problem solving new tips tricks to make sure that there isn't an innovative solution out there that gets rid of the conflict.

Delilah: And, and then the rest will really is very, very you know project of problems, specifically, depending on what you're trying to do.

Delilah: Okay, it might be something where you need to survey the customers to figure out what they want it may be other considerations and how you train them off.

Interviewer: Would it be useful to have.

Interviewer: Some sort of visual way to to see requirements are like the linkages between requirements or any sort of clustering something like that, but that'd be helpful in.

Interviewer: showing the relationships between things.

Delilah: have to see what you're trying to do too badly to that question generic have a question.

Interviewer: Right.

Interviewer: more like a graph based or sort of requirement network.

Delilah: I don't know.

Delilah: yeah it depends on what you're trying to show what.

Delilah: Problems you're trying to solve with it.

Interviewer: Okay okay.

Interviewer: Is what what other issues, I have you seen what would or common in the student projects.

Delilah: Nothing I can think of what just off the.

Delilah: Top my head.

Interviewer: Okay.

Interviewer: Okay, no, no common trends or anything like that okay.

Delilah: Nothing I can think of right now.

Interviewer: Okay.

Delilah: Not some again new requirements isn't one of the ones I've spent a lot time I.

Delilah: will say is a lot of the projects, I deal with it's the flavor of the project.

Delilah: it's a very early exploratory.

Delilah: types of projects, you know early innovation so you tend not to be quite as focused on what the specific requirements are because you keep a lot of flexibility.

Delilah: Okay there's a lot more consideration of things, or even feasible.

Interviewer: All of my questions.

Interviewer: We went through them quickly, but I think that's everything.

Interviewer: Okay.

Interviewer: I appreciate your time.

Delilah: No problem.

Interviewer: I'll take up too much more your time zone but I.

Delilah: Have a good day.

Interviewer: thanks you too.

Interviewer: bye bye.

Interviewer: Okay, and so I guess to get started a little bit, can you give me a little bit of background on your your job, your role and, specifically, that with regards to requirements and that sort of thing.

Diana: Okay, so I am right now and assistant professor in the department of engineering my backgrounds in mechanical engineering, so my bachelor's master's and PhD they were all in mechanical engineering.

Diana: The Department that I am working at is non discipline specific meaning we don't be graduate bachelor of engineers, we don't have a mechanical electrical etc, etc.

Diana: Okay um so and again feel free to interrupt me and ask questions if i'm not answering.

Diana: In the, or.

Diana: Answering enough details, so in my job as an assistant professor, you know.

Diana: i've been teaching design related classes, so at James Madison university, we have a design spine in our curriculum meaning freshman sophomore and junior seniors they all have design classes and all of their semesters.

Diana: Okay, so i've under last year I was teaching the software design and I think each engineer design, which is basically the first year of capstone design for us.

Diana: And so, as part of both of those classes.

Diana: are actually four classes and tools and software design one to an engineer design, three and four.

Diana: requirements to is part of teaching them the engineering design process, I can go deeper about how I go about teaching requirements, but again i'm not sure if those will be your questions that you asked me for RON.

Diana: You sort of give you an overview educating students about requirements ella cetacean documentation what to do with requirements, after the have.

Diana: elicited them as part of mine teaching my classes.

Interviewer: Okay.

Interviewer: And how do you define requirement to students or something like that what what exactly is a requirement.

Diana: So, are you asking how I defined requirements or how do I teach students, the definition of requirements.

Interviewer: Both actually.

Diana: So for me, you know very broadly speaking, requirements is anything that needs to be fulfilled, for your product, whatever that product could be.

Diana: To be viable.

Diana: Or to be.

Diana: accepted by your customer now.

Diana: To make it easier for my students to understand because you know if you look at the requirements in textbooks different types of stock about requirements in different ways.

Diana: So talk about constraints criteria somewhat must want whatever I kind of created this chart so let me.

Diana: pull it out and share it with you.

Diana: So my go to share screen yes.

Interviewer: Sir yeah yes.

Diana: Okay, so I am happy to email this to you if if it will be powerful.

Diana: But initially I created this map or chart whatever you want to call it.

Diana: Would you explain to the students or what what all these different terms in respect to requirements meeting, so it started off with broad design requirements, it could be objective specs means.

Diana: And again, I think, different textbooks talk about design objectives and specifications differently.

Diana: But I just feel like specs specifications are the requirements that have higher specificity, so you may start with a need that, as you go through the design process becomes a specification.

Diana: Right, so you may have project process product requirements, each of those would be a constraint for a criteria and those can further be functional or non functional.

Diana: So this is essentially what.

Diana: I teach.

Diana: To the students.

Diana: As far as the basics of requirements, then because of my.

Diana: own background.

Diana: of my own research, I also teach them about writing good requirements, so I talked about the completeness and specificity.

Diana: And I almost have like a workshop session during one of my classes.

Diana: Okay, when I walk them through an exercise of you know how to write a complete requirement or how to write more specific requirements, and then I make sure that they do that in their own projects.

Interviewer: Okay.

Interviewer: fetishes released one of my other questions to what how did how our students to talk to serve right requirements is there, like a specific format, you know some definitions have need subject object, you know number.

Interviewer: terms.

Diana: yeah absolutely so I like I said, you know I I conducted workshop almost four and again, let me be clear, so this is for my junior designer that's.

Diana: sophomores are taught slightly depending on in that they are not necessarily taught about the completeness and specificity of requirement, so all the details that i'm telling you.

Diana: Now onwards, will be in regards to the capstone or sorry that you know design, which is the first year of the past.

Diana: Okay, so when I talk about writing requirements, as I said, you might do a workshop so give them some examples of.

Diana: Complete requirements and complete requirements and sort of happen.

Diana: You know, identify why a complete with one makes more sense was is incomplete requirement same with the specificity and you know also kind of telling them it's okay to not have.

Diana: All the requirements specific right now.

Diana: They can they can become more specific, as the like I said follow the design process and gather more information from their client or for more information from their own testing and understanding what the problem.

Interviewer: So.

Diana: I guess the short answer to your question they're taught how to write requirements, through a workshop.

Diana: on how to write requirements.

Interviewer: Is there any sort of specificity and the is the format that requirements are recorded.

Diana: um so it's yes and no.

Diana: The reason I say that is because.

Diana: At James Madison you know, to give you some context.

Diana: While I teach.

Diana: Design each project is advised by a different faculty Member and.

Diana: To a large extent, how the process, how the project is completed depends on.

Diana: How that particular faculty member is mentoring.

Interviewer: With students okay.

Diana: So it may be different in terms of what the advisor asks them to do, but as far as the report is concerned, we do use a table, so you know the right the requirement, and I think that table is typically what was used at Clemson.

Diana: It came back when I was a Grad student and I.

Diana: Did research with my fellow students so again i'm happy to send you that table as part of their.

Diana: Report document so in in the report, you know the art acquire to talk about elucidation method so.

Diana: We encourage them to use at least two different methods by which they gather requirements either interviews and surveys, or you know observations of how people are using the product or whatever else and use at least two of those methods to then come up with a list of requirements.

Diana: And then, they have to.

Diana: differentiate between constraint and criteria, why is that a requirement to give a proper justification when was that requirement, that is to take elucidate and, if at all, there were any changes as they progress from day one to midtown or the final report.

Interviewer: Okay.

Interviewer: Can we talk a little bit more about the the solicitation methods that you teach sort of how our requirements elicited and then sort of who is really involved in that whole station process.

Diana: yeah definitely so actually let me again share my screen.

Diana: So this past year, so typically this would all have been covered in lecture but because we were.

Diana: Online or we were virtual in the last fall so typically model is happens in the fall semester.

Diana: So again, like I said, you know capstone as a for semester Program.

Interviewer: And in.

Diana: person, the first year has the two semesters So the first semester is more about our alum exploration and requirements and visitation.

Diana: Okay, roughly second semester, which is in spring is focused around conceptual design so that's where the line about the different concept generation methods concept evaluation methods they do some very, very preliminary.

Diana: experimentation prototyping.

Diana: And then their senior year the two semesters are focused on the detailed design embodiment design.

Diana: that's when they actually actually is, and there is a vast difference in the type of projects so like I said, you know the projects are proposed by different faculty members and depending on the background.

Diana: It could be a genetic engineering project or a product design project or a process design project.

Diana: So they are really, really different some are very well defined projects.

Diana: Like the show people marathon competition, so there are very specific rules which become requirements that the students have to fulfill and some are very open ended exploratory projects so with that context.

Diana: We in terms of teaching, you know we we talked about the different project stakeholders in terms of the methods, I primarily focus on three.

Diana: Because I try to teach methods that would broadly applied in any kind of project, so we start talking about surveys, you know how to conduct surveys surveys appropriate together requirements interviews and focus groups.

Diana: So I also want to just make sure.

Diana: yeah So these are you know the details that they get to how to conduct surveys, what are some of the do's and don'ts.

Diana: same with the interviews, you know what what consist of a good interview, how should we conduct interview and then focus group which I don't think a lot of students actually not but it's again something else that I talk about.

Diana: So those are the three primary methods.

Diana: oftentimes in class, I will also share some of the other methods.

Diana: Like ethnographic studies.

Diana: On if I feel any project would benefit from it.

Interviewer: Okay.

Diana: But it's not explicitly taught in the class.

Diana: And we keep changing.

Diana: Depending on the projects in that particular year I may teach an additional method, if I feel that my benefits and projects between the different sections and each different methods.

Diana: If it's more relevant to the projects in that particular section.

Interviewer: This is just the students who are conducting those focus groups or interviews.

Diana: Yet and project teams be conducted.

Diana: Be me may take inputs from either me or their project advisor so let's say they're conducting interviews.

Diana: The students will come up with the preliminary list of questions to ask and I always encourage them to do one mock interview, so that they know what makes sense doesn't make sense things like that, and then we may update the questions, not every not every team will do it, but.

Diana: The majority to do on our up for getting that additional feedback.

Interviewer: Okay.

Interviewer: So, once the requirements are really Britain and you have a requirement set or they renewed at all is that part of the process.

Diana: So i'm as an instructor for the class so again, I do not speak for the advisors.

Interviewer: and

Diana: As an instructor for the class becomes a part of their.

Diana: Report, and so I will be with when I am reviewing the report and I tell them very detailed feedback on the requirements.

Diana: And sometimes or actually oftentimes will have individual and team assignments or requirements are, for instance, will ask.

Diana: Each individual to you know document their understanding of the requirements and then.

Diana: You know, work with their teams to figure out if everybody had similar requirements different requirements this becomes individual assignment on which is graded by the ta most of the time, so I personally don't.

Diana: evaluate that but I evaluate all the requirements in the report.

Diana: And I yes so.

Diana: yeah that's that's the evaluation of the requirements.

Interviewer: And just students get that feedback and make changes to the requirements or tend to be very.

Diana: yeah so since I started teaching I introduced report group auto system.

Diana: And so, instead of waiting until the end of semester I having all the students submit their final report and never looking back when I say final report it's for that semester not entire project final report.

Diana: Right um so in turn back what I do is to have the Semester they there will be three or four times, where they will submit the report to the first time they write up a section.

Diana: i'll give them feedback we'll have some time to be work that feedback and submit an updated version of the report, along with the remodel on how they address my initial comments.

Diana: So, in that sense the the end of making changes to the document of requirements either you know, adding new requirements or making sure that the requirements that were written earlier are properly written with the details and things of that sort.

Interviewer: If you see changes made to the requirements.

Interviewer: Are the students like actually making these changes, or is it more of a response to the feedback.

Diana: it's both.

Diana: So from the first semester junior to the second semester junior oftentimes your requirements will be added by the students, which is more of an active.

Diana: Action on their part.

Diana: Right, you know they do acknowledge that Oh, we conducted this additional experiment or Oh, we did this test, and you have updated this requirement, so there are changes beyond what I give them.

Interviewer: Okay.

Interviewer: And, have you seen any sort of systems in place for managing those changes heard or recording them.

Diana: Not for me in the sense that I.

Diana: See on the report I don't tend to control how the teams internally manage the requirements, I know most students tend to use Google docs or Google sheets.

Diana: And in the report, I do ask them to strike out the requirements that were deleted or highlight the changes in the report but i'm not sure if that's something that they.

Diana: Follow along in the project throughout.

Diana: beyond just the report.

Interviewer: Okay.

Interviewer: any sort of.

Interviewer: Any requirement management techniques or anything like that.

Diana: not be on the table.

Interviewer: Okay.

Interviewer: Besides that table, are there any other tools or systems that are used in any part of the recording process.

Diana: The very first time I taught the class I did introduce how's the quality, but in the last few years.

Diana: A.

Diana: lot of the projects didn't really benefit from it.

Diana: Okay, and so I think it's just the table that has become.

Diana: sort of a primary method for them to track changes managed things like that.

Interviewer: Part of the research that i'm doing is also looking at.

Interviewer: Perhaps different ways to sort of track teach requirements, development and I guess the requirements life cycle process that sort of thing.

Interviewer: and see if there's any sort of tools or something that could be implemented to maybe help with that and.

Interviewer: So I have a few sort of hypothetical questions.

Interviewer: To see sort of.

Interviewer: If this functionality was in place if this would perhaps be useful and okay.

Interviewer: Are there ever any issues with.

Interviewer: requirement like redundancy so students are coming up with multiple requirements that are maybe addressing the same issue, but in different ways, or something like that.

Diana: I don't see a lot of that what I do see is they tend to combined with apartments a lot.

Diana: And I think that becomes a challenge, especially when they are thinking about the method of validating that requirement.

Interviewer: Okay.

Interviewer: Okay.

Diana: So I do encourage them to split those requirements into two different format so that's something that I remember seeing not necessarily the.

Diana: same requirement again.

Interviewer: Okay.

Interviewer: Is there ever.

Interviewer: Are there ever really conflicting requirements.

Interviewer: An issue.

Diana: I mean, I feel like the students are fairly aware of those typically those will happen in the competition things i've seen those happening there are two competitions that are happening pretty regular.

Diana: Every year, so the Chicago marathon and the decoder to get when competition, so I think for the shadow it's always the fuel efficiency versus speeds are being made it lightly, but at the same time, go faster or whatever.

Diana: Right and a lot and seeing with the wind I don't remember exactly the conflicts, but I know that those two things in particular.

Diana: Do bit complex but certainly because those advisors having run this project for a while those skills are very aware of lessons on this.

Interviewer: Okay.

Diana: And something that i'd like to add, is.

Diana: not specifically in context of requirements, but in their concept generation, I also teach press.

Diana: record for concentration.

Diana: So, during that time, the students are actively thinking about the conflicting.

Diana: requirements from their list so that they can apply this principles to sort of address those requirements.

Interviewer: sorry about that I am.

Interviewer: I, for no apparent reason.

Diana: So i'm not sure what was the last thing.

Interviewer: You just started talking about trees, I think.

Diana: yeah so what I was saying, is this is the only diamond they might be living in the conflict and requirements, but again, the context, there is constant development, not necessarily making the students not explicitly making us aware of of the conflicts.

Diana: Within the requirements that reference.

Interviewer: Sorry, excuse me.

Interviewer: Would it be useful at all to have any sort of as it may be a method for visualizing connections between requirements or or linkedin with that.

Diana: Absolutely.

Interviewer: i've i've heard a few proposals for using maybe some sort of like graphical based so they would show different like line weights and linkage weights, to show the strength and the connections that sort of thing.

Diana: yeah that would be very.

Diana: I do make them do that for stakeholders so speaker man.

Diana: that's ready in the mouth.

Diana: All the different people who might be affected by their design and how they relate to each other and things of that sort, but nothing.

Interviewer: What information, would you consider to be the most important to capture an apartment and.

Interviewer: Like the perhaps the subject like this specific scope that applies to target value.

Interviewer: Okay, nothing more important than the other.

Diana: Now, because I feel like each So if you talk about the subject we're object another, if you like.

Diana: It if you take one away the requirement kind of tends to lose its meaning.

Diana: right context, so I feel like they're all equally important.

Interviewer: Okay.

Diana: The only thing that I might wait a little bit more would be to make sure that the distinction between the criteria and constraints is fear so suddenly is a must be.

Diana: It should be a higher priority than a show or would like to have.

Diana: But That being said, if you're just looking at it as a model that it doesn't mean it.

Diana: The idea would be to have that model and not necessarily worry about whether it's a monster issue.

Interviewer: Right, I see.

Interviewer: This is a sort of very hypothetical question.

Interviewer: But would having a way to if you're sort of free typing a requirement, you know just just typing it into a spreadsheet or something would having a way to sort of recognize that and maybe giving you feedback on the quality of the requirement would that be helpful.

Interviewer: and

Diana: So, I guess, when you say quality are you talking about this aspect of it, or like How would you measure quality.

Interviewer: for something like completeness, maybe ambiguity.

Interviewer: If if if there's a database of that maybe you have a good track it against central conflicts that sort of thing.

Diana: yeah that would be helpful, especially as a tool for teaching the students.

Interviewer: Okay.

Interviewer: I think that's most of my questions, is there any aspect of the process that I didn't.

Interviewer: ask you about explicitly that you can.

Interviewer: Maybe expand on.

Diana: So it seemed like you're focusing a lot on the process of writing requirements itself.

Diana: But one of the things, and this may or may not be within the scope of what you're trying to do, but one of the things that I was the most frustrated.

Diana: With was once the students have spend all this time, writing of the requirements we tend to jump to concert development and there is never a connection.

Diana: clear connection between you know character requirements now you're using those concepts it's all it always seems to happen in isolation, even though it may not see because when you're generating concepts you're focusing on.

Diana: hold on one second.

Diana: yeah so that's and again like I said it may be out of the scope of what you're trying to do, but.

Diana: It would be interesting to see how that direct connection can be made so that you know you're moving from this black box of.

Diana: where you have your input as a problem and requirements as an upward not another black box where requirements are input and concepts are an output in the black box becomes a process using those requirements active Jerry is.

Interviewer: There any other sticking points or areas, you see, could be for improvement.

Diana: For within the context of requirements.

Diana: I um again, one thing that I, I was thinking about, as I was talking to you, I was giving you a context about the capstone designer and Jim you and.

Diana: I up until now i've mentored students at clemson for their capstone I taught capstone at JMU.

Diana: And here at James Madison and while you're all the capstone projects, they were quite different in how they are conducted and the scope of the projects and the time that the students have for working on the projects.

Diana: Okay, and so I don't know if.

Diana: in the tool, or whatever that you might build should have some sort of inbuilt.

Diana: mechanism to allow for the different scopes are the different timeframes.

Diana: And the different depth that the students are able to go, so a student completing their capstone in one semester, where students completing their capstone four semesters.

Diana: there's a lot of difference in in the scope of the project in the details that they are able to go through and whatnot, and so I wonder if that needs to be considered when you're designing your tool, or whatever.

Diana: Something that can have something to think about.

Interviewer: Absolutely yeah that's a really good point.

Diana: And also, you know whether it's industry sponsored none of the projects and gmu our industry sponsored.

Diana: i've worked at concern with industry sponsored projects and oftentimes they have very specific needs.

Diana: Right and there is very little scope for students to really explore a problem when you have this external stakeholder wanting you to do things a certain way.

Diana: And so, how would you factor, those in and you may not consider that it may be a out of scope thing, but just something to think about.

Diana: And there'll be a differentiation between.

Diana: You know something that is very specific in terms of appointments versus an open ended project which is really out there in the wild.

Interviewer: Right.

Diana: So is this going to be your doctoral thesis.

Interviewer: yeah this is part of my master's thesis.

Diana: Okay.

Interviewer: yeah i'm looking at sort of actually comparing the requirements change process to.

Interviewer: Actually manufacturing change processes and sort of seeing if you can take aspects of one and apply it to the other, and maybe how similar they are to each other, see if there's any sort of lessons learned.

Interviewer: We can take from there.

Interviewer: And then i'm also working on another project that's it's looking at sort of requirement solicitation tools and that sort of thing.

Interviewer: So.

Interviewer: given me some some very good food for thought here, some good information for sure.

Interviewer: I think I think that's all my questions.

Diana: Okay, well, again, you know feel free to reach out Hopefully there won't be as many reschedule the next time to reach out.

Diana: But yeah if you have any follow up questions or, if you want to chat again.

Diana: Okay i've also done a lot like to my doctoral research i've done a lot of work with them requirements now.

Diana: talks about it, so if you just want to chat or a cup of coffee or something just just feel free to reach out.

Interviewer: Okay Thank you so much that's very, very helpful very kind so.

Interviewer: With that i'll give you back a little bit of your time.

Diana: Okay sounds good.

Diana: All right.

Diana: Good luck with your research and i'm excited to see where it goes.

Interviewer: Thank you appreciate it.

Interviewer: Have a good rest of your day.

Diana: You too.

Interviewer: bye bye.

Appendix C: Notes from MCM Interviews

Lucy Interview Notes

- Quality Engineer, making sure parts meet specifications, ~4 years
- Design engineers make specs they need to meet; sometimes cannot meet; manufacturing engineers introduce design changes; validated by stakeholders' can come from design, production, suppliers (process/location), locations, logistics
- Doesn't initiate changes, but must validate to meet specs
- Have a team for ECM, goes through software, 150+ slide PPT for specs of how ECR, stages for uploading documents, ECR -> approved -> Change Order -> Implementation
- Everyone has ability to reject, with valid reason (current form request is denied), could be quality, metallurgy, designers; production doesn't have a big stake, more quality and design; production support needed for test
- Sometimes go ahead with changes before approval
- Documentation comes from design side; mostly up to them
- Axtelent, similar to SAP, basically requests for documents, approval sent through, changes status
- Typically don't notice any change after implementation; seems to be smooth; testing done before to smooth transition
- Don't really monitor after except for normal process monitoring, test beforehand
- Don't really have to worry unless testing phase showed potential for failure/error
- No frequent re-fixes
- No need to go back after implementation; serial production inspections shows if you've met requirements
- Usually ~6 months to a year for material/document changes
- Key importance is to make sure all stakeholders are involved; things that are tested are actually documented before approval

Susan Interview Notes

- Working since 2013, lead problem solver with S, problem solver with suppliers with healthcare, background in ME, Six Sigma black belt, RedX, improving products and processes out on the floor, underlying lean methods similar
- Always trying to meet print, hope drawing contains all info needed to produce the part, all manufacturing people come together to look at methodologies and capabilities within plant; once production starts, First Article Inspection (does company have experience to make these particular parts); assess capability once in production, capabilities show potential for changes; is it even capable to make in the long run, discussion/dialogue with designers, throughout part life cycle,

ECRs from suppliers, or from in-house production on floor or for cost reduction, discuss tradeoffs for cost reduction

- Automotive; ideas from manufacturing group, submitted to design group for evaluation, discussion with customer if specs are changing, manufacturing guys get feedback, come up with parts for testing, run trials based on desired capability, Review Board (final gate is Change Control Board) 4-5 layer process to make sure risk manageable, submit requests, approval, documentation and training out on floor, all documents go through revision; anything that changes goes through audit per industry standards; after implementation, control charts used to record readings based on parts (100% or sample sized by quality) SPC charts, look at trends as to product performance, intermittent maintenance, feedback from customer regarding defects so parts can be quarantined and do root cause analysis to find defect source
- Instead of full EC, also do approved deviations; teams go through drawing changes but go ahead and push through
- EC comes down to prioritization regarding timelines, automotive moves quicker than healthcare; deviations ~1 week, up to ~1 year, priority based on customer effects, quality, cost savings
- Design group heavily based on manufacturing group, segment/plant manager, technology expert, engineering manager, change board (included at beginning for kickoff meeting), multi-locations need other locations to be informed to potentially make same change
- Implementation less than week, prioritization again based on need and number of resources; paperwork and resources allocation can delay lead times for machinery, tooling, especially true for huge presses, raw material (especially chemical composition changes); regional holidays
- SPC is major documentation post-implementation, moving towards digital software to determine variations/provide caution/errors; customer feedback
- Depending on scale of change, can take no time or extensive time; operator training and demonstrate capability with supervision, gradually pull back supervision; must evaluate what will be new baseline (that analysis takes some time), then set new normal
- Inspections checked based on few batches, process monitoring never removed; slowly reduce monitoring/checks and frequency (sending parts to lab off of production floor)
- For daily production, worry ~3-4 weeks; at least 5 production batches, tendency to return to old practices, supplier management ~3 months
- Better analysis before implementation gives less propagation of changes, depends on type of change
- Predict certain pattern of result, collect data after running to make sure you meet limits already set, checking with statistical tests
- Statistical software used for evaluation, immediate decisions made manually by engineers, reference historical information from people and machines

- Change depends on scale of parts (vary drastically between components and assembly), how essential parts are and potential risk for determines depth of consideration; interface between part and user impacts scope/length of process; functional changes take longer than cosmetic; material changes very long; type of change effects what test need to be done (humidity, toxicity); end user really matters, what standards must be met for each part

Jill Interview Notes

- Clemson -> B co-op -> B manufacturing engineer (Charleston, Germany) -> auto firm manufacturing engineer ~8 years (process planner, assembly coordinator, ~1 year ago became innovation/university liason)
- B: EC package from design -> evaluate change and impact on process, if approved, gave timeline for implementation
- Auto firm: fairly similar, main types of changes: running changes, package changes (1 per quarter), launches (every 7 years)
- Assembly coordinator, making sure product changes understood, how to analyze change impact
- SBWE: manufacturing engineer job to implement changes and plan processes
- Manufacturing engineers must keep in mind how to verify process?
- Multiple evaluation methods for changes
- Running change steered by EC process; multiple layers of collaboration
- Manufacturing and production only one step of ECP specific to process changes; specific checklist that askes thought-provoking questions to trigger if validation is needed; funding evaluation done before ECP
- Design department responsible for product change; anyone can request; everyone has to be a part of the evaluation (purchasing, logistics, etc.)
- Package change process starts with a standard goal of 39-30 months before evaluation (Target agreement -> procurement and contracting -> etc)
- Normal operation immediately (4 different phases testing change in production environment, see where adjustments need to be made), should be no ramp-up for packet change; running change -> manufacturing engineering requests line trial to make sure all necessary changes made
- No specific monitoring beyond normal control measures/monitoring, testing before during test, assume production system modified to be self-contained
- No worry about changes, assume risk mitigated by process
- Fairly infrequent to have to go back and fix things
- Biggest control is auto firm’s version of FMEA/risk filter, answer specific questions and make sure you have the right controls in place to make a quality product; estimated occurrence, severity, detection, gives if controls in place are sufficient or not
- At least compare risk filters to current state, if no change, no need to update

- Very controlled, methodical process; by default, it mitigates a lot of risk
- Trial phases verify impact before implementation, pretty common across industry

Helen Interview Notes

- Worked for J ~6 years, 5 years in change management as project manager for higher-level customer-involved changes (~1000 parts, largest change affected 100 customers); need to get customer approval, data from plants; middleman between customers, plant, and corporate
- Had to get approval from many people; manufacturing and plant quality always signed off; plant managers involved sometimes; all change brought to design engineers, product managers, and quality engineers; application engineers usually involved as voice of customer; supplier management; sales *never* signed off on changes; system was all digital; had specific slots for each person that would auto-send email for sign off, had blank slots to add other people as needed; had corporate coordinator (business unit overseer) who would vaguely know what was happening with change and could make decision; corporate would make decisions based on PPAP 4th edition guidelines, coordinator would be the person to make the call on sharing with the customer
    - PPAP 4th is booklet that says what changes qualify as needing to be sent to the customer; very little wiggle room; important things (safety-critical) are always taken to customer; even machine moves should be shared with customer per PPAP (Valerie said that machines can break in the moving process)
- After corporate coordinator is either approved for implementation or pending customer approval (shared by sales with customer); PPAP tells what level of documentation is required; can take long time to receive customer approval (usually 3-6 months, can be up to 3 years); once approval granted, just implemented, implementation date recorded and documented in system
- Change defined by PPAP (design, process, and supplier changes)
- Need for a change identified at plant level, can come from individual operator, larger scale changes discussed at plant every fiscal year (i.e. purchasing new machine); supplier changes come from supplier (says they had to make a change) (others just shut down, yet others had fires), would go to supplier advancement team and would notify them to notify customers, no rules on who was allowed to submit ideas for changes
- Local change control board (CCB) (comprised of manufacturing engineers, quality engineers, plant managers, and supervisors) would make decision on change (okay with change happening at their plant; can also make decision to keep change consideration/work in-house) (corporate would meet with plants to discuss changes twice a year, would catch changes that needed to go to corporate); corporate CCB (comprised of quality engineers, design engineering,

product management, application engineers, supplier advancement, and safety (EHS, as needed)); each person has to individually sign off on change acceptance

- Implementation is quick if not passed off to customer (~2-8 months), with customer implementation can take ~2-3 years; type of change also dictates timeline
- Solution and implementation documented when opportunity arises or when sales determines is best for customer (can be because of plant shutdown); solution documentation should occur ASAP after idea generation
- After implementation, have a change owner at each plant (gives a main contact person at local level; usually submits change, marks change as implemented and date of implementation); larger changes get pre-production trials, if not required then no trials done
- PPAP process is generally only main tool; in-house created a workflow management software (developed using Sharepoint workflow system) tailored to company
    - User creates new change, fills out basic information detailed description of current and future states, dates for hopeful implementation, plant location

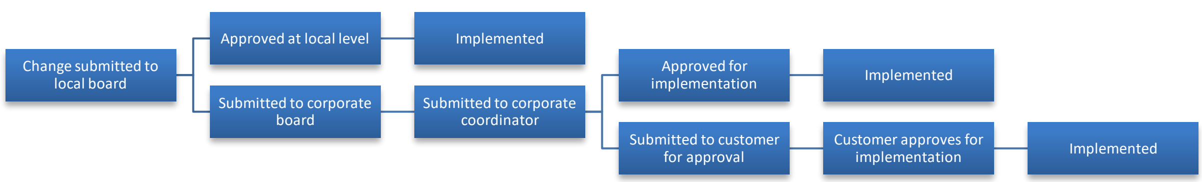

Figure A.1: Change management approval stages

- Usually process is vetted so no impact after implementation, supposed to make sure to have work instructions and other transition material beforehand
- No set process for monitoring after implementation, handled outside of MOC process
- After implementation, handled by individual plants
- Verification and validation includes production trial run, metallurgical reviews; verification of a process usually based on prior knowledge and experience and trial runs, heavily based in PPAP
- Specific formal flowchart and procedure documentation exist, supposed to be trained
- People struggled most with not providing proper documentation before submitting a change for approval; people would often leave changes dormant in system if not provided right documentation; communication just lacks, system helped (could add attachments, notes, etc.)

Appendix D: MCM Interview Transcripts

Interviewer: Can you tell me a little bit about what you do and, sort of, what your role is at your company, how long you've been there

Lucy: I work as a quality engineer, obviously to make sure that every product we make and send down the line meets our specifications. I've been there about four years, including internship time. That's kind of a brief introduction. Do you want me to go into a little bit more technical detail?

Interviewer: Yes, can you give me any more information about how you maybe sort of interact with engineering changes or manufacturing changes?

Lucy: So basically, as a quality engineer we, the design engineers have come up with specifications we need to meet. Sometimes, as production goes on, we will not be able to meet those specifications because of either machining constraints, item test constraints, at which point we basically run tests and typically it's a manufacturing engineer who would introduce a design change and it pops up as an engineering change request and basically that then gets validated by all the stakeholders in that problem

Interviewer: Okay

Lucy: So that change request can either come from someone in production who says hey we can't make it or someone in design who says we have a new iteration of this product, or it can come from a supplier if they want to make changes to their manufacturing process or their manufacturing locations, if logistics wants a change, if purchasing wants a change, anyone who is a stakeholder in the part being manufactured can raise this request

Interviewer: Okay. So, do you have a lot of experience with engineering changes coming through and handling them?

Lucy: Some of them, yes. I don't typically initiate any changes, there are other people, but any change to my parts has to be validated by me because I have to make sure that we can meet our testing and whatever changes have been requested meet our specifications or the new specifications

Interviewer: Okay, okay. So what sort of, you kind of walked me through it a bit, but what does the process itself for engineering changes look like. Is there like a change board, or sort of

Lucy: So we have a team, that's in charge of change management, all of its through a software. Basically we have a 150 slide presentation on how the process works. I use quotations because it doesn't always happen that way, but basically there's, there are detailed steps that they have to specify for the ECR, I'm just gonna say ECR now because that's engineering change request

Interviewer: Mmhmm yeah that works

Lucy: There's specific stages where whoever initiates it has to upload documents and then move it to the next stage in the process, are you familiar with manufacturing operations? Everything has an op number like op 10 20 30 40 depending on what stage it's in, this has similar numbers associated with it, but the ECR is first everyone's looking at it, so we call it in checking, once it gets approved then it becomes a change order, that's when people get ready to implement whatever change has been requested, I think that's the broad process. If you want any more detail, I think I'd have to talk with somebody to see if I could maybe share that presentation with you.

Interviewer: Okay

Lucy: Because it's a massive presentation and it, it makes you go crosseyed

Interviewer: Oh I understand. I know how that goes. So, do you know who sort of you mentioned what departments sort of or stakeholders that get involved. Do they all sort of weigh in on the change solutions? Do they weigh in equally or is it sort of just design engineers mostly?

Lucy: Not really, everyone basically has the ability to reject, but they have to give a valid reason. Now as quality I can say we got this new material in and we ran our trials and no matter what we did we could not get any of these trials to pass. So in this current form, this request is denied. Let's say that it's a new supplier for metal, the metallurgy lab will run their test on the sample pieces and if they say it does not meet the standards then metallurgy will reject the change, or if the design makes the change and then whoever supplies the components says okay this is what we supply to you and none of it meets your design you asked for, then design will fail it saying that this, these tolerances or these dimensions will not give us the desired function of the component and then will reject it

Interviewer: okay

Lucy: Typically production doesn't have a big stake in the change request, it's more engineering, tooling, quality, suppliers, logistics, because once the change request is made and the final dimensions are there, then production just produces

Interviewer: okay, gotcha

Lucy: and you know, but in order to run a lot of these tests we need production support because they have the machines and we need to basically ask them can we use can we get the machines for this much time so we can do our testing

Interviewer: so they're sort of in the loop but they don't really have a big say or stake in it

Lucy: they don't go like we reject this change request because of, they don't have that stake there, but they're the ones that have to make it

Interviewer: Gotcha, okay. How, once you've developed a solution and it's been approved, how quickly is it implemented? I'm sure it depends on the size of the change, but for an average sized change, average

Lucy: I can't give you one answer fits all, in some cases we have pretty much gone ahead with the change before everything's been approved because we've have no other choice, and in some cases we take 2 3 years to actually go through that in some cases it's been 4 5 6 years we're still requesting for a change and there's not been an approval so there is no one size fits all

Interviewer: Okay, I understand. Once you've finally implemented a change, when does that get documented. Is that like right away, after a certain period of time, or you just get to it when you get to it

Lucy: Most documentation comes from the design side because the change request is to a specification typically so when the change is approved, it's on design to put that documentation together and when they make that change and when they push that new revision in, that's when it's done

Interviewer: you mentioned there's like a software system that's used to sort of aid in the process is it sort of like a file repository or is it more of like an actual like tool, do you know

Lucy: it's called Axtelent, It's very similar to SAP but it's also not, and for someone who doesn't know any better they look identical, you kind of get the same vibes, it's basically all the requests are there, all the documents are uploaded there, all the approvals go through that software when finally you move the status from checking or testing to final approval or implementation all within the software

Interviewer: Okay, that sounds pretty handy, pretty useful

Lucy: it can get annoying

Interviewer: I understand. For a given value of normal, sort of like a steady state sort of thing, after a change has been implemented, how long does it take before you get back to that steady state sort of, you know, process

Lucy: Typically you don't notice the difference that is the purpose of the change process, because you go through all your testing and then once everything's approved there is a particular date that you just say okay, everything that this change request is asking for gets implemented and then you basically just flip a switch and basically just everything just keeps going on its own

Interviewer: Okay, that's nice

Lucy: Let's say you're you use a windows computer and you say July 2020 you're going to switch to a MacBook you spend the time from now to July setting up your MacBook with all your software, which is your testing and then on the day you change over that day you just have everything set up and you just use it MacBook

Interviewer: Okay, makes sense. So given that you test a lot, how long do you sort of monitor once you've made a change is that something that's done before the actual like implementation or is that you still monitor it afterwards

Lucy: Whatever we monitor afterwards is basically just regular production inspection. Yeah when whatever we test before implementation is basically evaluating all capabilities you make sure it runs it runs the way it is supposed to it'll give you your quality it'll meet your quality metrics beforehand and then the day you implement you just change it to regular production inspection

Interviewer: okay that's good, so do you really have to worry about it afterwards, I would guess not if you have it all tested

Lucy: Not really no, unless in the testing phase we've shown to have problems but we have to implement regardless but then sometimes you'll see some issues but then those are things we flagged up before or they'll pop up and then you do a root cause investigation and you figure out this was an unforeseen problem that was called by this change but once it goes into production it's just business as usual

Interviewer: how often do those sorts of little pop up issues happen and you have to go back in and fix something after you implemented a change

Lucy: I can't say that, it's random

Interviewer; okay, but not particularly frequently or anything

Lucy: no

Interviewer: okay

Lucy: okay for example there's been one process of this once change request that we made it's affected one product line but not any of the others so when we made it for that problem product line we weren't able to say that it would be a problem because we already used other product lines for that same change request

Interviewer: okay is there any sort of verification method that you would use to sort of go back in and make sure that like sometime down the road that the change is implementing as predicted in the long term sort of thing

Lucy: I personally haven't had to do that maybe there are some changes that do require that but from what I've seen is that you typically don't have to once you test I don't know how familiar you are with quality but we do capability studies and other metallurgical studies to make sure everything is okay but from that point on serial production inspection will show if you're meeting your requirements or not

Interviewer: okay, okay and then just sort of for an average sized change how long does the sort of start to finish process take?

Lucy: um for I'd say 6 to 8 months if there's like material changes or document changes, let's say 6 months to a year

Interviewer: and you said that's for like material or documentation changes

Lucy: yeah

Interviewer: okay, okay, that's covered all of my questions okay so I think that's everything so is there any sort of other information you could give me about the engineering change process and how it looks from your perspective that I haven't sort of covered

Lucy: my perspective, I guess the key importance is to make sure that all the stakeholders are involved with the change request process so let's say your advisory committee says okay we need you to have Meredith's thesis to have this change but then they don't tell you then that's a pretty stupid process but you have to make sure that all of the people involved the right people involved to make sure that the things that are tested are actually documented and not just we know we have to test this and we say okay you get these test in we approve it but you actually have to wait for test results to come in and not just say okay you can do these and then approve it but from an outside were done that's kind of the key critical points we see in some points I guess

Interviewer: okay those are good points. I think that about covers it for me, thank you for your time I appreciate the help

Lucy: Yeah no problem. Take care

Interviewer: Alright bye bye.

Interviewer: Thank you. Okay. So based on what you told me, what's been your sort of experience with Engineering changes. Have you handled many or is that something you come across often?

Susan: You actually, you cut out, can you repeat your question again

Interviewer: Yeah absolutely in your experience with these different companies what have you done with engineering changes themselves, like with the process is that something you come across often

Susan: so when you say engineering changes are you looking for something preproduction or postproduction that's something I wanted to ask you

Interviewer: Yeah okay I guess sort of production and postproduction, not necessarily like the drawing changes more of like the changes to how something is made or something in the production itself

Susan: okay so there are a couple of things first of all is whatever industry you're in you're always trying to meet the prompt and hoping that the engineering drawing covers all of the requirements that you want from a particular product then give that the manufacturing floor to make that product and usually the way the whole production floor is set up is as manufacturing experts we all come together and look at various methodologies and various production methodologies and methods of how you can make a particular product, so you can make it in ten different steps you can make it in 20 different steps it all depends on the technologies you have out there and also what expertise you have in the plant already. So usually that's the first and foremost thing it goes to the evaluation of that as to hey what are all the current machines that we have how can we use them to already use make this particular product or if we have to purchase new machineries there is all of the budgeting and all of that stuff that goes into picture and then finally we have to acquire all of the machines that are required for the production and once you start production the higher level process the way it goes is that you make the first first parts you know it's formally called as first article inspection if you will and from that what they try to di is that they try to understand if that particular company has the expertise to do those parts and all it is telling us is yes we can make this particular part but you're still not at this point you don't know the capability of each of those processes for production and as the production picks up and as it ramps up that's where you start assessing your capabilities and once you do that that's when usually you run into a lot of these changes that you have to make

Interviewer: mmhmm

Susan: so you can um the first and foremost thing that you can run into is that yes I can make this part but I'm really not capable and that I'm introducing a lot of scrap with these parts and things of that sort and you assess it and come up with hey what are the engineering changes that I might have to do to this part to make it more capable so first thing is let's say you have some specs on the drawing so you kind of assess is this even realistic to make this in the long term and then the dialogue happens between the production group of people the design group of people and also the customer asking hey guys I know you asked for 10 microns of surface finish let's say is that really a requirement for you, how is the product going to work in the field and that dialogue usually it happens in the initial parts of prototyping and things of that sort but a lot also happens through the development of the product I mean not the development of the product sorry throughout the life cycle of the product all throughout production and even when the number going down you know let's say it's phasing out that particular product that dialogue still keeps happening on a daily basis and these are called as engineering change requests in companies you know suppliers if it's coming from a supplier then they put in a change request and the team tells them back yes this is acceptable or this is not acceptable, that's one kind and the second kind is where the company itself on the production floor whenever they run into these issues they keep asking for engineering changes. These are two things, the third one is for cost reduction so yes we ca make this product great but when you come up with new technologies and new techniques to make this product and you want a little bit of tradeoff from the customer that when you always go back to them and ask hey I know previous of historically we met this particular spec here is the new process we came up with we can give you a ten cent reduction if you're willing to let go of this particular spec or willing to like compromise and there's always a discussion and you know then you talk about that and perform a lot of trials and these would be a combination of production trials and engineering trials to see how it lasts on the field and then you make the change

Interviewer: Okay

Susan: So those three are like major categories one on the production floor for capability stuff the second one is for cost reduction and the third one is anything coming from suppliers or suppliers you have for production

Interviewer: Okay gotcha. Um so for like the formalized process is there like a laid out specific formalized process at your company?

Susan: So different companies have different engineering change processes right so when I was in automotive the process for an engineering change for a production process again because this is not talking about product performance itself its more of the production layout right and is that what you're looking for

Interviewer: mmhmm right

Susan: so in that case usually the ideas come from the manufacturing group and they submit it to their design group the design guys evaluate it and see if it makes sense in terms of how the part is being made and then if required they have a discussion with the customer because if we are making any changes within those limits you really don't need to get the approval of the customer but if it's going outside of those limits and changing customer specifications then you definitely have to have that dialogue with them as well

Interviewer: Right

Susan: so based off of where it is in the limits you basically have a discussion with the customer or not and then once that is done you give your manufacturing guys some feedback alright and then they do the trials and come up with parts for testing and you get the results and depending on your statistical confidence that you want you pick different sample sizes so usually everyone goes with a 95 percent confidence level and then your six sigma experts come up with a sample size and they run the trials based off of that and they check the capability and if you're able to hold it up for quite a long time then and then there used to be something called as a review board and this review board is really like a final gate review if you want to call it that so there are so it's technology experts its' a group of technology experts, production experts plant managers and the find say you know whoever has it and they're called as you know change control board every company has a change control board so it has to go through them before you can make any of these changes to your processes. So it can be four or five tier, four or five-layer process and it goes through these different layers of people to make sure everyone agrees yes this is a lower risk no problem or yes it's a high risk but we can handle it really well, you know all of this swot analysis is usually done and then you submit the results and you go through the results and then based off of that you get the approval.

Interviewer: Okay

Susan: yeah and again once you get the approval it's not as easy as just let me switch it, it's going to be a lot of documentation and training out on the floor so these documentation usually includes your control plans, work instructions, work instructions to set up the machines so that's called like setup instruction right and if an operator is required to make those changes then you have to give them some training um and when you change these documents all of these go through a revision so it goes through the quality department of that company and they make the revision change and make sure that the new documents are out on the floor for production because anything that changes also goes through an audit usually it's once or two months in a year or whatever the frequency that's set up in that industry standards and when they come in for an audit that's what they see that hey the part that you produced is it is it following all of the paperwork you have out on the floor is it the exact numbers or is something changes and you didn't record it and things of that sort and you never want to get caught in those audits because it's very important for new business and continued business to go through all of these procedures before it can be out there on the floor.

Interviewer: okay

Susan: So that's usually the high level I wouldn't say high level but that's usually the process and each step also has a lot of details depending on the company and their internal procedures

Interviewer: Gotcha okay.

Susan: So what is your research looking at?

Interviewer: I'm looking at in particular the once a change has been implemented out on the floor I'm looking to see if companies tend to go back and go back and before it's implemented you have to assess the impact of it and get input from all the stakeholders but seeing if after it's implemented if people go back in and verify that their predictions for the impact hold and that sort of thing

Susan: Yeah yeah so this is all to get a change implemented, right, so once you implement it the way they keep a record of it so all manufacturing process and this is especially true for automotive so they have the control plans that I previously mentioned some charts and tables and they note down all the readings for that particular shift or day or even multiple days even a month sometimes continuously they record the readings on there, right, this could be 100 percent of the parts depending on how big the part is and what is the run rate of the part or it could also be a sample and again this is where six sigma sampling comes into picture let's say I'm just literally shooting parts out of the machine for things like OD grinding and things of that sort and then it's almost impossible to collect every part and measure that and you're also spending a lot of time so what they do instead is agree upon a sample size and they take down the readings for that sample size and the also chart them and these are called as SPCs statistical process control charts. We have a lot of them out there depending on the type of defect or defective item you are recording you come up with a sample size and a kind of chart and once you record those what they do is to see the trends as to how the product is performing um so is it a lot of variation that I'm able to see in the process or is it less variation. Can I sustain this production for a long time um what are the intermittent maintenance things I have to do on the machines and you know all of those kind of things so they track that that's how they get the feedback of how it's performing in the manufacturing and the second thing is once it goes out to customer there's also always the feedback loop there so if there is a defect found you know it's immediately reported and there is a I need another word right now like a quarantine of the other parts so they don't go out to the customer

Interviewer: Right

Susan: And the customer usually sends back all of the product they already have and then we go through sorting and then you do some root cause you do some root cause analysis there and try to understand why this occurred we thought it was going to perform well why didn't it and maybe you'll find something, maybe someone didn't understand their work instructions and produced incorrect feed, parts incorrectly, hopefully it's as simple as that but sometimes you run into issues only after you get the customer feedback and then you realize uhoh this parts not gonna work and then it's gonna be another engineering change control and everything and usually that goes quick because it's an immediate thing that has to be fixed so for this there is another term. Instead of doing a full engineering change because that take time going through review boards and the drawing changes we have something called as a deviation. So the customer says we need this immediately please change that produce the parts and send them to me so there is a team that is going through the drawing change so there is this other team that is saying okay let's put this concession out there there already is an approved deviation let's use that and start producing parts so at this point of time you're not doing a mistake because it's been approved by the customer that that's what they want even though it didn't change according to the drawing. The quality manager or someone is the one that makes that makes the call and puts their signature on all of the forms required out on the floor and they keep making these intermittent parts before the complete drawing change. So not always does it take that long.

Interviewer: Okay, so what does the sort of like for the whole like formal process how long about how long does that take?

Susan: Good question, uh

Interviewer: For like an average sized change

Susan: Yeah it really depends it's such a varied timeline really and it depends on a lot of factors. As silly as this sounds it really comes to prioritization at this point. Whenever it goes through these engineering changes the first thing they look at is which category of these changes impacts customers and then they go through pretty quickly and depending on which industry you're in, automotive moves quicker than healthcare but you can have changes go through within a week or even less than a week with deviations but if it has to go through a full change it might take a week or two, sometimes months, and uh few times depending on the complexity if there are multiple changes that they have to do for like a next generation of product or something like that then it kind of almost goes through that life cycle development thing even though it's just a couple of changes on the drawing and that sort of thing it can take more time depending on the impact it has on the product. Yeah so it can vary anywhere from a couple of weeks up to a year like I said and the priority here would be what's affecting my customer, that's the first one, the second one is quality of the product then the third one again would be cost savings and things of that sort

Interviewer: Okay. So when you're sort of working through the actual change solution, who are the stakeholders who get to weigh in on that decision? Who gets to talk about what they think could be a solution

Susan: Yeah so you'll have a couple of people who definitely from the design group and it will be heavily from the manufacturing group so you'll have the manufacturing engineer who'll be working on that, an engineering manager, the segment or the plant manager, the technology expert because the way it works is even through the manufacturing engineers are the experts at what's happening on the floor and things of that sort, you also have technology experts like milling grinding heat treatment all of these kinds so based on the process you're trying to change you'll pull them in whenever required so they'll be part of that, also this change board that I was talking about. They would review it when everything is put together but you have to call them in at the beginning of the project tell them what you're trying to do so that you don't waste a bunch of time trying to do something that they'll just shut it down right at the end right so for the kickoff meeting and when you're putting the project charter together definitely pull them in and have a kickoff meeting with all of these different people and based off of the size of the company you have different groups that get involved if it's a small company then just these people that I mentioned if it's a company that's spread across multiple locations and they have like an overseas head you know and then you have to pull them in as well

Interviewer: right

Susan: Again this is just to make sure that if you make this change in one plant it has to be also changed in the other plants across the world who are making a similar product right and if this change is applicable on a different product, even if it's for a different customer, it follows the same post process and why couldn't we use it there and so forth for that reasons based on the size of the company you might call in some additional people but the ones that I mentioned before they are definitely mandatory

Interviewer: Okay okay. So you gave me sort of the timeline for the full process, how long does it take just to implement a solution?

Susan: yeah so I have worked on projects where implementation took less than a week again it all comes down to what's the priority on this one really. So I worked on a couple of products where it was a customer complaint and products were failing in the field, so it was not something where we could say oh let's wait for a couple of weeks and then slowly get in there it was more of like I have the solution I need to implement it in the next four hours and it was actually done at that kind of pace we couldn't afford any uh any parts failing in the field so it can be as quick as that wherein you have a lot of resources and that's good whenever you're working on those high priority projects you get all of the resources and everyone's willing to change and put the people up and wait on production.

Some of the times a couple of the things it has to go through, which takes time is like the paperwork I talked about and resource allocation so normally you have the cost centers and cost heads that we cannot simply juggle people between them you know you have to like take permissions and they have to work out their schedule and make sure that they are not falling behind and all of those resources and optimize those as well and not just people. If you make a change you need a machine and sometimes there can be a lot of lead times for those machines or access areas for those machines especially things like feeder bowls and tooling tooling is a big one because no company has their own tooling department if you will yes they have a department but the tools actually come from outside vendors so if it happens to have a long lead time on of the tools then you're kind of stuck, you can't do anything. This is true especially for things like huge presses this press tooling it just takes months to get in here because they have to go through the process to make one and the lead time is quite long. so if based on that people resources the materials resources yeah raw material is the other one when you make a change to the chemical composition of the raw material that can take the longest because you literally have to wait for that raw material to be made that metal to be made so those things take a lot of time and also if your supplier is in overseas suppliers not in the north American region so Asia, Europe, Europe is quicker but Asia takes a little bit longer and uh hate to mention this but regional holidays and with everything going on this is specific to with Europe because people go on vacations for extended periods of time and sometimes you can't do anything about it especially if it's not your burning priority right now so all of these things cause a delay or an effect in the end to when can I make this change up and running.

Interviewer: Okay gotcha. Um you mentioned the I wrote down the name of it like the statistical process control sort of documentation that's used after or like in post implementation?

Susan: Um depends on the company, mostly statistical process control would be the documentation and now they are shifting now the industries are slowly moving into digital, right, instead of making notes on paper and putting that into documents to review later this one would be a software wherein you give the readings and it automatically tells you that hey wait a minute since the last hour this is running a little bit higher variation than normal and then it just errors you out or at least cautions you to look at maybe you forgot to fill the coolant in and maybe the temperature is just a lot or maybe there is just like a burr that is stuck up in there in the passage so it'll definitely error you out and then you stop the machine and make the changes and so really the postproduction really during the production is what I'm talking about right so you have this to give you like a live feedback of information about the performance of the machine itself and then going on to the customer would be the customer feedback and and that's more critical you don't want to get that feedback really but the system is definitely set up

Interviewer: Okay gotcha

Susan: and if something is wrong then they let you know immediately based on their system that is set up different companies have different interfaces but really the process is the same so the moment they find the part they put a ticket on it and they try to send it back to you for analysis for root causing and that's something that you always ask for ad sometimes customers send that a little later because that's not really their priority they have to be packaging parts ad shipping back to the supplier is not really their biggest concern and then they'll demand you to do stuff but you really cannot because you need to get the part to be able to see what is wrong so that's a delay that you'll usually experience as well in reality

Interviewer: Okay. Once you've like implemented a change, how long does it take before your process goes back to normal or like steady state? Is there a big time gap in there or is it usually pretty quick?

Susan: So when you say normal, the change is the new normal, right so I think you're talking about how long does it take for everyone to adjust to the new process? Again so like depending on the change so if it's just a small parameter change on the machine oh it takes no time I just have to move the knob and keep running parts. If it's like a full process change where it interacts a lot with people then people have to get trained towards it, it's a new process so that takes a little bit longer. They go through a training process first and then they have to demonstrate that they can do it with supervision and slowly the way it works is that you cut down supervision, so slowly you check on them occasionally and then you pull back when you're extremely comfortable knowing that yep they're doing the right thing and we don't have to shadow them or anything like that. So depending on how big a change that is on if it's a whole process change then it takes a little bit of time but if it's just a change on the machine then it's quicker. Again with a new change you have to also evaluate what is going to be your new baseline. You already know that your yield is going to be lower with this new process let's say so maybe previously your baseline was 90 percent first pass yield and now it could be 80 percent and that sort of analysis takes some time because it depends on how often am I running the parts am I running them every day then that will be quicker you know you observe the process for a little while you try to choose so you can optimize the process and set up your baseline and from the baseline you decide what the normal for this process is going to be so there is that timeline in between. You do the change there is that timeline for those adjustments then you set the record you set the limit and from then it becomes the new normal. So that timeframe really depends on project to project I've not seen a cookie cutter yet in the last seven years.

Interviewer: Okay, okay. How long do you sort of monitor new changes? I'm sure it depends on the size and like the scale of it but

Susan: If it's inspections and you're trying to see if you need to remove an inspection then you would check a few batches but if it is a process control like I said before then you never remove the monitoring process it's an ongoing monitoring process so it depends on this change that you're talking about where in the process does it happen you know if it's if it's a final process where I have to make sure that I send the right part to the customer you cannot take it out you cannot take the monitoring out it has to be in there so if you can tell me which kind of process change you are looking at then it would be easier to gauge how long they should be monitoring

Interviewer: Right so like an equipment change so if you had this one type of press and you switched to a different kind, it was vertical and now it's pressing from a different direction, something like that

Susan: So initially you would look at each part as it was coming off of the press, once you were comfortable with yep this is running how I want it to be then you slowly reduce it to your current SPC standards so let's say to begin with you'll check every part a lot of part and then send it to the lab to get checked because when we say I'm checking the reality with how it works is at the production floor you cannot have all of the greatest and latest equipment for measurements so you'll have a separate CMM lab for that. So you can only measure certain things on the floor you can have certain height gauges certain roundness gauges not everything sometimes a surface finish gauge but if it's at a press they usually wouldn't put a surface finish gauge out there because of the vibrations it would be sending out so you need to take parts away from that into a lab so depending on that's sort of resource as well they make the call of how may parts do I want to check for every batch that I want to feel comfortable with so you slowly ease into that normal SPC where maybe you just check five parts a batch or five parts a shift sometimes

Interviewer: Okay, gotcha. A sort of similar question how long do you worry about new changes?

Susan: How long do I worry about new change? Usually, if it's on a daily production, I'd say 3 to 4 weeks you know you still want to keep an eye on what's happening and things of that sort because it's very easy to fall back into old practices so that's one thing that you want to keep in mind and so when you talk about batches at least for five production batches. And then you ease into it knowing that yeah it's predictable I can rely on it yep so if it's the number of months and now I'm into supplier management and now I know that there is a change done at their plant and I know that It is highly affecting us in terms of quality then that monitoring would usually go for three months assuming they're sending different batches each month.

Interviewer: Once you've sort of implemented a new change, how often do you have to go and fix things, like if this change breaks something down the line or you find that because you changed this dimension now it won't fit in this, how often does that occur?

Susan: of the processes that I've worked on I haven't had to worry about that it's the better you do that analysis to begin with before a change the less number of issue you'll face later. That's one thing that often that I saw as I moved into more of a managerial role what I saw with a lot of engineers is that they were getting super excited about this new change and you'd just go out there and change too many things a t the same time rather than understand what are all the repercussions that it could have right have that depth of analysis so I have seen projects where I didn't have to worry about that at all because to begin with we did all of that analysis and I've also seen projects where after the change was implemented everything just went catastrophically downhill it's like oh my god how did you not think about that how did you make this change but they didn't think about it so and it depends on the type of change again because change is such a generic word and depending on the product you're making and the complications associated with it it can have different things involved.

Interviewer: Is there any sort of verification method you use to make sure that the analysis you've done previously is actually what's happening out on the floor?

Susan: yes, yes. You predict a certain pattern of result this is what I predict the result to be and then once the parts are up and running what you do is go collect data and try to see if you're able to hit that particular target or not. For example, let's say the output is a certain height a height on the product a very simple length of the bar let's say. You go out there and you collect data and you do some statistical analysis and you do like two sample t test or t test or anything of that sort of statistical analysis but what's fitting to that particular purpose you collect data you make the production collect data and you see if it's within the limits you have set already and only if it is then you release the product for to go down the line. If not, then they put that aside as a hold product, usually you don't use it until you get extra approvals and things of that sort before it goes down the line. So definitely yes.

Interviewer: Okay. Um and are there any sort of computer tools or sort of methodologies that are used to sort of help out in the change process

Susan: um

Interviewer: I know you mentioned statistical softwares but

Susan Yeah so statistical softwares are more for and this is not production line it's just more of the monitoring and to make sure that nothing changed drastically but if you're trying to make a decision right after implementing a change you know hitting those targets or not that's more of a manual that's really left up to the engineers and the teams who are involved with the change to say hey how many samples do I need how ma parts do I want to make before I make the call that yes this is good go ahead or if I need to stop the production. So that's more on the manual side that's where the engineering expertise comes into play.

Interviewer: Gotcha okay.

Susan: and also a lot of times on these technologies you have a lot of um historical information so there could be an engineering manager running that particular segment for quite a long time and he has said so previously when we made this sort of change it took two weeks to get it back so based off of that also you will counter that in definitely make sure you use that information and that's the reason why in the kickoff you pull all these people together so you can get that historic information about that technology.

Interviewer: Okay. I think that's all of my questions. Is there any other sort of information about engineering change that I haven't hit on that I should be is something I should consider?

Susan: Yeah, so at least when I started the interview today one thing that I was constantly thinking about is if the question was applicable to a component an assembly a really high level assembly or what kind of product so maybe based off of that maybe your answers because so every time I used the word well it depends I actually hate to use it because me as an engineer want a definitive answer but it really depends it really depends on the level in which your part is. A change to a small little nut would be very different from a change to a big assembly. So I'd say based off of that information at which subsystem level or assembly level I am at, things vary a lot. So just fyi out there.

Interviewer: Yeah that's definitely a good thing to consider.

Susan: Yeah that's one thing and also how close I am or how essential is that change to the performance of the part and not all parts are as essential to say safety not so important to safety so say if the part fails the product might stop working but it isn't going to hurt anyone but certain things are going to be where it would hurt someone so those things are deadly and those engineering changes go through a lot rigorous process than the ones that wouldn't so that's something that heavily decides the duration of engineering changes as well due to the need for additional testing and the type of product. Healthcare has a lot of regulations and tings and if you making a change there because things are interventional like surgeries and things you don't want anything to fail. So it really depends on the interface that that product or that part has with the end user so where in your whole product that part falls in also heavily impacts the engineering change request and its length for approval so that's one thing. Um let's see and uh if the change is in regarding to a function of the part if it's gonna change the function of the part then it's going to take longer than cosmetics because there are a lot of engineering change request for cosmetics as well so okay is it a cosmetic one or is it a functional change so based off of that there's a split there. Let's see oh like I said yeah material changes material changes are the worst. They take forever to come in. And in all those other categories that I previously mentioned as a pain is it tooling is it material change what does it require to make that change ad those take time for implementation purposes. Not so much for the change but for implementation. And also what testing needs to be done effects too like for example some products when you make a change on them you have to go to a certain list of tests you have to do it could be humidity testing it could be strength testing, tensile strength, how is the ductility of the product right now, porosity, the toxin levels in that thing and things like that. So like I said the end user really matters when we talk about engineering change because off of that you need to do these certain types of testing and what kind of industry standard do we need to follow for that particular part. If it's user interface and it's with medical stuff, then it needs more testing. In automotive then it really again comes down to is it causing fatality you know and if it is then it is going to be more testing involved. So I guess just those different categories would help in answering questions like how long does it take for engineering change to happen. If I knew which of these thing was happening with the product, then I can help giving numbers based off of again my experience which would be different in different companies but off of my experience I could give more of a range of yeah it would take so many days so I guess that's it.

Interviewer: Okay those are good points. I think that's all I've got. Thank you.

Susan: Great well good luck with everything else.

Interviewer: Thank you I appreciate it. Thank you for taking the time to help me out.

Susan: Have a good day bye bye.

Interviewer: You too bye bye.

Jill: So that's a joke.

Interviewer: So just kind of get started. Can you tell me a little bit about what your role is at BMW? how long you've been there? And then

Jill: Yes, yes. So my current role maybe isn't as interesting to you as what I've done previously, so maybe I kind of give you a little bit of a background on what I've been involved with. So I'm, I'm a Clemson grad. And then, while I was at school, I was co opting for, for Bosch and Anderson. And then I ended up taking a full time job with Bosch and Charleston, and cautious on timing in 2001. And so I was manufacturing engineering. And so I worked with Bosch as a manufacturing engineer, did a expat assignment in Germany for a couple of years. And then I was a manufacturing team leader for a little bit. And then ended up switching to BMW about, I guess, eight years ago. And then the first bit while I was at BMW, I was in manufacturing engineer in some sort of form of manufacturing engineering up until about a year ago. So I started as a process planner, did some lead planning work for for one of the new vehicle launches that we had did an expat assignment also with BMW. And then I was in a role for a little while called what we call assembly coordinator. And it's a project management function within manufacturing, engineering and production to implement to do change implementation. So I think is what you're most interested in. So managing the changes to our product and the changes to our processes, as a result, and then about two, excuse me, about a year ago, we started this new department, which is called innovation and digitalization. And you can through university collaboration on there as well. So that's where Natalie and I kind of work together a little bit. And it's kind of how I've worked a little bit with Dr. Summers in the past, in this new role, so that's, that's me in a nutshell.

Interviewer: Cool. So can you give me a little more detail about like, what what's your experience with like engineering changes and sort of change implementation? What that sort of look like?

Jill: Yeah, um, so I mean, as a CIO, as a manufacturing engineer, so we'll take it back. So a lot of times, and I guess it's a little bit different. There's like the Bosch world. And then there's the BMW world that I can kind of tell you about. So maybe starting with the Bosch world a little bit, um, they had a process, what did they call that? Man, I can't think of all the Bosch acronyms now. But basically, there would be an engineering Change Package to the products that we were working on coming from design. And then so what would happen is we would evaluate the we would evaluate what the product changes and what the impact is on the process. And then we would provide costs for the for the required changes to the process to accommodate the product change. And then if that change got approved, we were given a timeline for implementation. And really, the process at BMW is not all that different. It's just a little bit more. I guess the formalized isn't the right word. Just because the product is so much more complex, you know, cars and much more complex product than a fuel injector. The processes by which you make them are not as complicated, but you have a lot more moving parts. Say. So, with BMW, it's, it's fair, it's comparable. But there are two three main types of changes that we implement here. We do have running changes, which is just something that has to be done on the fly. Then we have what we call package changes. And we do those once every quarter. So well, they'll they'll package a series of product changes. And then we have obviously what we call launches so you know, we launch a new vehicle every seven years. And then those are that's that's, that's a big, that's not much as much of a much as change management as it is and you probably watch but I mean, I've been on all promoted from a manufacturing standpoint, not from a product design. endpoint? I've, I've been involved in all sides of that type of thing. So, okay. Yeah. So what is it? Maybe give me a little bit more information on what it is that you're working on that give me a little more context in terms of the type of information that you might want?

Interviewer: Yeah. So I'm trying to look at more manufacturing type changes, this stuff is driven by production, or that more affects the actual production of the part rather than, like a specific component or that sort of thing. And I want to see, sort of, because you said that, like you do, like the impact analysis beforehand. But I'm looking at sort of how that in that analysis is verified? How, like after implementation to see like, we thought this would do this is is actually what it does, sort of seeing how different people approach that issue. And when it's done, yes.

Jill: So are you working on? Is this a paper or a research project? Or is a research project? Okay?

Interviewer: My thesis

Jill: okay. I mean, there may be a couple of things I can pull out that I'd put together that might help to clock through. If I can remember where in the world I would have saved that. Um, okay. Let's see if this is the one that I want. Let's go through this. First, let me share my screen. And I've got two presentations open here that might help provoke some discussion. Okay. I can now figure out how to share my screen. Where did the zooms anger? Here we go. Post disabled participant screen sharing? So do you see something where you can? Let's see, can you try it now? Yeah, now it's working. Okay. Alright, so I have a couple of different things that we can work our way through. So in my previous role, I'm coming from right before this job, like I said, My job was called assembly coordinator. And so what I was responsible for, was making sure that the product changes were understood by by the manufacturing engineers in the group, and that they were able to do the evaluation about how much it costs, and then help them kind of along the way, with the tools that they needed, in order to to implement the change. So it's kind of a valley of what what you're looking for here. And so what I had put together, you know, I've kind of tried to make, trying to figure out which slide which presentation, it makes most sense to, to go through, let's go through this one, I'm not gonna be able to do it in presentation mode. So as we get as we get through this, I kind of give you an idea what all the acronyms are so So, TP TSS, are just department acronyms. geo one, for example, is one of our is a is one of the car derivatives that we build. So it's an x three. And then SB wV is a German acronym stands for Syrian petroleum on the Vita and weeklong. So basically, it's the part of the manufacturing engineers job to to improve the production process and to implement changes as they call them. And that's kind of what this covers. So, this was like if we had a new engineer in the group, this is kind of what I would lead them through to kind of explain to them what the process is. And the the, the, the very first thing you know, as a process planner, that you have to our manufacturing engineer that you have to understand is what are your inputs and outputs. And so if you are in this department process, planning your input Product Design, we have project structure. And then we have what the, what the plant looks like. And then what those as inputs to the expected output is a safe, cost effective and robust process that we feed directly back to the plant. And so these are just some of the things that we would step through to kind of show what their core outputs would be. So you know, all the process documentation being being a big part of it. So how to do what it is that it is how to describe what it is that the associate on their production line supposed to do. We are responsible for providing any type of tooling that's needed to do the processing, any type of equipment, and then any type of product or process validation. So did we do it right. And those are always the kind of things that as a manufacturing engineer that you have to keep in mind when you're implementing a new process or changing processes. And so I'm gonna skip around a little bit, some secondary outputs, it's not so important for you. So this is the way that BMW does the evaluation process of change. And there are several ways that things are evaluated. And it's really, really confusing, it's going to be difficult for me to explain to you what those are. But basically, any one of these things that you see here after a comma is a evaluation method for a type of change, whether it's a product change, or a volume change, or what have you. And they're all evaluated differently, depending on what tier of the development loop that we're in. What's more important, I think that, see, maybe let's go here, what's more important? is the one slide that I'm looking for that shows maybe it was in the other presentation, let me check this out. Yeah, that's probably this is somewhere. So as a manufacturing engineer, that works here, like I mentioned before, and I'm not going to talk about the base launch, when we're actually building a new vehicle. That was let's assume that we're built, we're running a vehicle, there are two basic types of changes that come in. There's a running change, which I talked about before. And that's steered by what we call the ECP process, which is the engineering change process. And then we have a package change, which I like I mentioned earlier, are the quarterly implemented changes that happen four times a year. And then there are several layers of collaboration where people talk about what those changes are. And the input from the manufacturing engineer is okay, I understand the change. This is how much it costs and we implement it into a sear into a system depending on what type of change that is. And then let's see what else to say. is not really good. So, let's see the evaluation of change can be steered. This says this has a lot of BMW nomenclature in here, which isn't gonna be very helpful for you. Maybe, yeah, maybe it's better. So I have I have information maybe it's better if you asked me some questions and then we can kind of bridge the two ends here.

Interviewer: Okay. Gotcha. Um, so, you mentioned that there is like the ECP process is like a breakdown of the different steps that sort of thing that what exactly is involved in that

Jill: there is but the ECP processes driven by our launch and change coordinator department here at the plant, it's a different department gotcha. Um, I'm you know, from from a manufacturing or production side, we are only one piece of that puzzle, because you know, obviously, you know, evaluations of the supply chain have to happen evaluation of logistics processes have to happen. So, we, we are only a part of the the change that is specific to this and we process. But with that, you know, there's a standard checklist that kind of comes comes with an ECP That asks thought provoking questions to the engineer that's responsible to try to help understand how this proposed change may impact the process.

So it talks about, you know, are you adding a variant of apartheid? are, you know, do you know? What is the FMEA analysis of of, of the process so that it can kind of trigger you to know if you need to do some sort of validation method and that type of stuff. So, so that goes through the ECP process. That funding though, this is where it gets really kind of complicated in BMW world, the funding, actually, and the evaluation to the funding happens prior to the ECP process, and that's called the M gams process. But that's basically where you decide how much money you will need to invest in the process to accommodate the change. Okay.

Interviewer: Oh, I love working from home.

Jill: Yeah, that's great. Okay, if it happens to me all the time. So we're doing about 50%, Home Office 50%, at the plant right now, so I totally get it.

Interviewer: So, so some other questions I had, who all like gets to feed into sort of like, the changes that are like to be made to give sort of like input onto what the actual change will be, is that mostly designers, or just like a manufacturing side gets to feed into?

Jill: Well,I mean, they're there. I mean, there are all kinds of different changes, right? I mean, so sometimes you make changes to the product to, to, to increase the functionality of the product, sometimes you make changes to improve the quality, sometimes you make changes to, to make things more manufacturable, or even cheaper. But I mean, the entire, the entire plant has input on on this changes. You mean, who has I guess, is the question, Who gets to decide if the product gets changed? Or who gets to do the evaluation? A little bit of both? But like, yeah, yeah, I mean, it's so I mean, ultimately, the design department is responsible for any type of product change. They're, they're the ones that have to do any type of product change, not anybody can request the change, depending on what their interests are. But once a change is determined that it's feasible, and it makes sense, to go into the evaluation phase, everybody has to be a part of the evaluation, like I mentioned, because even if it's a product change, that doesn't seem that significant, it could have impact on supplied components, which impacts purchasing, which impacts logistics. And so, you know, they can, you know, change can impact a lot of different facets, everybody has to have input on what it is that needs to be done to accommodate the change.

Interviewer: Okay. Gotcha. Once you finish like sort of implementing, or evaluating something, how long does it take before that solution is implemented?

Jill: Change it, you know, that that can vary depending on the significance of the of the change, if you take a look at to what our theoretical process was sharing my screen. So this is kind of this is showing one type of change. And of course, this isn't going to be large enough. Let me see one second.

Jill: So if you take a look at our process for our package changes, so the changes that happen every every quarter, right, theoretically, theoretically, the process starts this is saying 39 to 30 months before SAP. So that would be when you do the evaluation. And then you have a timeline that goes from there. Now, that's, that's, that's a pretty long lead time. And that's kind of the that's kind of the standard. But of course, we have running changes and things that happen on much, much more tighter timetables than that. But that's kind of what the, let's say the standard is at the moment is that basically 30 months before you start production with that change is when you should have provided the evaluation data.

Interviewer: Okay. Gotcha. Once you implemented a change, how long does it take for the process to sort of go back to like a steady state or during normal operating condition?

Jill: Um, I mean, that, yeah, the expectation is, is that it, that it goes back to normal operation immediately, okay. So like, for us on this package changes a lot of times. So for a package change, what ends up happening is we have different build phases, where, prior to the start of production, we have, I think, four different phases where we're testing the, the change and our production environment, so that we're eyes, you know, we're not flipping a switch on but we're, we're slowly opening the tap, and we're building maybe three or four cars with that content, on to kind of shake out the dust in the cobwebs, so to speak. And to to to understand, you know, where there are some assumptions and things that we made that were incorrect or that where we need to make adjustments. But from the time that we actually start production, there should be no ramp up at that point for no more change. And then for the ECP process, which is the running change process. Usually what will happen there is the manufacturing engineer will or request a line trial, where we say, okay, we agree to the change, we have to make these changes. But we need in order to do the final evaluation, before we turn this change on, we need to run a certain number of vehicles or a certain number of statistically significant trial parts in order to verify that the changes that we do it, we understood the change correctly, and that we've made all the changes that we needed to the production system.

Interviewer: So once you have the change, how long do you sort of monitor it in place? I'm sure you have like some sort of like continuous process monitoring, but like for a specific change.

Jill: I mean, it's we don't really necessarily do anything above and beyond our normal monitoring, once we've implemented the change, we rely on the existing controls. I mean, we obviously verify that they can. And that's the reason that we run these pre series, you know, the pre series builds in the trial builds beforehand is to validate that our control method measures that we have already in place, or ones that we have to add, because the changes are working properly. So we do a lot of specific monitoring after implementation. The expectation is is that the the production system has been modified and that it is self contained and self monitoring.

Interviewer: Once you've implemented changes, do you worry about them afterwards? How long sort of

Jill: not necessarily just because we have such a robust change process going into it that expectation is to make sure that we do everything upfront to mitigate the risk or to identify potential gaps and understanding and all of the various change processes that we have built.

Interviewer: Do you once you've sort of, again, implemented this change? Do you ever have to go back in and fix things? Because it's broken? Or it's messed something up down the line?

Jill: Yeah, I mean, sometimes that'll happen where, you know, again, you know, despite, you know, the controls that we have in our change management processes, you know, there was some things that were unforeseen or they're not fully understood. And then we'll have to go back and make additional accommodations, or that does happen. Is it like a frequent thing or pretty? No, it's fairly infrequent, just because of the checks and balances that we have in place in the evaluation.

Interviewer: Right. Okay. You, you, I think you mentioned that like in your in the training for, like manufacturing engineers, you sort of like verify that they've done like the right sort of analysis. What does that sort of look like? Are there any specific methods?

Jill: Yeah. So there are, I mean, the biggest, the biggest control that we have is, it's it's a BMW version, let's call it of a of an FMEA, or risk risk filter, where you go, and you answer a set of standard questions. And it will kind of steer you into understanding what you need to have in place from a control standpoint, to make sure that you're producing quality products. So it has a lot to do with what the severity, so if something goes wrong, what's the severity of that? risk? So what what will what will the end product, what will the defect of the end product resultants, severity wise, then you do an estimation on what you think the occurrence rate would be of that failure mode. And then you do a, an estimation on on what you think the likelihood of detecting that quality problem would be? And that we'll end up giving you a an evaluation that tells you that either the controls that you have in place are sufficient, or you need to do additional checks. In your process.

Interviewer: Is that Oh, that would be used for like, every sort of running change?

Jill: Yeah, the expectation is that we do, the expectation is that we do a risk filter. Or we compare, at a minimum, we compare the existing risk filter against the proposed change, to see if updates are necessary. And then if updates are necessary, we would update it. But it is possible to say, Oh, yeah, okay, that doesn't this specific change doesn't change the risk. So we don't have to do any additional control measures.

Interviewer: Okay. That's all the, like, the main questions I had. Okay. Is there any sort of like, additional information? I should know about your process or just process in general?

Jill: No, I mean, the, the biggest thing to know is it's a very controlled and monitored process. It's not, you know, it's not something that, you know, we throw out and see what happens, it's, there's a very methodical front end to our change management that, by default, by default, mitigates a lot of risk. And then, in addition to that process, in the evaluation of the evaluation, process then we have the trial phase where we do different build phases to verify the assumptions that were made. And in the evaluation phase, we actually turn turn the switch on. So a lot of the work a lot of the work is done prior to implementation to avoid having impact on the running system. So that's okay, that's, that's pretty, that's pretty standard. That's pretty standard across the, across the industry. Um, you know, a lot of like I said, I've worked with BMW and with Bosch, and you know, some of the acronyms are different and some of the tools are different, but the overall change management process is very comparable. Okay. Cool. Well, and if you know, if you think of things later on, as you get a little bit further along in your paper and you want to meet up again, just let me know.

Interviewer: Okay, thank you so much.

Jill: Cool.

Interviewer: I really appreciate it. Thank you for your time.

Jill: Awesome. Well have a good day and stay safe and healthy.

Interviewer: Thank you. You too. Alright, bye bye.

REFERENCES

Akao, Y. (2004). *Quality function deployment: integrating customer requirements into product design*. Taylor and Francis.

Albuquerque, D., Guimaraes, E., Perkusich, M., Costa, A., Dantas, E., Ramos, F., & Almeida, H. (2020, March). Defining agile requirements change management: a mapping study. In *Proceedings of the 35th Annual ACM Symposium on Applied Computing* (pp. 1421-1424).

Bauer, H., Schoonmann, A., & Reinhart, G. (2017, October). Approach for model-based change impact analysis in factory systems. In *2017 IEEE international systems engineering symposium (ISSE)* (pp. 1-7). IEEE.

Bhatti, M. W., Hayat, F., Ehsan, N., Ishaque, A., Ahmed, S., & Mirza, E. (2010, October). A methodology to manage the changing requirements of a software project. In *2010 International conference on computer information systems and industrial management applications (CISIM)* (pp. 319-322). IEEE.

Blessing, L. T., & Chakrabarti, A. (2009). *DRM: A design reseach methodology*. Springer London.

Blessing, L. T., Chakrabarti, A., & Wallace, K. M. (1998). An overview of descriptive studies in relation to a general design research methodology. *Designers*, 42-56.

Bree, R. T., & Gallagher, G. (2016). Using Microsoft Excel to code and thematically analyse qualitative data: a simple, cost-effective approach. *All Ireland Journal of Higher Education*, *8*(2).

Carter, Nancy *et al.* (2014, September). The use of triangulation in qualitative research. In *Oncology nursing forum*(Vol. 41, No. 5, p. 545).

Cassell, C., Buehring, A., Symon, G., Johnson, P., & Bishop, V. (2005). Qualitative management research: A thematic analysis of interviews with stakeholders in the field. *Benchmarking good practices in qualitative management research: Final report*.

Clausing, D. P. (1993). World-class concurrent engineering. In *Concurrent Engineering: Tools and Technologies for Mechanical System Design* (pp. 3-40). Springer, Berlin, Heidelberg.

Dale, B. G. (1982). The management of engineering change procedure. *Engineering management international*, *1*(3), 201-208.

DelSpina, B., Gilliam, S., Summers, J., & Morkos, B. (2018). Corporate requirement culture in development of a large scale medical system: A case study. In *DS 92: Proceedings of the DESIGN 2018 15th International Design Conference* (pp. 2621-2632).

Eckert, C., Clarkson, P. J., & Zanker, W. (2004). Change and customisation in complex engineering domains. *Research in engineering design*, *15*(1), 1-21.

Eckert, C., Clarkson, P.J. & Zanker, W. 2004, "Change and customisation in complex engineering domains", Research in Engineering Design, vol. 15, no. 1, pp. 1-21.

Elena, M. V., & Summers, J. D. (2019, August). Requirement Generation: Lecture

Intervention Impact on Variety and Novelty. In *International Design Engineering Technical Conferences and Computers and Information in Engineering Conference* (Vol. 59216, p. V003T04A011). American Society of Mechanical Engineers.

Elena, M. V., Wentzky, C., & Summers, J. D. (2019, August). Requirements culture: a case study on product development and requirement perspectives. In *International Design Engineering Technical Conferences and Computers and Information in Engineering Conference* (Vol. 59278, p. V007T06A030). American Society of Mechanical Engineers.

Evans, C., & Lewis, J. (2018). *Analysing semi-structured interviews using thematic analysis: Exploring voluntary civic participation among adults* (pp. p1-6). SAGE Publications Limited.

Fowler, M., & Highsmith, J. (2001). The agile manifesto. *Software development*, *9*(8), 28-35.

Furuhjelm, J., Segertoft, J., Justice, J., & Sutherland, J. J. (2017). Owning the Sky with Agile: Building a Jet Fighter Faster, Cheaper, Better with Scrum. *Global Scum Gathering, San Diego, CA*.

Garzaniti, N., Briatore, S., Fortin, C., & Golkar, A. (2019, March). Effectiveness of the scrum methodology for agile development of space hardware. In *2019 IEEE Aerospace Conference* (pp. 1-8). IEEE.

Giffin, M., de Weck, O., Bounova, G., Keller, R., Eckert, C. & Clarkson, P.J. 2009, "Change Propagation Analysis in Complex Technical Systems", Journal of Mechanical Design, vol. 131, no. 8.

Giffin, M., de Weck, O., Bounova, G., Keller, R., Eckert, C., & Clarkson, P. J. (2009). Change Propagation Analysis in Complex Technical Systems. *Journal of Mechanical Design*, *131*(8).

Graessler, I., Oleff, C., & Scholle, P. (2020). Method for Systematic Assessment of Requirement Change Risk in Industrial Practice. *Applied Sciences*, *10*(23), 8697.

Guion, L. A., Diehl, D. C., & McDonald, D. (2011). Triangulation: Establishing the validity of qualitative studies. *EDIS*, *2011*(8), 3-3.

Hafeez, Y., Riaz, M., Asghar, S., Naz, H., Gilani, S. M. M., Batool, A., ... & Hassan, M. S. (2012, December). A requirement change management framework for distributed software environment. In *2012 7th International Conference on Computing and Convergence Technology (ICCCT)* (pp. 944-948). IEEE.

Hamraz, B., Caldwell, N. H., & Clarkson, P. J. (2013). A holistic categorization framework for literature on engineering change management. *Systems Engineering*, *16*(4), 473-505.

Han, J., Lee, S. H., & Nyamsuren, P. (2015). An integrated engineering change management process model for a project-based manufacturing. *International Journal of Computer Integrated Manufacturing*, *28*(7), 745-752.

Hein, P. H., Voris, N., & Morkos, B. (2018). Predicting requirement change propagation through investigation of physical and functional domains. *Research in Engineering Design*, *29*(2), 309-328.

Hofer, A., Brandl, F., Bauer, H., Haghi, S., & Reinhart, G. (2020). A Framework for

Managing Innovation Cycles in Manufacturing Systems. *Procedia CIRP*, *93*, 771-776.

Htet Hein, P., Morkos, B., & Sen, C. (2017, August). Utilizing node interference method and complex network centrality metrics to explore requirement change propagation. In *International Design Engineering Technical Conferences and Computers and Information in Engineering Conference* (Vol. 58110, p. V001T02A081). American Society of Mechanical Engineers.

Huang, G. Q., & Mak, K. L. (1999). Current practices of engineering change management in UK manufacturing industries. *International Journal of Operations & Production Management*.

Huang, G. Q., Yee, W. Y., & Mak, K. L. (2003). Current practice of engineering change management in Hong Kong manufacturing industries. *Journal of materials processing technology*, *139*(1-3), 481-487.

Hussain, W., & Clear, T. (2012). GRCM: a model for global requirements change management.

Jarratt, T. A. W. A., Eckert, C., Clarkson, P. J., & Schwankl, L. (2002). Product architecture and the propagation of engineernig change. In *DS 30: Proceedings of DESIGN 2002, the 7th International Design Conference, Dubrovnik* (pp. 75-80).

Jarratt, T., Clarkson, J., & Eckert, C. (2005). Engineering change. In *Design process improvement* (pp. 262-285). Springer, London.

Jarratt, T., Eckert, C., Clarkson, P.J. & Schwankl, L. 2002, "Product Architecture and the Propagation of Engineering Change", International Design Conference – Design 2002. The Design Society, May 14 - 17, 2002, pp. 75.

Joshi, S., Morkos, B., Shankar, P., Summers, J. D., & Mocko, G. M. (2012). Requirements in Engineering Design: What are we teaching?. *Tools and methods for competitive engineering*, *1*(38), 1319-1326.

Judger, N. (2016). The thematic analysis of interview data: An approach used to examine the influence of the market on curricular provision in Mongolian higher education institutions. *Hillary place papers, 3rd edition, University of Leeds*.

Knackstedt, S. & Summers, J.D. 2017/11/03, "Part Change Management: A Case Study on Automotive OEM Development and Production Perspectives", ASME 2017 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference. American Society of Mechanical Engineers Digital Collection, , August 6–9, 2017.

Knackstedt, S., & Summers, J. D. (2017, August). Part change management: a case study on automotive OEM development and production perspectives. In *International Design Engineering Technical Conferences and Computers and Information in Engineering Conference* (Vol. 58165, p. V004T05A009). American Society of Mechanical Engineers.

Knackstedt, S., Summers, J., Sutton, M. (2021), "Part Change Management: A Case Study on an Automotive OEM Comparing Development and Production Perspectives", CERA Journal, accepted May 2021

Koch, J., Gritsch, A., & Reinhart, G. (2016). Process design for the management of changes in manufacturing: Toward a Manufacturing Change Management process. *CIRP Journal of Manufacturing Science and Technology*, *14*, 10-19.

Lam, W., & Shankararaman, V. (1999, September). Requirements change: a dissection of management issues. In *Proceedings 25th EUROMICRO Conference. Informatics: Theory and Practice for the New Millennium* (Vol. 2, pp. 244-251). IEEE.

Lam, W., Loomes, M., & Shankararaman, V. (1999, March). Managing requirements change using metrics and action planning. In *Proceedings of the Third European Conference on Software Maintenance and Reengineering (Cat. No. PR00090)* (pp. 122-128). IEEE.

Lash, A., Murray, K., & Mocko, G. (2012, August). Natural language processing applications in requirements engineering. In *International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*(Vol. 45011, pp. 541-549). American Society of Mechanical Engineers.

Maguire, M., & Delahunt, B. (2017). Doing a thematic analysis: A practical, step-by-step guide for learning and teaching scholars. *All Ireland Journal of Higher Education*, *9*(3).

Masmoudi, M., Leclaire, P., Zolghadri, M., & Haddar, M. (2017). Engineering Change Management: A novel approach for dependency identification and change propagation for product redesign. *IFAC-PapersOnLine*, *50*(1), 12410-12415.

Masood, T., Kern, M., & John Clarkson, P. (2021). Characteristics of changeable systems across value chains. *International Journal of Production Research*, *59*(6), 1626-1648.

McLellan, J. M., Morkos, B., Mocko, G. G., & Summers, J. D. (2010, January). Requirement modeling systems for mechanical design: a systematic method for evaluating requirement management tools and languages. In *International Design Engineering Technical Conferences and Computers and Information in Engineering Conference* (Vol. 44113, pp. 1247-1257).

Mokammel, F., Coatanea, E., Christophe, F., Ba Khouya, M., & Medyna, G. (2013, August). Towards an approach for evaluating the quality of requirements. In *International Design Engineering Technical Conferences and Computers and Information in Engineering Conference* (Vol. 55867, p. V02BT02A024). American Society of Mechanical Engineers.

Morkos, B., Joshi, S., Summers, J. D., & Mocko, G. G. (2010, January). Requirements and data content evaluation of industry in-house data management system. In *International Design Engineering Technical Conferences and Computers and Information in Engineering Conference* (Vol. 44113, pp. 493-503).

Namouz, E. Z., Mears, L., Mocko, G., & Summers, J. (2011). *Lazy Parts Indication Method: Application to Automotive Components* (No. 2011-01-0428). SAE Technical Paper.

Nordin, N., & Deros, B. M. (2017). Organisational change framework for lean manufacturing implementation. *International Journal of Supply Chain Management*, *6*(3), 309-320.

Nurmuliani, N., Zowghi, D., & Williams, S. P. (2004, September). Using card sorting technique to classify requirements change. In *Proceedings. 12th IEEE International Requirements Engineering Conference, 2004.* (pp. 240-248). IEEE.

Oduguwa, P. A., Roy, R., & Sackett, P. J. (2006). Cost impact analysis of requirement changes in the automotive industry: a case study. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, *220*(9), 1509-1525.

Pandey, D., Suman, U., & Ramani, A. K. (2010, October). An effective requirement engineering process model for software development and requirements management. In *2010 International Conference on Advances in Recent Technologies in Communication and Computing* (pp. 287-291). IEEE.

Park, T., & Kim, K. J. (1998). Determination of an optimal set of design requirements using house of quality. *Journal of operations management*, *16*(5), 569-581.

Paul, J., & Mau, R. (2011). *Deep Orange-A Framework for Research, Education and Collaboration for a Sustainable Automotive Industry* (No. 2011-01-1110). SAE Technical Paper.

Podolak, D. (2019). Application of Critical Chain Project Management to the Production Part Approval Process.

Qattawi, A. A., Venhovens, P. J., & Brooks, J. (2014, June). Rethinking automotive engineering Education–Deep orange as a collaborative innovation framework for Project-Based learning incorporating Real-World case studies. In *2014 ASEE Annual Conference & Exposition* (pp. 24-1052).

Quintana, V., Rivest, L., Pellerin, R., & Kheddouci, F. (2012). Re-engineering the Engineering Change Management process for a drawing-less environment. *Computers in Industry*, *63*(1), 79-90.

Raffaeli, R., Malatesta, M., Marilungo, E. & Germani, M. 2014/02/12, "An Approach for Managing Engineering Changes in Product Families", ASME 2013 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference. American Society of Mechanical Engineers Digital Collection, , August 4–7, 2013.

Ramzan, S., & Ikram, N. (2006, December). Requirement change management process models: Activities, artifacts and roles. In *2006 IEEE International Multitopic Conference* (pp. 219-223). IEEE.

Rawal, V., O'Shields, S. T., Summers, J. D., & Myers, O. (2016). Motivations and perceptions of capstone benefits for industry sponsors and academic advisors: A retrospective study. In *Proc. Capstone Design Conf.* (pp. 1-4).

Rouibah, K., & Caskey, K. R. (2003). Change management in concurrent engineering from a parameter perspective. *Computers in industry*, *50*(1), 15-34.

Schmidt, T. S., Chahin, A., Kößler, J., & Paetzold, K. (2017). Agile development and the constraints of physicality: a network theory-based cause-and-effect analysis. In *DS 87-4 Proceedings of the 21st International Conference on Engineering Design (ICED 17) Vol 4: Design Methods and Tools, Vancouver, Canada, 21-25.08. 2017* (pp. 199-208).

Shankar, P., Morkos, B., & Summers, J. D. (2012). Reasons for change propagation: a case study in an automotive OEM. *Research in Engineering Design*, *23*(4), 291-303.

Shankar, P., Morkos, B., Yadav, D., & Summers, J. D. (2020). Towards the formalization of non-functional requirements in conceptual design. *Research in Engineering*

Design, *31*(4), 449-469.
Shankar, P., Summers, J., & Phelan, K. (2014). A verification and validation planning method to address change propagation effects in engineering design. *Proc. Proceedings of TMCE*, 635-648.
Singh, J., & Singh, H. (2009). Kaizen philosophy: a review of literature. *IUP journal of operations management*, *8*(2), 51.
Sobek II, D. K., Ward, A. C., & Liker, J. K. (1999). Toyota's principles of set-based concurrent engineering. *MIT Sloan Management Review*, *40*(2), 67.
Storbjerg, S. H., Brunoe, T. D., & Nielsen, K. (2016). Towards an engineering change management maturity grid. *Journal of Engineering Design*, *27*(4-6), 361-389.
Sutton, M., & Summers, J. (2021). Comparing Change Management Processes for Requirements and Manufacturing: An Interview Based Study. *In ASME International Design Engineering Technical Conferences and Computer in Engineering Conference*, Virtual, August 2021, IDETC2021-69694.
Teegavarapu, S., Summers, J. D., & Mocko, G. M. (2008, January). Case study method for design research: A justification. In *International design engineering technical conferences and computers and information in engineering conference* (Vol. 43284, pp. 495-503).
Teng, J. T., Grover, V., & Fiedler, K. D. (1996). Developing strategic perspectives on business process reengineering: from process reconfiguration to organizational change. *Omega*, *24*(3), 271-294.
Terwiesch, C., & Loch, C. H. (1999). Managing the process of engineering change orders: the case of the climate control system in automobile development. *Journal of Product Innovation Management: AN INTERNATIONAL PUBLICATION OF THE PRODUCT DEVELOPMENT & MANAGEMENT ASSOCIATION*, *16*(2), 160-172.
Ullah, I., Tang, D., & Yin, L. (2016). Engineering product and process design changes: a literature overview. *Procedia CIRP*, *56*, 25-33.
Ullman, D. G. (1992). *The mechanical design process* (Vol. 2). New York: McGraw-Hill.
Ullman, D. G. (2019). *Scrum for hardware design: supporting material for The mechanical design process*. David Ullman LLC.
Wright, I. C. (1997). A review of research into engineering change management: implications for product design. *Design Studies*, *18*(1), 33-42.
Yin, R. K. (2017). *Case study research and applications: design and methods*. SAGE.
Zhu, A. Y., Von Zedtwitz, M., Assimakopoulos, D., & Fernandes, K. (2016). The impact of organizational culture on Concurrent Engineering, Design-for-Safety, and product safety performance. *International Journal of Production Economics*, *176*, 69-81.