Establishing a People Qualification Framework at Embraer Executive Aircraft, Inc.

by

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Abstract

Title: Establishing a People Qualification Framework at Embraer Executive Aircraft, Inc.

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Technical training in the aviation industry is a multi-faceted and complex topic. Research efforts in aviation maintenance training are extensive, however, we observe a paucity of studies directly focused on aircraft manufacturing environments. Nevertheless, the recent growth of the training industry and the advent of more disruptive technologies such as virtual and augmented reality solutions are making training program design efforts more and more relevant.

The research and design contributions presented in this thesis focus on the establishment of a people qualification framework at a local aircraft final assembly and testing plant in Melbourne, FL. The design thinking cycle was used both as a philosophy and problem-solving approach. The design contributions were managed as projects using an agile complex work management framework called Scrum. Content, presentation, and interaction were used as socio-technical dimensions and considered carefully both for design of training offerings and evaluation purposes. The focus of the evaluation was to measure effectiveness.
in terms of trainee satisfaction using a survey method. The nature of the evaluation was formative and exploratory in order to gather insight into the main improvement opportunities to target.

This thesis begins by providing a brief history and context of the corporation and facility that is the business case being analyzed. Next, best practices and selected research efforts in aviation and training are explored. After presenting the training program road map and project management considerations, we dive into the training improvement design efforts. Using the design cycle, we provide a staged approach to define problems, identify needs, benchmark, ideate, prototype, and evaluate various contributions to the aircraft manufacturing operation. Finally, conclusions are drawn regarding the state of research in aviation manufacturing training, the continuation of the design efforts presented herein, and the potential future growth of people qualification at this company.
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Dedication

For my beloved mother, we did it...
Chapter 1
Introduction

1.1. The Embraer Story and Context

Celebrating 50 years of existence is a significant milestone for any company. In August 2019, the Brazilian aircraft manufacturer Embraer will reach this point in its history. Founded by the government of Brazil in 1969 at a time when embryonic efforts in the development of a local aviation industry resulted in repeated failures, Embraer’s birth and sustained growth were the result of Ozires Silva’s vision. In fact, Silva was appointed by the government as Embraer’s first president. Prior to this appointment, as the Chief of Aircraft Development in the years preceding the company’s birth, his involvement in the development of the first Embraer model (EMB 110) known as the Bandeirante1 was key to the success not only of that aircraft but also of the subsequent Embraer journey. Through his disruptive perspective of the Brazilian and Latin American aviation markets, he influenced the design of the Bandeirante to ensure that it was tailored perfectly to its prospective customers. Characteristics of ruggedness, durability, “high-dispatchability”, versatility, and affordability gave the EMB 110 all the tools to create an impact by presenting a fresh alternative to the Douglas DC-3. The Bandeirante was a resounding success and the fact that

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1 The Portuguese word “bandeirante” means pioneer.
there are still close to 150 of these airplanes flying around the world in a large variety of roles is a true testament to its pedigree. Furthermore, Oziros Silva and his team had emphatically delivered on their promise and placed Embraer at the forefront of a nascent regional aviation market (Machado & Hatakeyama, 2018).

Fast-forward nearly half-a-century and Embraer is now the third largest aircraft manufacturer in the world behind Boeing and Airbus (MOI Global, 2018). The company has bloomed into a full-blown leader in the regional jet market. In addition, Embraer’s business aviation division (Embraer Executive Jets) market share has grown to approximately 18% between 2000 and 2016 thanks to the company’s philosophy of constant evolution and relentless innovation. At the time of writing the world of aviation could potentially be on the verge of a major market consolidation event as Boeing attempts to acquire an 80% controlling stake of Embraer. This proposed joint venture would allow Boeing to establish themselves fully in the regional jet market and directly compete with Airbus². Embraer would retain control over its Executive Jets division as well as its Defense & Security division (Tomesco, 2018) (Eyck, 2017).

From an organizational standpoint, the announcement of the potential joint venture has garnered an interesting mix of speculation and enthusiasm. Despite the inevitable uncertainty

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² In 2018, Airbus took control of Bombardier’s struggling regional C Series jet program in a strategic move to dominate the global market for regional jets.
that comes with massive business shifts the size of this potential joint venture, Embraer employees across the world continue to be focused on the corporation’s motto:


Innovation in the realm of people qualification is of paramount importance for Embraer now more than ever as the company moves forward in its quest to deliver aircraft of the highest quality and reliability to an ever-growing global customer base.

1.2. Embraer Executive Aircraft – A Case in People Qualification

Technical training in the realm of aircraft assembly can be a complex enterprise. In the United States, Title 14 of the Code of Federal Regulations (CFR) specifies the various requirements for the different segments of the aviation industry that fall under the oversight of the Federal Aviation Administration (FAA). While pilot training and certification are heavily regulated, technician and quality inspector training recommendations provided in FAA Order 8120.23A Certificate Management of Production Approval Holders are generally best practice guidance which is not considered enforceable from an audit standpoint. However, it should be noted that from an aviation industry perspective, it is widely accepted that specific shop floor employee training is an important element of a quality system. This also stems from the fact that industry standards such as AS9100 and ISO 9001, often used as a basis for elaborating and developing the quality system of Production Approval Holders (PAH), do emphasize the significance of shop floor employee training. Furthermore, Order 8120.23A’s Risk-Based Resource Targeting (RBRT)
organizational risk assessment tool highlights the importance of organizational stability, of which growth and turnover are key indicators that FAA audit teams are expected to take into consideration (Federal Aviation Administration, 2017). The regulatory and industry considerations described herein are taken as the basis for analysis of training at a specific PAH facility in Melbourne, FL that produces the EMB 500 (Phenom 100), EMB 505 (Phenom 300), and EMB 550 (Legacy 450/500 & Praetor 500/600) type certified Embraer business jet models. This thesis aims to discuss the establishment of a training program at Embraer Executive Aircraft, Inc. (EEA) focused on enhancing the shop floor trainee experience, instating training effectiveness measurements, and overall positive impact of improved people qualification on organizational key performance indicators.

1.2.1. EEA Melbourne, FL – A Brief History

EEA is the business jet subsidiary of Embraer S.A. The latter is headquartered in São José dos Campos, Brazil while its business jet division headquarters were recently moved to Melbourne, Florida. The appointment of Michael Amalfitano as CEO of Embraer Executive Aircraft, Inc. in March 2017 displays the Brazilian corporation’s efforts to establish a stronger presence in the United States as a truly global aviation industry giant.

In 2011, the EEA final assembly facility located at the Orlando Melbourne International Airport delivered its first Phenom 100 aircraft. The first Phenom 300 aircraft assembled in the United States was delivered in early 2013. The company has delivered more than 340 airplanes in eight years of existence. While the Phenom 100 aircraft has struggled to establish itself as a market leader in the very light jet segment, new customers and applications as a
jet trainer aircraft for both commercial and military pilot training have injected new life in this model’s program. On the other hand, the Phenom 300 is the most delivered light jet for the seventh year in a row and has dominated its segment with more than 50% of the market share since 2012 (Peciulyte, 2019).

EEA began final assembly operations of the mid-size and super mid-size Legacy 450 and 500 models in 2016 under close oversight and supervision from the FAA Orlando Manufacturing Inspection District Office (MIDO) as part of a Management Plan established between Embraer S.A., EEA, the Federal Aviation Administration (FAA), and its Brazilian equivalent, Agência Nacional de Aviação Civil (ANAC). Since then, Embraer S.A. has made some strategic changes and decided that the Legacy 450/500 and Praetor 500/600 flight critical assembly operations would be accomplished in Brazil and that the Melbourne facility would be responsible for the interior assembly, paint operations, completing the production flight regiment, and delivery to final customers for these models.

1.2.2. Organizational Risk Assessment and Challenges for EEA

The aerospace job market on Florida’s Space Coast has evolved tremendously in the past decade with the end of NASA’s Space Shuttle program and the advent of heavy weights in the private sector of the industry such as SpaceX and Blue Origin. Furthermore, new aerospace defense contracts with corporations like Northrop Grumman, Harris Corporation, and Lockheed Martin have also contributed to breeding more competition in hiring talented,

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3 The Praetor 500/600 models are upgrades to the Legacy 450/500 models.
experienced, and motivated technicians and quality inspectors. This movement in the aerospace job market initially brought a pool of talented and experienced individuals to EEA at its inception in 2011. However, recent developments in this job market have negatively affected EEA’s ability to retain its most experienced shop floor employees as competition fiercely.

The FAA’s organizational risk assessment of a PAH facility is meant to be performed in a dynamic manner and should be revisited in the case of significant changes that could affect the facility’s ability to produce a compliant product. As listed in section 3.9 of FAA Order 8120.23A, several factors could lead to a change in risk assessment including:

- “Significant quality system changes;”
- “Significant turnover of key staff;”
- “Significant increases or reductions in workforce.”

The factors listed above are important to consider in EEA’s current scenario as the company’s recent strategic changes to add the Legacy and Praetor product lines to the Melbourne operations have warranted some necessary and significant quality system changes (Federal Aviation Administration, 2017).

Turnover of key staff has been another point of interest from an organizational risk assessment perspective at the Melbourne facility. In less than eight years, EEA has had three different Senior Quality Managers. This position is of paramount importance in the
production certificate management responsibilities as the site Senior Quality Manager is the direct point of contact between regulatory bodies (FAA and ANAC) and the PAH facility. In addition, there has been significant turnover in other senior management positions as well as quasi single-point failure production support engineering positions.

While the turnover of key staff represents a potential threat to the organizational stability of the company, high shop floor turnover could represent direct operational risks with regards to the quality of the aircraft produced. Over the past three years, EEA has seen a sharp increase in production technician workforce while also suffering from an increasing turnover of experienced shop floor employees.

As a result of the aforementioned changes and challenges that EEA has been recently faced with, the FAA has raised the Melbourne facility’s risk level. This translates to a higher full Quality System Audit (QSA) frequency as well as more frequent Principal Inspector (PI) audits. It is important to keep in mind that “the FAA is the government agency responsible for aviation safety in the United States” (Wood, Sweginnis, & Lederer, 2006) and that the organizational risk assessment performed is part of a broader effort to reduce and mitigate risk factors for the aviation industry and for the general public. At the time of writing, EEA and the FAA continue to nurture a healthy organizational relationship based on transparency and effective communication.

1.2.3. Key Improvement Opportunities at EEA

My involvement as a researcher at EEA began in August 2017. Drawing from over two years of experience with EEA working as a Quality Analyst, I analyzed the organizational
layout of the company and proposed a pyramid model designed to identify key improvement opportunities at various levels and stages in the operations of EEA. Highlights of this model are presented below. This model proved to be useful by providing insight to EEA’s management team for targeting specific areas with strategic improvement projects. Furthermore, EEA’s management team has an important role spanning across the levels listed below as the collective orchestrator of strategic change within the organization including both bottom-up and top-down initiatives.

- The Apex
- The Fulcrum
- The Core
- The Foundation

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The initial iteration of the pyramid model developed is provided in Appendix A.

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process. Finally, the apex of the pyramid model represents the complex and bottom-line critical aircraft delivery process. Opportunities and feedback loops are detailed in the full diagram provided in Appendix A.

The foundation level includes production planning, methods planning, training, logistics, process improvement, manufacturing engineering, material review board, quality engineering, and documentation control. The teams, groups, individuals, processes, and systems involved at this level are responsible for a variety of foundational activities including

- Coordinating training for all shop floor and support group employees and contractors,
- Delivering the required parts and assemblies to the shop floor on time,
- Ensuring proper configuration management is respected for every aircraft build,
- Providing correct drawings and specifications as well as helpful instructions for the execution of production and inspection tasks,
- Dispositioning non-conformances effectively,
- Analyzing defects and process breakdowns,
- Implementing robust corrective and preventive actions to mitigate risk.

Many opportunities for improvement were identified within the activities performed at this foundational level such as
• Communicating changes in the production plan more rapidly and effectively across the organization,

• Ensuring that all shop floor and support group employees are trained and qualified theoretically and practically,

• Reducing part shortages,

• Improving tooling and equipment calibration and availability,

• Developing and utilizing data analysis systems efficiently to prioritize problem solving efforts.

The problem statement in this thesis focuses on the establishment of a people qualification framework aimed at reducing non-conformance occurrences and their associated costs to EEA, targeting first and foremost the shop floor environment (i.e. the core) and expanding to include the foundation, the fulcrum, and the apex levels of the organization. The research and tangible contributions described herein are part of one of EEA’s main site-wide strategic projects which fits into the corporation’s global quality plan.
Chapter 2
Best Practices and Research Efforts in Aviation and Training

2.1. Fundamentals of Technical Training

Technical training is of critical importance in any industrial enterprise. Its origins can be traced back to the early concepts of apprenticeship developed in ancient Greece (Williams, 2001). Since then, the roles of workers in various industrial environments have changed tremendously with the advent of technology and more specifically automation. This in turn has caused changes in the needs of technical workers in terms of training as their job functions have evolved and continue to evolve. Technical training can be defined as “the most common type of skill improvement instruction, designed to increase the technological capabilities of workers” (Williams, 2001).

In 1988, Carnevale and Schulz published a review of technical training in America looking at several different aspects of this field. They highlighted the importance of training systems as two-way streets “which both teach employees and learn from them” (Carnevale & Schulz, 1988). They presented the perspective that new industrial revolutions lead to new problems. This idea brings forth the necessity to rethink our approach to design the integration of technology into our industrial environments and do so continuously in order to keep up with the speed at which new technology is being developed (Hollnagel & Woods, 2005). Carnevale and Schulz went on to emphasize the evolving skillset requirements of manufacturing technicians as well as the importance of developing their adaptation skills.
and ability to “learn to learn” (Carnevale & Schulz, 1988). This concept is in line with Jens Rasmussen’s model of operator behavior (skills, rules, knowledge – SRK) in which the knowledge-based behavior is observed in situations where individuals are presented with a problem they have never faced before and are in essence forced to problem solve (Rasmussen, 1983).

Changes in technology also impact the organizational structure of companies. This in turn leads to more employee independence, autonomy, and responsibility from the bottom up. As a result, the significance of employee self-management becomes key as managers “intervene only when the work is unsatisfactory” (Carnevale & Schulz, 1988). The employee becomes responsible for his/her advancement within an organization impacting both their career development and personal development (Carnevale & Schulz, 1988).

When discussing career and personal development, one can refer to the concept of ‘human capital’. According to Blundell et. al., ‘human capital’ is composed of three main components:

- “Early ability (whether acquired or innate)
- Qualifications and knowledge acquired through formal education
- Skills, competencies, and expertise acquired through training on the job” (Blundell, Dearden, Meghir, & Sianesi, 2005).
Blundell et. al. provides an in-depth economic impact analysis of professional education and training on the individuals, the organizations they work for, and the economy at large. While observing a paucity in research efforts in training at that time, the researchers were nevertheless able to draw some significant conclusions about the benefits of human capital investments from both micro and macroeconomic perspectives. They observed through data analysis that training is generally transportable from one employer to the next. They found that individuals who have reached higher levels of education or received prior training “are more likely to participate in further training” (Blundell, Dearden, Meghir, & Sianesi, 2005). Finally, they present the argument that investments in training can contribute to increasing the productivity of companies (Blundell, Dearden, Meghir, & Sianesi, 2005).

Evaluating training effectiveness is key to understanding what improvements can be made to a given training program. An important aspect of training effectiveness evaluation is the role of the technical trainer. In most industries, there is a tendency to promote technical subject matter experts (SMEs) to technical trainer positions. However, this trend brings up two important questions:

- Is technical expertise a pre-requisite for trainer roles?
- Is technical expertise sufficient to yield effective training?

Once again, the paucity of research on this specific aspect of technical training renders difficulties in answering these key questions. Nevertheless, it is generally accepted that there are some clear advantages to relying on the use of SMEs as trainers such as
• Their thorough understanding of the technical concepts at hand

• Their ability to relate to the learners or trainees

• Their “instant credibility” with the learners or trainees

While the advantages listed above can contribute greatly to training effectiveness, it is important to note that SMEs should receive training in adult education in order to adequately deliver training content. Often, the surplus of knowledge that SMEs have about a given subject can make it difficult for them to filter the information needed by the learner. The main takeaway from this discussion of subject matter experts as trainers is the need to recognize that ineffective training resulting from a lack of trainer expertise or knowledge of adult education principles can cost the industry a tremendous amount of money, can be counterproductive, and can lead to increased risk (Williams, 2001).

Ultimately, research efforts in the realm of technical training from the late 1980’s to the early 2000’s have concluded the following:

• Not enough technical training is provided which represents an underinvestment in human capital

• Technical training provided is not good enough to cope with current and future industrial challenges especially related to technological evolutions

• Technical training provided is not distributed appropriately to ensure the right skills and knowledge are developed at every organizational level.
2.2. The Training Industry Today

Thankfully, recent evolutions in the training industry go in the direction of increased investments, diversification of content and delivery methods, as well as a more homogeneous distribution of training across organizational levels. In 2018, trainingmag.com published the 37th edition of its annual Industry Report providing valuable data and insight into the training industry trends. Using comprehensive survey methods to gather information, the study provides data spanning multiple industries including but not limited to manufacturing, health and medical services, and finance and banking. The 2018 report shows that over the past six years total training expenditures across multiple industrial classifications have increased by approximately 58% despite a 6.4% dip from last year’s figure. Based on the figures collected and analyzed in this study which “are weighted by company size and industry according to a Dun & Bradstreet database available through Hoovers of U.S. companies,” the total training expenditure value for 2018 was approximately $87.6 billion (2018 training industry report, 2018). This reflects that across the board, companies of all sizes continue to show a sustained trend of increased investment in training. Figure 2 shows the summarized total expenditure figures.

![Figure 2 Training Expenditures 2013-2018](2018 training industry report, 2018)
The 2018 Training Industry Report does not dive into questions of whether the training dispensed effectively addresses the challenges of the ever-evolving industries it serves. As seen in Figure 2, it does, however, provide insight into the fact that companies are spending more on outside training products and services. This trend illustrates how training consultancy is becoming a truly lucrative niche market of the training industry most likely fueled by positive returns on investments within the various companies that have integrated this approach as part of their training strategy. Finally, among other interesting data points, the report estimates that 69% of training hours in 2018 were dispensed through a combined or blended method while the figure for instructor-led training hours decreased by approximately 6.5% from last year’s figure (2018 training industry report, 2018). This suggests that companies of small, medium, and large sizes are actively diversifying their training delivery methods to improve trainee experience and knowledge retention as well as to produce positive changes in professional behavior. Figure 3 displays the breakdown of training delivery methods used by companies surveyed in 2018.

![Figure 3 Training Delivery Methods by Company Size 2018](2018 training industry report, 2018)
2.3. Understanding Human Error

Human error is far more complex than it may seem. Human operators can be modeled as integral parts of the systems they operate in a similar manner to hardware and software components. Analyzing human error often results in a focus on the outcomes of situations where human operators have failed to perform adequately, however it is important to take organizational and contextual aspects into consideration. Latorella and Prabhu provide an in-depth review of methods employed to identify, report, and manage human error emphasizing the specificities of aviation maintenance environments and their importance in the analysis of human errors (Latorella & Prabhu, 2000).

A common method used for making sense of human error is that of error taxonomies. One of the most popular error taxonomies is that of James Reason which breaks down human error into three main categories:

- Slip – unconscious and usually associated with action execution
- Lapse – also unconscious and generally associated with forgetting
- Mistake – considered intentional and often associated to poor decision making (Reason, 2009).

Having a better understanding of human error invariably involves some form of categorization which consequently helps address the different types of errors more effectively.
Another important aspect of human error is the performance aspect. In industrial contexts, human behavior can be analyzed within a set of levels defined by Jens Rasmussen as skills, rules, and knowledge-based (SRK) levels of operator behavior. Figure 4 taken from Rasmussen’s 1983 paper on distinctions in human performance models illustrates the three levels of operator behavior.

![Diagram of three levels of performance of skilled human operators](image)

Figure 4 "Simplified illustration of three levels of performance of skilled human operators" (Rasmussen, 1983).

When analyzing task performance by a human operator, this model can be extremely useful to determine the level of consciousness, attention, and control. In addition, depending on the level of familiarity with the task and the system being operated, the operator may be
operating in a different performance level. It is important, however, to note that human operational behavior does not necessarily occur only in one level at any given time – rather the model can be thought of more as a continuum of human performance with different tendencies depending on the situation at hand.

The skill-based level represents actions being performed “without conscious attention or control” (Rasmussen, 1983). Within this level of operator performance, human actions tend to resemble automated actions as they are generally performed seamlessly and subconsciously.

The rule-based level represents a more goal-oriented approach to task performance with emphasis on the usage of previously stored rules in the operator’s mind. These stored rules can be the result of trained behavior following a set of pre-defined procedures or internally defined rules from previous familiar situations. Rasmussen mentions that “the boundary between skill-based and rule-based performance is not quite distinct, and much depends on the level of training and on the attention of the person” (Rasmussen, 1983).

Finally, the knowledge-based level represents a problem solving cognitive space in which a human operator may be faced with an unfamiliar situation and may not have the ability to rely on stored rules or quasi-automatic sensory motor responses. At this level, a thorough analysis of the environment and goals are taken into account in the formulation of a plan that can be tested functionally. Knowledge-based behavior often involves the elaboration of “mental models” to better understand the structure of the problem or situation
being faced by the human operator and these mental models may “take several different forms” (Rasmussen, 1983).

Understanding the different levels at which skilled human operators perform is another fundamental aspect of human error analysis. Thanks to the work of Rasmussen and other researchers, characteristics of the different types of human errors in practice can be mapped with respect to a continuum of human performance levels that take into account consciousness, attention, control, goals, task/system/situation familiarity, and level of training.

In aviation, human error is a far more researched concept with regards to the role of pilots than it is with regards to the roles of mechanics and inspectors (Salas & Maurino, 2010). Perhaps this observed imbalance in the volume of research stems from the fact that an estimated 70-80% of all aircraft accidents can be attributed to pilot-related errors. This figure has generally been accepted as true within the aviation industry for many years despite fluctuations from year to year. The 27th Joseph T. Nall Report published by the Aircraft Owners and Pilots Association (AOPA) Air Safety Institute claims that 73.8% of general aviation accidents that occurred in the US in 2015 were the result of “improper actions or inactions of the pilot” (AOPA Air Safety Institute, 2015). Nevertheless, the roles of mechanics and inspectors should not be neglected as they bear the responsibility of ensuring that aircraft are manufactured according to specification as well as maintained appropriately for continued airworthiness and safe operation.
Human error management and mitigation are also significant topics of interest in aviation. As suggested by Salas and Maurino, reducing vulnerability to human error becomes key – several ways to achieve this goal are summarized by Carroll as follows:

- Avoid the “Blame and Punish” mentality
- Recognize (and remediate) organizational pressures
- Well designed training
- Checklists in hand with techniques to manage attention
- Review procedures to ensure they recognize cognitive vulnerabilities (Carroll, 2018).

In addition to the items listed above, Latorella and Prabhu provide seven detailed “intervention strategies for controlling human errors in aviation maintenance and inspection” (Latorella & Prabhu, 2000):

1. A maintenance incident reporting system with limited immunity for reporting
2. A standardized, but rich, vocabulary/indexing scheme for characterizing situational and operator factors in error reporting
3. Technologies to facilitate recognition of hazardous patterns in situational and operator factors
(4) Aviation maintenance system simulation

(5) Virtual environmental simulations to support experimental investigations

(6) Methodologies for identifying organizational structures and job design characteristics which dampen the likelihood and perseverance of human errors

(7) Truly human-centered, integrated task aiding, automation, and training (Latorella & Prabhu, 2000).

Hence, it becomes abundantly clear that understanding human error is not a simple matter. In analyzing human error, one must take the environment as well as the organizational context into consideration. While classifying human errors based on their characteristics may be desireable in theory, it is far more useful and practical to map those characteristics with respect to a model of human performance such as SRK. Within the aviation industry, there are a number of ways to reduce error vulnerability and improve error management and mitigation. One of the most important strategies is the elaboration and delivery of training which is the focus of the contributions presented herein.

2.4. Situation Awareness in the Aviation Industry

A reality of today’s world that is true not only within the aviation industry but also in our everyday lives is that “more data does not equal more information” (Endsley, 2001).
Figure 5 illustrates the concept of “the information gap” highlighting how data is found, sorted, integrated, and processed to become useful information. Endsley and Rodgers’ formal definition of situation awareness is the “perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future” (Endsley, 1988).

Much research has been conducted regarding the concept of situation awareness within aviation. Most of this research is focused on flight operations and flight crews more specifically. As described by Endsley, issues related to situation awareness are not limited to flight decks but can rather be found in a multitude of professional and personal contexts. Endsley further breaks down situation awareness into three levels:

- “Level 1 SA – Perception of the elements in the environment
• Level 2 SA – Comprehension of the current situation

• Level 3 SA – Projection of future status” (Endsley, 2001).

As individuals move from one level of situation awareness to the next level up, their actions gain in effectiveness.

Shifting our focus from the fundamentals of situation awareness to a specific application, we may look at situation awareness in aviation shop floor environments. Here the concept of shared situation awareness becomes key as teamwork dynamics play a significant role in such activities as performing maintenance on an aircraft, assembling an aircraft system for the first time, or inspecting an aircraft before a test flight. According to Marx and Graeber referenced by Endsley and Robertson, 12% of aviation accidents can be attributed to maintenance and inspection faults. Endsley and Robertson highlight the importance of situation awareness in human error management. Using a methodical approach, these researchers were able to collect information related to situation awareness requirements analysis as well as situation awareness resource analysis. This information allowed the researchers to develop a situation awareness training offering for aviation maintenance teams which can easily be tailored and exported to other facilities as well as other segments of the aviation industry. Ultimately, the work of Endsley and Robertson led to the development of a prototype situation awareness training offering that was implemented and evaluated at Continental Airlines (Endsley & Robertson, 2000). The positive results in terms of perceived
usefulness and perceived effects on behavior for training participants in the study have motivated many other companies in the industry to develop and deliver situation awareness training to their employees. These results are provided in Figure 6 and Figure 7 below.

Figure 6 "Overall Course Evaluation" (Endsley & Robertson, 2000)

Figure 7 "Perceived affect of course on behavior" (Endsley & Robertson, 2000)
2.5. Common Models Used in Aviation Maintenance

In this section we provide a brief overview of three models that have a human factors focus and are commonly used in aviation maintenance.

2.5.1. PEAR Model

The PEAR Model is a mnemonic device used to recall the four main elements of human factors in aviation maintenance:

- People
- Environment
- Actions
- Resources (Johnson & Maddox, A model to explain human factors in aviation maintenance, 2007)

Figure 8 shows the different categories and issues that can be encountered in each element of the PEAR model (Johnson & Maddox, 2007b).
2.5.2. The Dirty Dozen

The Dirty Dozen concept was introduced in 1993 by Gordon Dupont while he was working for the Canadian equivalent to the FAA called Transport Canada. This list of twelve
common human pitfalls have become a standard in human factors analysis and training (Airport Council International, n.d.). The FAA provides an infographic pamphlet tailored for maintenance environments that contains useful information regarding each component of the Dirty Dozen concept – we have provided this pamphlet in Appendix B and list the twelve components below (FAASTeam, 2012):

- Lack of Communication
- Complacency
- Lack of Knowledge
- Distractions
- Lack of Teamwork
- Fatigue
- Lack of Resources
- Pressure
- Lack of Assertiveness
- Stress
- Lack of Awareness
2.5.3. Maintenance Error Decision Aid (MEDA)

This hands-on human error analysis and prevention tool was developed by Boeing starting in the early 2000s. The main assumptions of MEDA are the following:

- “Maintenance technicians do not make errors on purpose,”
- “Errors result from a series of related contributing factors,”
- “[Contributing] factors are largely under management control” (Rankin, Hibi, Allen, & Sargent, 2000).

These assumptions are verified as valid by Rankin et. al. through in-depth field tests consisting of evaluations of the method in practice at several airlines and repair stations as well as a survey-based portion aimed at collecting feedback and suggesting improvements to the implementation of MEDA. Rankin et. al. highlights the importance of management buy-in for the successful implementation of MEDA and mention that the tool is compatible for use in aircraft manufacturing or assembly environments (Rankin, Hibi, Allen, & Sargent, 2000).

The Boeing Company provides a MEDA user guide that can be used both for training and implementation purposes.
2.6. Training as a Safety Improvement Tool

The importance of safety in the aviation industry is paramount. In fact, the FAA’s primary concern expressed in its mission, vision, and value statements is safety (Federal Aviation Administration, 2010). When it comes to the implementation of safety measures, having a Safety Management System (SMS) in place has become the standard in the aviation industry (Federal Aviation Administration, 2016).

According to the FAA website, the Notice of Proposed Rulemaking (NPRM) pertaining to the establishment of a requirement for Part 21 facilities to have a SMS in place has been placed on hold until at least 2020. Nevertheless, some organizations that fall under Part 21 have gone forward with a voluntary SMS implementation effort as is the case at EEA (Federal Aviation Administration, 2018).

A clear distinction is necessary between a Quality Management System (QMS) and a Safety Management System (SMS):

- “QMS Objective is Customer Satisfaction.”
- “SMS Objective is Aviation Safety Focused” (Federal Aviation Administration, 2016).

This distinction is important especially in aircraft manufacturing environments in which most organizational planning aspects are delivery driven and seldom take into consideration safety perspectives systematically.
While the basis for SMS is rooted in the evolution of safety thinking as seen in Figure 9 and is focused on moving towards a predictive model of decision-making and actions (see Figure 10), the brutal reality of the industry from a safety standpoint is still largely reactive and pursuant to the blood-priority concept.

![Figure 9 Evolution of Safety Thinking – Factors in Accidents (Federal Aviation Administration, 2016)](image)

![Figure 10 Typical stages of SMS implementation (Federal Aviation Administration, 2016)](image)
The four SMS components shown in Figure 11 provide an excellent road map for establishing the fundamental structure and resources to support and promote the safety culture. It is arguable that within the organizational structure, methods, and processes to achieve safety objectives, an aviation company should strongly consider the development of a sound people qualification framework aligned with its safety needs.

Figure 11 The four SMS functional components (Federal Aviation Administration, 2017)
Chapter 3
Enhancing the Training Experience: A Design Thinking Approach

3.1. Integrating the SCRUM Framework and the Design Thinking Cycle

Planning, managing, and executing complex work requires a sound approach. Breaking complex work into small pieces can be a helpful way to make it more manageable. An agile task and project management approach like the SCRUM framework can be useful to break complex work into smaller and more digestible pieces. Coupling it with an innovative design philosophy is a recipe that has proven to be fruitful.

2.5.4. SCRUM Framework

According to Michael James, a Certified SCRUM Trainer for CollabNet, Inc., the scrum approach emerged from the shortcomings of traditional waterfall management methods. Scrum highlights “collaboration, functioning software, team self-management, and the flexibility to adapt to emerging business realities” (James, n.d.).

Here is a brief history of scrum:

Provided a better understanding of rapid innovative product development within American and Japanese companies.

Drew a parallel between common principles of self-organization, cross-functionality, and iterative work by teams observed in a variety of industries and the sport of rugby\(^5\). Figure 12 is a photograph of a rugby scrum during an international game.

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\(^5\) In the sport of rugby, the term scrum is used to describe a phase of a game when play needs to be restarted. Each team’s forward members interlock arms and push against the other team’s pack to gain control of the ball.
• **1995** – Jeff Sutherland and Ken Schwaber announced scrum as a framework to be used by software development teams with characteristics and work profiles aligned with Takeuchi and Nonaka’s study.

• **2001** – The “Agile Manifesto” is created and signed.
  
  o Bringing product development teams, software development teams, and project managers together to define all agile methodologies and their value in planning, managing, and executing complex work.

  o Since then, several technology giants including Google, Yahoo, and Microsoft have adopted scrum as well as other agile methodologies.

  o In addition, many organizations in a variety of industries have implemented scrum. This continues to contribute to their successful efforts to reduce time and costs of complex projects.

• **2015** – Embraer implemented scrum using the software Atlassian JIRA as a facilitating tool.

  o Embraer’s Global Vice President for Quality introduced the concept to quality departments across the entire Embraer corporation.

  o Scrum masters were identified and trained within each quality department.
Scrum continues to be used to plan, manage, and execute complex projects within the Embraer organization.

While scrum is still mainly an agile framework geared for software development teams, it is garnering tremendous interest among many different industries. Thanks to the transportable nature of many of its core principles, successful implementation is possible for an ever-growing field of scrum practitioners (Keith, 2007).

The scrum framework defines three roles:

- **Product Owner** (described in Figure 13)

![Figure 13 Product Owner main attributes and responsibility](image)

- **SCRUM Master** (described in Figure 14)

![Figure 14 SCRUM Master main attributes and responsibility](image)
SCRUM Development Team (described in Figure 15)

Scrum practitioners organize work in fixed “time-boxes” called “sprints”. The typical duration for a sprint is two weeks but can range from one week to one month. Sprints have different phases often referred to as “ceremonies”:

- **Sprint Planning Meeting** – All three roles meet to determine the goals of the upcoming sprint. The product owner provides direction in terms of priority of deliverables. The team strives to break down the work into well-defined tasks with “definitions-of-done (DoDs),” deadlines, and estimates of time needed to perform the tasks.

- **Daily SCRUM Meeting** – The team and scrum master meet daily to review progress towards the sprint goals. This meeting typically lasts approximately 15 minutes and each team member answers the following three questions in a verbal report to the whole team:
  
  o What did I accomplish yesterday?
What will I accomplish today?

Do I have any impediments?

- **Sprint Review Meeting** – All three roles meet to review what was accomplished during the sprint and determine which items are considered done and which ones are not. This meeting serves the purpose of demonstrating and showcasing the team’s incremental accomplishments to the product owner as well as any interested outside stakeholders.

- **Sprint Retrospective Meeting** – The team and scrum master meet to reflect on their performance during the last sprint and make decisions on adapting individual and team behavior to improve performance for future sprints (James, n.d.).

Limitations to scrum implementations usually happen when certain aspects of the framework are modified since they are considered uncomfortable (James, n.d.). A good example of this appears when product owners attempt to delegate some of their prioritization responsibilities to the scrum master or simply do not participate in the meetings required to fully support the team. Such issues have been encountered within the EEA Quality Engineering team. Keeping in mind that the successful implementation and continued proper application of the scrum framework is an iterative process in itself, all three roles should strive to adopt a “lessons learned” philosophy in order to promote their own continuous improvement.
At EEA, the quality department uses the scrum framework. The implementation is done using a software called JIRA from the Australian software enterprise Atlassian. I received Embraer training to become a scrum master in August 2016 – I have learned about the application of the framework as well as using the JIRA software proficiently. Currently, I serve as the scrum master for EEA’s training team which is discussed in a later section of this thesis.

Within JIRA, users can create dashboards and display a wide range of data in “gadgets” to help visualize information regarding their individual or their team’s progress. An example of a dashboard layout for the EEA training team is shown in Appendix C.

2.5.5. An Introduction to Design Thinking

To understand the power of design thinking and its fundamental importance in today’s world, one must first acknowledge the concept of “meaning.” About this subject, Krippendorff proposes the following axiom:

“Humans do not see and act on the physical qualities of things, but on what they mean to them” (Krippendorff, 2006).

We often take design for granted and do not realize that it is constantly happening around us and likely within us as well.

“One always acts according to the meaning of whatever one faces” (Krippendorff, 2006).
This introduces nuances in our traditional views of causality as it leads us to always consider the human interactions with products, artifacts, and processes as a key parameter rather than an afterthought. Today, there is an emerging design culture resulting from the advent of “information technology and human-centeredness” (Krippendorff, 2006). As we navigate through our everyday lives, we find that much of our thoughts, decisions, and activities have abundantly more in common with the design thinking paradigm than they do with a function-centered society (Krippendorff, 2006). This is further shown in Figure 16 from Krippendorff’s book entitled *The Semantic Turn – A New Foundation for Design*.

<table>
<thead>
<tr>
<th>Functionalist Society</th>
<th>Design Culture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology-centered</td>
<td>Human-centered</td>
</tr>
<tr>
<td>Hierarchical knowledge structures</td>
<td>Stakeholder networks, advocacy, and markets</td>
</tr>
<tr>
<td>Rationally derived and assigned functions</td>
<td>Interactively negotiated and supported meanings</td>
</tr>
<tr>
<td>First-order understanding</td>
<td>Second-order understanding</td>
</tr>
<tr>
<td>Technology serves to predict and control</td>
<td>Technology facilitates design in everyday life</td>
</tr>
<tr>
<td>Finding technological solutions to social problems</td>
<td>Proposing desirable futures and paths to them</td>
</tr>
<tr>
<td>Re-searching past records for patterns</td>
<td>Creating and exploring required variability</td>
</tr>
<tr>
<td>Know-what was, how something worked</td>
<td>Know-how to transform possibilities into realities</td>
</tr>
</tbody>
</table>

*Figure 16 "Ingredients of emerging design culture" (Krippendorff, 2006)*

Recognizing that there are different perspective models to take into consideration is a key principle of design thinking. While user and designer models will always vary based on context and nature of the design effort at hand, “insiders to design” (Krippendorff, 2006) tend to share certain common motivations summarized by Dr. Lucas Stephane in one of his lectures on design thinking:
• Coming up with innovative ideas,

• Synchronizing multiple disciplines,

• Advocating for users,

• Balancing socio-political, cultural, and ecological considerations (Stephane, Design Thinking [.pdf], 2018).

Ultimately, Krippendorff brings us to an unequivocal conclusion that is central to design thinking:

“Design constitutes being human” (Krippendorff, 2006).

Liedtka et al. focus their approach to design in the concept of “designing for growth” (Liedtka, King, & Bennett, 2013). They identify four stages of design thinking as part of a “systematic end-to-end process” (Liedtka, King, & Bennett, 2013) for addressing innovation:

1. What is? – exploring the current reality.

2. What if? – envisioning options to create the future based on what we learn.


Figure 17 is a visual representation of these four stages. We can see that the process described is clearly a series of diverging and converging phases that eventually brings us to a result that is in line with the principle of growth.

Liedtka et al. also provide a toolkit that inventories the various categories and methods commonly used by design thinking practitioners. Figure 18 lists the 10 elements contained in this toolkit.

![Figure 17 Diagram illustrating Liedtka et al.’s four stages of design thinking (Liedtka, King, & Bennett, 2013)](image)

![Figure 18 Design thinking categories and methods toolkit (adapted from Liedtka, King, & Bennett, 2013)](image)
Finally, Liedtka et al. provide valuable insight into management roles and responsibilities in nurturing design thinking within organizations (Liedtka, King, & Bennett, 2013). Tim Brown, CEO of IDEO, further emphasizes this aspect by suggesting that while managers are not expected to become designers, there is a need for them to think like designers and understand the designer perspective (Brown, 2005).

Figure 19 Iceberg analogy of changes from design thinking (Liedtka, King, & Bennett, 2013)

Design thinking has a proven record of helping businesses solve complex problems that are limiting factors to their growth. Organizationally, this is best illustrated by Liedtka et al.’s iceberg analogy that focuses on the multi-level and progressive positive impact of design thinking (see Figure 19). This diagram has been used as a conversation starter at EEA to discuss some of the changes in behavior, attitudes, conversations, and outcomes that the
management wants to see. The key has been to show them that by impacting the mind-set of their employees, they have the power to create measurable changes in the company’s bottom-line.

One simply cannot introduce design thinking without speaking about the contributions of Christoph Meinel and Larry Leifer. According to Meinel and Leifer, “the heart of the design thinking process lies at the intersection of technical feasibility, economic viability, and desirability by the user” (Leifer, Meinel, & Plattner, 2011). We will focus here on two key contributions that synthesize most of the other design thinking contributions previously presented. These two contributions also provide a useful roadmap for applying design thinking:

- The Rules of Design Thinking,
  - “The Human Rule: All Design Activity is Ultimately Social in Nature.”
  - “The Ambiguity Rule: Design Thinkers Must Preserve Ambiguity.”

The first rule of design thinking is reminiscent of Krippendorff’s axiom of meaning and his view of a shift towards a design culture. It also highlights the centric nature of humans in design for all stakeholder levels.

- “The Ambiguity Rule: Design Thinkers Must Preserve Ambiguity.”

The second rule of design thinking suggests that it is not enough to think outside the box as we understand it. Pushing the limits of knowledge and ability becomes a necessity.
“The Re-design Rule: All Design is Re-design.”

Needs of human beings have not changed much, however we continuously find new ways to address them. Anticipating future conditions to better design for them becomes pivotal.

“The Tangibility Rule: Making Ideas Tangible Always Facilitates Communication.”

There is now a recognition that prototypes are more than the tangible results of design iterations. They have become means of communication between stakeholders. This rule highlights the power of making the design process tangible as a whole – creating a catalyst for successful design outcomes through constant knowledge sharing.

- The Five Major Stages of Design Thinking
  - “(re) Define the Problem,
  - Needfinding and Benchmarking,
  - Bodystorm
  - Prototype
  - Test” (Leifer, Meinel, & Plattner, 2011).
Figure 20 shows the stages of the design thinking cycle listed above in a “standard” configuration.

Meinel and Leifer argue that in reality design thinking tends to happen in a more scrambled mode that is a function of a “higher order intellectual activity that requires practice and is learnable” (Leifer, Meinel, & Plattner, 2011). This configuration is illustrated in Figure 21.
A perfect example of the design thinking cycle applied to a practical case is Boulnois and Stephane’s work on the “Onboard Weather Situation Awareness System (OWSAS).” Here, the researchers used the design thinking cycle in a scrambled configuration to delineate the different iterations of their design. Figure 22 presents the schematic representation of this example (Boulnois & Stephane, 2018). The design contributions presented in this thesis rely on a similar approach in the practice of design thinking.

Figure 22 Schematic representation of an example of applied scrambled design thinking (Boulnois & Stephane, 2018)
2.5.6. An Example of Integrated SCRUM and Design Thinking

Häger et al. presented a process model called DT@Scrum which was published in a chapter of Plattner et al.’s book Design Thinking Research: Building Innovators. Focusing on software development contexts, they were able to demonstrate the complementary characteristics of scrum and design thinking in the common goal of generating innovative ideas and successfully implementing them. To help structure the work of design teams beyond the Meinel and Leifer’s major design thinking stages, they propose three preset modes of operation to be used within the framework of scrum:

- Design Thinking Mode,
- Initial Development Mode,
- Fully Integrated Mode (Plattner, Leifer, & Meinel, 2015)

The Design Thinking Mode is a combination of the problem definition, needfinding, and ideation stages. In this mode, teams can explore both the problem and potential solutions to it iteratively and simultaneously. This mode can be thought of as the “problem space.” A schematic representation of the scrum process and the embedded Design Thinking Mode is shown in Figure 23 (Plattner, Leifer, & Meinel, 2015).
Moving into the Initial Development Mode involves solution selection, which is more of an ideation activity, and transitioning into initial prototyping. The advantage that this mode brings to the design team, is that it also integrates high-level evaluation aspects that match the maturity level of the solution prototype developed at this point. This makes it far easier for design teams to detect fundamental viability issues early on in their process and correct them seamlessly. This mode can be described as the “solution space” (Plattner, Leifer, & Meinel, 2015).

Finally, in the Fully Integrated Mode, a final solution is expected as an output based on the iterations of the Initial Development Mode. Maturity is gained progressively until a point where a solution not only meets technical feasibility requirements as well as any other
relevant requirements, but also emerges as a realistic answer to the problem (Plattner, Leifer, & Meinel, 2015). Of course, the cycle is never-ending, and the increment achieved in the Fully Integrated Mode will soon be re-approached from a different perspective or in a different context thereby potentially uncovering a new problem to be solved.

As expressed previously, agile task and project management is rapidly becoming the norm across multiple industries. Implementing scrum, for instance, has been effective in increasing on-the-job performance at EEA. The contributions to the establishment of a more robust, diversified, and effective people qualification framework at EEA described herein have been managed using scrum via the JIRA software. In addition, we have injected as much of the design thinking philosophy as possible across multiple organizational levels.

### 3.2. EEA People Qualification Road Map

Using the pyramid model presented in Section 1.2.3 and Appendix A, an initial people qualification road map was developed with the EEA management team. The goal of this road map was to provide direction to the EEA training team and create an alignment with management regarding priorities. At the beginning, the road map was created in a work breakdown structure (WBS) with four main branches as seen in Figure 24. These four branches were:

- Basic Training – general training offerings common to all shop floor and support group employees,

- Essential Training – in depth role-specific technical training offerings,
• On-the-Job Training (OJT) – hands-on and in situ job specific technical training,

• Recurrent Training – used as refresher training offerings targeting specific areas of improvement.

Next, each branch was broken out into smaller pieces that consisted of existing offerings and new offerings to be created. An example of the second level of granularity at an early stage of the basic training improvements is shown in Figure 25.

![Figure 25 Basic Training - Second Level of Granularity](image-url)
Finally, the third and last level of granularity reached in this iteration was the action item level. Through semi-structured weekly and daily meetings between the training team and managers, we detailed training action items, identified target trainee populations, determined how much outside stakeholder input was needed, where this input should come from, and whether or not there were any apparent impediments to the success of each action item. An example of the third level of granularity is shown in Figure 26.

![Figure 26 Basic Training - Third Level of Granularity Example](image)

After we defined some deadlines and duration for each action item, we deployed them into a Gantt chart format with priorities and precedence data – a critical path emerged. The WBS and Gantt were developed using a tool called MindView from the software development company MatchWare. This software was preferred to Microsoft Project
because it has a built-in WBS editor and can generate and export reports in many different formats. It also allowed us to easily track completion at any desired granularity level and provided us with the ability to allocate specific resources such as assigning an action item to a team member.

In theory, this approach was sound. However, in practice it severely neglected emerging conditions and problems, and it did not support the concept of impediment removal in a dynamic manner. Eventually this led to some undesirable micromanagement situations and a sense that the management team did not fully grasp the reality of some of the training team’s constraints and therefore had no reason to adjust their expectations or offer more targeted assistance.

The training team and management team quickly identified some performance-to-plan gaps. The stark realization was indeed that this traditional project management approach inherently forced certain limiting assumptions to be imposed on both the training team and management team:

- Assumption 1: All requirements are known upfront

It turns out that the complete opposite is true in practice. As expressed in CollabNet, Inc.’s Scrum Training Series, “today is the dumbest day of the rest of our project” ([CollabNet], 2016).

- Assumption 2: Most important decisions need to be made upfront
In reality, decisions should be made as responses to change which can happen at any time during the project. Due to Assumption 2, in traditional project management there is often a reluctance to make necessary decisions in-process especially if they clash with decisions made upfront ([CollabNet], 2016).

As a result of the aforementioned realizations, the researcher suggested to use a more agile approach to the training improvement action items. Scrum being the framework that was already implemented and utilized by EEA’s quality engineering team, it emerged as a natural choice. A dashboard (see Appendix C) was set up to provide task and project visibility and transparency for both the training team and management team. All action items previously defined were re-evaluated in terms of definitions-of-done, deadlines, duration, and priority – the training team seamlessly embraced the scrum approach with all its complex work performance agility benefits.

Today, micromanagement has decreased significantly in this context since the EEA training team continues to self-organize in planning, managing, and executing complex work. Gains in scrum proficiency among the training team and scrum master are evident with every sprint. This contributes to enhancing the trainee experience as the needs of the shop floor and support groups are better understood and catered to.

Limitations to achieving a greater scrum proficiency are mainly related to the management team. In the context of EEA’s people qualification project, they act as the collective product owner considering that no single supervisor or manager has full authority over the training team. As a result, vision is often inferred by the training team rather than
directly communicated from a product owner. Additionally, the lack of diligence from the management team in attending scrum planning and review meetings gives the training team an impression of lack of support. Addressing these key deficiencies in the application of the scrum framework is a necessary steppingstone to unlocking the next level of benefits that this methodology can potentially offer.

3.3. Project 1 – Analysis of the Content, Presentation, and Interaction of Basic Training at EEA

The current and following sections present our design contributions to the establishment of a holistic people qualification program at Embraer Executive Aircraft, Inc. Each project targets either a specific portion of the training package or an organizational aspect. Each project is summarized in a table providing highlights based on answering the questions “what?, when?, why?, how?, and who?.” Furthermore, each project is presented through the lens of Meinel and Leifer’s design thinking cycle (Leifer, Meinel, & Plattner, 2011). The sequence of design thinking stages explored for each project is shown in a similar fashion to that of Boulnois and Stephane (Boulnois & Stephane, 2018). Project 1 concerns the improvements to the basic training offerings at EEA (see Table 1 and Figure 27).

| PROJECT 1 |
|------------------|------------------|
| **What?** | Analyze the content, presentation, and interaction in Basic Training. |
| **When?** | Fall 2017 - present |
| **Why?** | * Reframe the corporate message to resonate more.  
* Refocus attention on aviation industry fundamental concepts. |
| **How?** | * Traditional presentation style with videos and interactive mind mapping exercises.  
* Lessons learned from internal and external case studies. |
| **Who?** | * Target instructors: Quality Engineer, Technical Trainer, and Production Trainer  
* Main target learners: shop floor new hires  
* Other target learners: all current shop floor and support group employees |
In Project 1, the main objective was to gain a better understanding of deficiencies in the content presentation, and interaction of the basic training provided at EEA.

Content, presentation, and interaction are socio-technical perspectives that cover the main dimensions to consider in design for visual intelligence. Capabilities in these three dimensions can be evaluated in many different modalities and used to identify improvements to the design (Stephane, 2013).

We began by looking at the list of topics that were covered initially under basic training. These items are mapped in Figure 28.
3.3.1. Defining the Problems

Quality Assurance Supervisors were invited to review and audit some of the basic training courses. Several issues were identified in terms of content, presentation, and interaction aspects of the existing basic training offerings. These are summarized in Appendix D.

3.3.2. Needfinding and Benchmarking

In addition to the opportunities presented in Appendix D, we found, through a series of semi-structured interviews with shop floor and support group individuals, that there was a need for additional basic training topics to be covered. These are listed below:

- Basic Hardware Knowledge
- Basic Aircraft Handling and Servicing Practices
- Hangar Practices
- Human Factors Awareness
Benchmarking was also conducted to gather information about what EEA could do better in terms of basic training. In November 2017, I took a trip to Nashville, Tennessee to visit another Embraer subsidiary called Embraer Aircraft Maintenance Services (EAMS), which is an Embraer maintenance and repair station that serves the corporation’s commercial fleet.

Considering that EAMS is an approved repair station under 14 CFR Part 145 and that EEA is a production approval holder facility under 14 CFR Part 21, there are some intrinsic differences from a regulatory aspect that directly affect training requirements. Under Part 145, a repair station “must have and use an employee training program approved by the FAA that consists of initial and recurrent training” (Title 14 CFR §145.163, 2019). By contrast FAA Order 8120.23A, which governs the activities of PAH facilities, only vaguely addresses requirements for training on special processes (“e.g. heat treating, cadmium plating, additive manufacturing, welding”) and statistical process control techniques (Federal Aviation Administration, 2017). Neither of these topics address operator and inspector training as it relates to most of their tasks.

While Part 145 facilities are required to maintain a training program previously approved by the FAA which follows the recommendations provided in DOT/FAA/AR-04/36 Title 14 Code of Federal Regulations Part 145 Approved Training Program – Research and Recommendations, there is virtually no regulatory best practice for addressing shop floor training at a Part 21 facility.

As a result of these observations regarding regulatory contexts, our benchmarking effort was two-fold:
• Analyzing Part 145 research and recommendations in order to identify relevant best practices that could be applied to our training efforts at EEA.

• Gathering best practices first hand from a structured training organization within Embraer.

The underlying purpose of the trip to Nashville was to understand key differences and similarities between the organizations and how these elements have impacted the planning aspect, the resource allocation and management, the records keeping and performance management, and the perceived quality of the training program. While the sector of activity and the regulating bodies for the companies are quite different, challenges in the realm of competence development and people qualification are very similar.

At EAMS the compliance and certification focus revolves around the concept of airworthiness at all stages while at EEA the focus revolves around the “build-to-blueprint” and meeting type design requirements. The key point here is that the ultimate goal for both companies is to deliver a compliant product efficiently; one that meets all the specified requirements the most critical of which is continued airworthiness.

At the time of the visit, EAMS had a small training department set up which included a training manager and four technical trainers. EAMS had four training rooms including a

6 Getting inspired from Part 145 training program requirements is useful to EEA not only for basic training but also for essential training and OJT.
dedicated Computer-Based Training (CBT) lab. This provided the repair station with flexibility and efficiency with training material delivery and allows the technical trainers to have time for proper performance evaluation as well as course planning and development. It was evident during the visit, from a quality engineering standpoint, that this team has had and continues to have a large impact on the company’s ability to mitigate risk, contribute to individual development, and continuously deliver a training experience that raises the knowledge and competence level of the shop floor.

EEA on the other hand was in the early stages of developing its framework for a training program. Planning challenges were significant considering the fact that only one small room (capacity of 12 people) and one technical trainer were dedicated to the production area at that time. Expanding the training team would be a step in right direction to provide additional support to the shop floor in Melbourne.

Investing in training can be tricky for organizations that work in highly regulated environments. The perception that the organization itself establishes enough boundaries and guidelines to limit the need for skills, knowledge, and competence education is a fallacy. The key is that investment in training is first and foremost an investment in human capital and that with the right methodology and iterative approach it can be an excellent tool to improve quality, efficiency, and productivity. At EAMS, the focus on continuous improvement as a bed rock for moving training forward is surely the way to go and the organization seems to understand the human investment aspect fully. At EEA the situation is quite different. While the Melbourne facility has matured over the past nine years in many
respects, it appears that training was not identified early on as a fundamental need that evolves proportionally with the company’s production volume and commercial objectives.

3.3.3. Ideating

Fundamental problems in most industrial environments tend to be rooted in the lack of a strong company culture and lack of understanding of the “bigger picture” from all employees. Since it is the role of management to help their employees understand the bigger picture and care for it, the main ideation efforts for this project were deployed at the management level. Basing the participatory design methodology for this creative design thinking effort on Dr. Guy André Boy’s Group Elicitation Method (GEM), a leadership workshop was carried out at EEA Melbourne in February 2018 involving middle and senior level managers (Boy, 1997). I acted as a facilitator for this process and the session was centered around the following two issue statements:

- **How can we improve quality engagement within our organization?**

- **How can we strengthen our application of compliance concepts?**

Individuals familiar with GEM reading this thesis may notice a deviation from the general recommendations that surround GEM in practice. In fact, sticking to one issue statement is expected when using this method however as we will demonstrate further, the narrow link between quality engagement and compliance allows us to present the participants with two formulations of the same fundamental question. Moving forward with the methodology, other adaptations to GEM were made to fit the use case more naturally.
The workshop with the management team involved 17 participants: mainly managers and supervisors as well as some members of the support team including a Human Resources Business Partner and the local Embraer Air Safety Technical Representative. After a 20-minute presentation about the importance of quality engagement and compliance highlighting recent internal cases of non-compliance, all the participants were provided with a sheet to write down viewpoints related to the issue statements formulated above. Every two minutes the sheets were shifted in a clockwise manner from one participant to the next and the participants were asked to elaborate on or generate new viewpoints for another two minutes. The process was repeated three more times after that. This effectively constituted the viewpoint generation phase which concluded the initial in-person portion of the workshop.

In a typical GEM session, the next step would have been the “reformulation of viewpoints into more elaborate concepts” (Boy, 1997). In this case, a concept categorization approach performed by the facilitator was preferred considering the inability to have many key individuals committed to a full day of knowledge elicitation. The concept categorization phase was completed through a color coding and mind mapping exercise (see Appendix E for all documents generated around this workshop). The concepts were transcribed in FreeMind and categorized. The result was in the form of nine categories each containing 10 concepts (except for one category containing 3 concepts). The categories that emerged were:
• Communication

• Culture

• Process Engineering

• Training

• Hiring and Employee Retention

• Root-Cause Analysis, Corrective Action, and Continuous Improvement

• Supply Chain Management and Production Planning

• Expectations vs. Resources

• Leadership

A fillable spreadsheet was sent via email to all participants with a ranking column for each category.

In the concept ranking phase, the participants received the spreadsheet via email and were asked to provide a 1-10 ranking for each category of concepts based on importance and priority. As most of the viewpoints generated constituted formulations of potential action items, the importance and priority aspects seemed fitting. The next step was to evaluate the rankings. Instead of ranking concepts relatively using a +1 / 0 / -1 scale as proposed by Boy (Boy, 1997), we decided to reverse the 1-10 scale and use the numbers as scores. For
example, in the Training section the top-ranking concept provided by a given participant receives 10 points. Total points were then calculated and the top three concepts for each category were identified.

Table 2 Communication concepts ranked from the modified GEM session

<table>
<thead>
<tr>
<th>Concept</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improve communication about quality between all departments, teams, shifts, and areas.</td>
<td>1</td>
</tr>
<tr>
<td>Explain how individuals can contribute to company goals CoPQ, AOG, etc.</td>
<td>2</td>
</tr>
<tr>
<td>Add some visual aids on the shop floor to remind staff that their family could be on the plane.</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 2 shows the top three ranked concepts in the Communication category from the modified GEM session.

The top concept listed in Table 2 was addressed head on by Embraer’s global quality organization through the establishment of a weekly quality dialog. This initiative was launched by Embraer’s Global Vice President for Quality with the intent to educate and bring awareness about quality concepts that may not be well understood by many shop floor employees. The researcher made suggestions to the team responsible for the development of the quality weekly “talking points” to pay close attention to the relevance of the material presented and discussed vis à vis the targeted groups.

The second concept listed in Table 2 was also addressed by the quality group. By organizing site wide events such as Quality Week and the observance of the International World Quality Day, EEA Quality Management was able to bring the voice of the customer to the facility and share the customer perspective with the men and women responsible for building and inspecting the aircraft. The researcher was heavily involved with these efforts, presenting on numerous occasions to the shop floor teams and support groups about such
subjects as the “risks of rework” and “aircraft documentation pitfalls and how to avoid them.” Ultimately, these initiatives provoked an overwhelmingly positive response and sparked excellent discussions about everyone’s role in improving the quality of our product.

Finally, the third concept listed in Table 2 was addressed through another positive initiative. The EEA Quality Engineering team worked together using the scrum framework to come up with a common theme of excellence and a template for visual shop floor reminders. The idea was to fill the template with as many reminders that could help prevent simple slips, lapses, and mistakes, and display them on the shop floor monitors as screen savers. The team continues to develop these visual shop floor reminders with input from key individuals in the production and quality teams and it is becoming one of our most useful preventive action tools. Several examples of these visual shop floor reminders are provided in Appendix F.

<table>
<thead>
<tr>
<th>Concept</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do not cut corners. Do the right thing even when it takes more time.</td>
<td>1</td>
</tr>
<tr>
<td>Give employees the &quot;power&quot; to stop the line without retribution.</td>
<td>2</td>
</tr>
<tr>
<td>Instill importance of each job function to overall safety + quality of product.</td>
<td>3</td>
</tr>
</tbody>
</table>

The concepts listed in Table 3 are related to the idea of a “just culture.” We have seen tremendous improvement with regards to this especially in the preventive reporting of potentially dangerous or hazardous situations related to air safety. Unfortunately, many opportunities remain when it comes to occupational safety as incident and accident rates continue to go up for the EEA facility.

<table>
<thead>
<tr>
<th>Concept</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improve work instructions that are unclear.</td>
<td>1</td>
</tr>
<tr>
<td>Need more ME's to help improve work instructions.</td>
<td>2</td>
</tr>
<tr>
<td>Improve drawing details.</td>
<td>3</td>
</tr>
</tbody>
</table>
The concepts listed in Table 4 are of paramount importance. The large volume of work instruction issues coupled with the aggressive 2018 shop floor hiring strategy brought about a significant amount of confusion and highlighted the necessity to eliminate as much “tribal knowledge” as possible from EEA’s processes. The process for requesting, prioritizing, and executing work instruction clarifications and corrections was standardized, thereby saving time, helping increase productivity, and raising the level of quality of the product. With regards to drawing detail improvements, the Product Development Engineering teams both in Melbourne and in Brazil have been dedicating more engineers to small drawing corrections and changes through an expedited pre-budgeted review board.

Table 5 presents the concepts ranked for the Training category. The need for increased training resources which was identified here is discussed in Section 3.4 of this thesis. With regards to the second concept listed in Table 5, the training team has been focusing more and more on providing rationale to trainees every time a standard or procedure is used for training purposes. This brings on a new challenge for the production and technical trainers as they are sometimes forced to do a small amount of additional research to find technical answers. This healthy behavior is conducive to a more inclusive and focused training environment.

The third concept listed in Table 5 was one that the management team expressed with some level of apparent frustration. They felt that they did not have a set of standard performance measuring tools in terms of competence and knowledge. Further discussions about this

<table>
<thead>
<tr>
<th>Concept</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase training resources.</td>
<td>1</td>
</tr>
<tr>
<td>Not only focus on what our quality requirements are but why we do them.</td>
<td>2</td>
</tr>
<tr>
<td>Assess competence and knowledge before assigning responsibilities.</td>
<td>3</td>
</tr>
</tbody>
</table>
subject revealed that most of the competence and knowledge the managers are concerned with evaluating is focused on on-the-job tasks. Eventually, it became clear that there was a need to overhaul the existing on-the-job training process with improved specific aircraft build activity tracking and more frequent task-specific proficiency evaluations.

**Table 6 Hiring & Employee Retention concepts ranked from the modified GEM session**

<table>
<thead>
<tr>
<th>Concept</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retain your best employees - they set the example.</td>
<td>1</td>
</tr>
<tr>
<td>Change hiring perspective to question candidates on technical and quality related topics.</td>
<td>2</td>
</tr>
<tr>
<td>Hire staff focused on quality.</td>
<td>3</td>
</tr>
</tbody>
</table>

Employee retention has been a difficult battle for EEA as illustrated by the concepts listed in Table 6. As mentioned in the introduction of this thesis, turnover has increased greatly at the shop floor, support group, and management levels. Since poor employee retention numbers are more of a consequence than a cause, EEA should continue focusing on all the other categories presented in this ideation effort and employee retention should improve over time. Organizational growth can bring a period of uncertainty in terms of employment as priorities shift and competition in the job market increases. In terms of retaining its most talented individuals, EEA has struggled but has recently adopted a more aggressive approach by constantly engaging in promotion potential evaluation. This has led to some great success stories where the promoted employee feels empowered, develops a renewed faith in the company’s commitments, and truly takes ownership of their new role within the organization.
From a hiring perspective, the talent acquisition department has done a tremendous job since this brainwriting exercise was conducted by improving résumé screening and reducing the number of individuals hired that have limited aviation experience.

It is well known that the nature of any process is continuous improvement. Empowering individuals to tackle technical problems every day should be the focus of any organization. As expressed in the concepts listed in Table 7, assigning blame to individuals is often counterproductive and can create animosity that festers and hurts the organization. More importantly, it almost never addresses the real problems that are process-driven. These concepts go well together and have been well addressed through the implementation of weekly quality problem solving sessions. Each production team lead is responsible for developing a Quality Clinic Program Chart (QCPC) item that addresses a technical problem encountered. The leads must define the problem, gather data to characterize it, and work with their teams as well as the support groups to develop solutions. The management team is involved with the process as a guiding resource that continuously challenges the team to find new problems to solve. This approach has created a healthy competitive environment on the shop floor among leads who now feel empowered to take ownership and lead the way for improvements.

### Table 7 Root Cause, Corrective Action & Continuous Improvement concepts ranked from the modified GEM session

<table>
<thead>
<tr>
<th>Concept</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus on standardizing processes rather than assigning blame to individuals.</td>
<td>1</td>
</tr>
<tr>
<td>Recognize quality and process improvements regularly.</td>
<td>2</td>
</tr>
<tr>
<td>Empower employees to make positive changes without so much red tape.</td>
<td>3</td>
</tr>
</tbody>
</table>

RCCA & CONTINUOUS IMPROVEMENT
The difficulties incurred from planning problems at EEA continue to strain the organization’s ability to deliver efficiently. One of the biggest problems that EEA has been facing over the past few years has been the high amount of part shortages. In an industry where market consolidation is happening both at the equipment manufacturer and final product manufacturer levels, the game of leverage becomes tricky. In fact, Embraer’s difficulties holding its suppliers accountable for delays and quality issues are common problems with many different OEM’s both in the aviation and automobile industries. With that said, it has become critical that EEA adopt a risk-based planning and scheduling approach such as the one advocated by Dr. C. Dennis Pegden, CEO of Systems Modeling Corporation, in his book entitled *Delivering on Your Promise* to mitigate the impacts of part shortages and supplier quality issues (Pegden, 2017).

**Table 8 Supply Chain Management & Production Planning concepts ranked from the modified GEM session**

<table>
<thead>
<tr>
<th>Concept</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Align programs and contracts with our limits of production.</td>
<td>1</td>
</tr>
<tr>
<td>Drive/improve supplier quality.</td>
<td>2</td>
</tr>
<tr>
<td>Reduce the pressure by better planning, parts, and retaining skills.</td>
<td>3</td>
</tr>
</tbody>
</table>

**Table 9 Expectations vs. Resources concepts ranked from the modified GEM session**

<table>
<thead>
<tr>
<th>Concept</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Give employees the resources they need to succeed.</td>
<td>1</td>
</tr>
<tr>
<td>Raise the bar on expectations for all functions:</td>
<td></td>
</tr>
<tr>
<td>- Production adherence to plan &amp; process.</td>
<td>2</td>
</tr>
<tr>
<td>- Logistics providing more transparency and reliable dates.</td>
<td></td>
</tr>
<tr>
<td>- Quality of Work Orders &amp; Maintenance Orders.</td>
<td></td>
</tr>
<tr>
<td>- Accurate allocation of costs for NC's.</td>
<td></td>
</tr>
<tr>
<td>Ensure roles, responsibilities, and expectations are well defined</td>
<td>3</td>
</tr>
</tbody>
</table>
Table 9 provides the concepts ranked for the Expectations vs. Resources category. These are clearly linked to many other concepts generated in other categories. One key aspect that is highlighted here is the need for a better definition of roles, responsibilities and expectations across the board. This could contribute to reducing the high turnover rate and increase employee retention. Considering the high turnover rate in the middle management positions, this continues to be a challenge as each new supervisor needs some time to adjust to new responsibilities and better understand the strengths and weaknesses of his/her team. With regards to the accurate allocation of costs for non-conformances, EEA’s quality department has improved this process greatly by working closely with the financial department. In addition, high cost-of-poor-quality (CoPQ) items are addressed with more attention now than they were prior to this brainwriting effort.

Table 10 Leadership concepts ranked from the modified GEM session

<table>
<thead>
<tr>
<th>LEADERSHIP</th>
<th>Concept</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leadership as a mentor to empower employees.</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Leadership support in removing roadblocks instead of following day to day.</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Leadership development more events.</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

Leadership concepts highlighted in Table 10 are similar to some of the concepts listed in the Hiring and Employee Retention category as well as the Root Cause, Corrective Action and Continuous Improvement category. The significance of employee growth is recognized here and presented as a fundamental tool to improve organizational stability and health. Additionally, the management team noted somewhat introspectively that it needs to do a better job of anticipating and removing impediments to the teams’ success rather than simply following the day to day activities.
Overall, the ideation effort was positive and beneficial to EEA as it gave the management team a chance to look at their organization frankly. Many of the areas of improvement identified as viewpoints and consolidated into concepts have been addressed through various successful initiatives that helped improve quality engagement within the organization and strengthen the application of compliance principles. In the end, however, it must be noted that only 5 out of 17 brainwriting participants provided concept rankings. As such, the participatory problem-solving values of shared responsibility and full participation were not fully respected by the management team. Had there been a better follow through in this ideation stage, discussions about some of the tougher problems may have led to more solutions.

3.3.4. Prototyping

Many improvements were developed on the basic training offerings. The ones that surely had the most impacts in terms of content, presentation, and interaction were the ones related to Quality Engagement.

The goals were to reframe the basic concepts of quality through interactive mind mapping and provide compliance education based on industry standards. Figure 29 shows the researcher conducting one of these interactive mind mapping exercises with a group of shop floor new hires. Two main questions were asked to lead the discussions:

- What is quality?
- How can we build quality into a product or service?
By exploring the multi-faceted nature of the concept of quality and by projecting themselves in ways to enact quality, the learners would get a perfect introduction to dive into the corporate vision and strategy and achieve higher standards of quality.

Compliance education was accomplished through the use of Section 7.8 Compliance Education Guidance from the International Aerospace Quality Group (IAQG) Supply Chain Management Handbook. This resource is free to aerospace professionals and offers excellent training content that can be tailored to fit the organization’s message. Finally, internal and external cases were selected to illustrate the importance of meeting and exceeding requirements and the importance of following procedures diligently (International Aerospace Quality Group, 2016).

In addition to the improvements to the Quality Engagement training offering, a Human Factors Awareness course was developed by EEA’s Air Safety Technical Representative. This offering was reviewed by the training team to ensure that it fit the qualitative
expectations in terms of the content, presentation, and interaction dimensions and was integrated into the basic training loop.

To address the identified need for better basic hardware knowledge and basic aircraft handling and servicing practices, the training team conducted semi-structured interviews with senior level technicians. The most common response gathered was to provide a quick reference handbook to all technicians and inspectors that contains useful information including thread patterns, conversion tables, wiring conventions, and aircraft marshalling procedures among many topics. Aircraft maintenance technician handbooks were researched and found to be a perfect match for this application. A specific edition was selected, procured, and distributed to all shop floor employees. This represented a $4,000 investment.

3.3.5. Evaluating

Training effectiveness evaluation is key to making continuous improvements to a people qualification program. Donald Kirkpatrick provides an approach that can be tailored to fit virtually any training program. Kirkpatrick’s model focuses on these four levels to evaluate the impact of training on an organization and its individuals’ performances.

- Level 1: Reaction

This level can be thought of as a measure of trainee satisfaction. This is generally done through course evaluation surveys.

- Level 2: Learning
Level 2 is a measure of knowledge absorption by the learners and is generally collected through some form of pre- and post- assessments.

- Level 3: Behavior

This level happens after a few months after the training session and is used to evaluate the impacts the training has had on the behavior of the trainees.

- Level 4: Results

Level 4 is an evaluation of the effect the training has had on an organization’s key performance indicators (Kirkpatrick & Kirkpatrick, 2007).

For the evaluation conducted on the contributions of Project 1 in this thesis, we decided to focus on the immediate reaction of the trainees. Since the target learner population is composed mainly of new hires, the idea is to provide them with strong messages that resonate with them as they transition into their new job functions. A course evaluation survey was selected from Kirkpatrick based on the nature of the statements and their coverage of the concepts of content, presentation, and interaction (Kirkpatrick & Kirkpatrick, 2007). The survey uses a likert scale format that goes from “1” (strongly disagree) to “8” (strongly agree). Furthermore, demographic questions were added to better understand the population of individuals responding.

Initially, the surveys were distributed on paper after each class, but this method quickly became unmanageable due to the fact that it was too time consuming to enter all the data and
analyze it manually. In addition, the excessive use of paper was wasteful. As an alternative, the survey statements were turned into a Google Form that was shared via email with each learner after every training session. Per university policy, this study was reviewed by the Institutional Review Board and granted a Certificate of Clearance for Human Participants Research. An approved electronic consent form was added to the Google Form as required. The EEA course evaluation survey is provided in Appendix G.

The results for the Quality Engagement training offering are provided here. The overall results for basic training are also provided with respect to the content, presentation, and interaction socio-technical dimensions based on a classification of the survey statements.

In the Kirkpatrick Level 1 survey responses collected for Quality Engagement, the population of individuals that responded to the survey was composed of 34 new hires for production technician positions. Note that an improvement should be made to this demographic measure to differentiate between different areas for production technicians and quality inspectors (final assembly, interiors assembly, paint, and flight preparation). The distribution of participants in the survey is provided in Figure 30 based on their amount of experience in aviation. As we can see, the efforts from the hiring perspective to ensure a greater level of experience have been fruitful since 79% of new hires surveyed claimed to have at least two years of experience in aviation.
The results for the EEA Quality Engagement course evaluation are presented in Figure 31. Note that question statement number 10 (The handouts will be of help to me.) was omitted considering that no handouts were distributed for the Quality Engagement course. Based on the results of this survey, we can see that the reaction to this training was mostly positive to very positive for all the survey statements. The average scores for each survey statement are displayed in with the highest average and lowest average scores highlighted in green and red respectively Table 11.
Figure 31 EEA Quality Engagement Course Evaluation Survey

Table 11 EEA Quality Engagement Course Evaluation Survey - Averages

<table>
<thead>
<tr>
<th>EEA Quality Engagement Course Evaluation Survey - Averages</th>
<th>Average Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>The material covered in the training course was relevant to my job.</td>
<td>7.5</td>
</tr>
<tr>
<td>The material was presented in an interesting way.</td>
<td>7.2</td>
</tr>
<tr>
<td>The instructor was an effective communicator.</td>
<td>7.4</td>
</tr>
<tr>
<td>The instructor was well prepared.</td>
<td>7.6</td>
</tr>
<tr>
<td>The audiovisual aids were effective.</td>
<td>7.2</td>
</tr>
<tr>
<td>I will be able to apply much of the material to my job.</td>
<td>7.6</td>
</tr>
<tr>
<td>The facilities were suitable.</td>
<td>6.7</td>
</tr>
<tr>
<td>The schedule was suitable.</td>
<td>7.2</td>
</tr>
<tr>
<td>There was a good balance between presentation and group involvement.</td>
<td>7.5</td>
</tr>
<tr>
<td>I feel that this training course will help me do my job better.</td>
<td>7.5</td>
</tr>
</tbody>
</table>
For the Quality Engagement course, it appears that the course preparation was effective. On the other hand, the facilities were essentially considered less than adequate by approximately 12% of the participants. In addition, five participants registered the comments listed below related to facility improvements:

- “More classroom environment w/ more space.”

- “A larger room where everyone has a clear view of the presentation.”

- “Better teaching facility.”

- “Chairs.”

- “Cushioned seats.”

Improvements to the dedicated training environment are discussed in Section 3.4.

To evaluate the overall effectiveness in terms of learner reaction to the basic training package, we started by evaluating the participant population based on level of prior aviation experience (see Figure 32) and position/title at Embraer (see Figure 33). A total of 55 survey responses were registered for basic training offerings. We also looked at the number of survey responses registered for each basic training course (see Figure 34).
Figure 32 EEA Basic Training Course Evaluation Survey
Level of Experience

Figure 33 EEA Basic Training Course Evaluation Survey
Position/Title at Embraer
Returning to the three socio-technical dimensions of content, presentation, and interaction we categorized the survey statements as follows:

- **Statements relevant to Content:**
  
  - The material covered in the training course was relevant to my job.
  
  - I will be able to apply much of the material to my job.
  
  - I feel that this training course will help me do my job better.

- **Statements relevant to Presentation:**
  
  - The material was presented in an interesting way.
The audiovisual aids were effective.

The facilities were suitable.

The schedule was suitable.

There was a good balance between presentation and group involvement.

I feel that this training course will help me do my job better.

• Statements relevant to Interaction:

  The instructor was an effective communicator.

  The instructor was well prepared.

  There was a good balance between presentation and group involvement.

  I feel that this training course will help me do my job better.

The results for the content dimension are presented in Figure 35. Average scores are reported on Table 12 and the highest average and lowest average scores are highlighted in green and red respectively.
The results for the presentation dimension are presented in Figure 36. Average scores are reported on Table 13 and the highest average and lowest average scores are highlighted in green and red respectively.
The results for the interaction dimension are presented in Figure 37. Average scores are reported on Table 14 and the highest average and lowest average scores are highlighted in green and red respectively.
In summary, this analysis of the basic training package including the implementation of a Kirkpatrick Level 1 reaction feedback loop has uncovered some useful insight for improvements.
Overall, in the content dimension, despite a strong result in terms of relevance of the material to the learners’ jobs, there is room for improvement in improving the perception that the training will help individuals perform better on the job. This could be supported by more in-depth analysis of internal cases for the entire span of topics listed in Figure 28 as well as new offerings such as Human Factors Awareness and any new basic training offerings. This would increase content relevance and further support the lessons learned approach. Ultimately, perceptions of self-efficacy are useful in understanding the confidence in future performance. A more objective on the job performance evaluation could be conducted following Kirkpatrick’s 3\textsuperscript{rd} level.

In terms of the presentation dimension, when considering the participant responses for all of the basic training offerings surveyed, we see that the facilities are clearly an area of improvement. Efforts in this direction are discussed in Section 3.4. In addition, the comments listed below were made regarding the presentation style:

- “More video instead of 90% slide presentation. Be more animated when presenting. Make the content more interesting.”
- “More video.”
- “More video presentations.”
- “Less monologue type presentation.”
Evidently, the many of the learners appreciated the embedded video style of presentation and would appreciate seeing more of it. The training team took note of this feedback and will seeking ways to integrate more relevant video content into the style ensuring that it does support the learning objectives.

Finally, in terms of the interaction dimension, the focus of the feedback was more related to the human interactions between the instructors and learners. We can consider that this was mainly driven by the verbiage in the questions as well as the limited amount of technology involved in most of the basic training courses. In general, the group involvement element could be improved across all basic training courses by integrating more brainstorming, mind mapping, and scenario-based interactive learning for all the courses in a similar fashion to what was done in the Quality Engagement course. Another aspect of the interaction that could be further considered is the instructor perspective. It is important to note, however, that this can introduce a bias since the instructors are generally responsible for the content creation and have freedom in terms of delivery method. As an instructor for the Quality Engagement course, I felt that the interactions with the learner groups were more effective when dealing with larger groups (10-15 participants) versus smaller groups (1-5 participants). Comments registered regarding the interaction aspects are listed below:

- “Would be good to have more group involvement.”
- “Virtual / real time walk thru.”
- “More interactive and hands on.”
As the basic training courses were offered every two weeks when the hiring volume was at its peak between January and November 2018, the training team had the opportunity in between cycles to utilize the feedback and make some improvements. For example, as part of the Introduction to Phenom and Legacy Aircraft course, we introduced a visit to the EEA Customer Center with all new hires to show them the aircraft interior mockup used to present the features to prospective customers. The reactions observed were extremely positive as the new hires appreciated the opportunity to visualize and touch a rendition of the finished product they were hired to build.

Table 15 Quality Engagement Course – Improvement Opportunities vs. Objective Countermeasures

<table>
<thead>
<tr>
<th>Quality Engagement - Improvement Opportunities and Objective Countermeasures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Content</strong></td>
</tr>
<tr>
<td>Improperly translated from Portuguese.</td>
</tr>
<tr>
<td>Several misspelled words.</td>
</tr>
<tr>
<td>Poor attempts at humour regarding a serious subject.</td>
</tr>
<tr>
<td>No real structure, mostly a series of vague statements and definitions.</td>
</tr>
<tr>
<td><strong>Presentation</strong></td>
</tr>
<tr>
<td>Incoherent presentation template. No videos or other type of media - dry presentation.</td>
</tr>
<tr>
<td><strong>Interaction</strong></td>
</tr>
<tr>
<td>Instructor could not wait to get it over with. Very little group involvement, discussions, or questions. Interaction was virtually non-existent.</td>
</tr>
</tbody>
</table>

With regards to the Quality Engagement course, several countermeasures were taken to address the improvement opportunities identified in Section 3.3.1. These are summarized in Table 15.

3.3.6. Project 1 – Looking Forward

Looking forward with Project 1, the training team at EEA has begun taking a closer look at occupational safety training. Recent increases in incident rates within the facility have
prompted a review from the management team and the need for more OSHA training was highlighted.

Currently, the OSHA General course is dispensed via computer-based training (CBT) with off-the-shelf content purchased from an approved vendor. As the learners were reporting a general dissatisfaction with the training material and method of delivery, we decided to consider alternatives for occupational safety training.

An in-depth review of the content contained in the CBT offering was conducted with the local Embraer Health and Safety (EHS) Coordinator. The consensus was that many of the topics addressed in the CBT were not relevant to the employees working on the EEA shop floor or within the support groups. In addition, the CBT offering in question was not engaging and the knowledge retention level was considered low as well based on the causal analysis of several incidents provided by the EHS Coordinator. In most cases, non-compliance to proper personal protective equipment (PPE) usage rules, lack of functional knowledge of various ground support equipment (GSE), and blatant at-risk behavior led to injuries on the job.

As a result, the EHS Coordinator proposed a plan to overhaul the training and turn it into a series of live instructor offerings. The key here is to increase the engagement level of the learners as well improve their knowledge retention levels by offering more hands-on practice and demonstrations. Supplementing this approach with internal case reviews and a scenario-based approach to lessons learned could greatly help decrease the number of incidents at
EEA. The training team and EHS Coordinator are currently working very closely to develop
the content, presentation, and interaction aspects of the proposed live instructor offerings.

3.4. Project 2 – Expanding the Training Team and Improving the Training Facility

In Project 2, we discuss the expansion of the training team at EEA as well as the design
of improvements to the training environment. Table 16 presents the highlights of the project
and Figure 38 details the general sequence of design thinking stages that were employed in
this effort. For Project 2, the main research question was how to expand the training team
and enhance EEA’s training facility.

Table 16 Highlights of Project 2 – Expanding the training team and improving
the training facility

<table>
<thead>
<tr>
<th>PROJECT 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>What?</strong></td>
</tr>
<tr>
<td>* Expand the training team.</td>
</tr>
<tr>
<td>* Improve the training environment.</td>
</tr>
<tr>
<td><strong>When?</strong></td>
</tr>
<tr>
<td>Spring 2018 - present</td>
</tr>
<tr>
<td><strong>Why?</strong></td>
</tr>
<tr>
<td>* To continue supporting the aggressive hiring strategy effectively.</td>
</tr>
<tr>
<td>* To increase learner comfort and engagement.</td>
</tr>
<tr>
<td><strong>How?</strong></td>
</tr>
<tr>
<td>* Learning from the outcomes of Project 1.</td>
</tr>
<tr>
<td>* Setting up new team and individual roles.</td>
</tr>
<tr>
<td>* Team informal participatory design.</td>
</tr>
<tr>
<td><strong>Who?</strong></td>
</tr>
<tr>
<td>* Training team Scrum Master</td>
</tr>
<tr>
<td>* Technical Trainer</td>
</tr>
<tr>
<td>* Management Team</td>
</tr>
<tr>
<td>* Human Resources</td>
</tr>
</tbody>
</table>
3.4.1. Needfinding

In the ideation and evaluation stages of Project 1, it became clear that there were improvement opportunities with the training environment. The brainwriting effort with the management team also showed that further investments in training would be needed to positively impact quality engagement and strengthen the adherence to compliance principles within the organization. While these perspectives gave us general direction, they did not specifically define the problems that were present with the existing training environment and resources.

3.4.2. Defining the Problems

There is a running joke about investments in training that essentially goes like this:
“CFO asks his CEO, ‘What happens if we invest in developing our people and then they leave the company?’

CEO answers, ‘What happens if we don’t, and they stay?’” (Natural Training, n.d.).

The point of that joke is that investments in training tend to cost far less than the alternative of not providing training. In fact, it is arguable that in most industries, investments in training are recouped fully and then some. When employees are not trained adequately, they are more prone to making mistakes that could cost the company and ultimately can affect its bottom line.

At EEA, the lack of investment in training started from the inception. When the company was started, there was a heavy reliance on outside partnerships with educational organizations such as the Brevard Community College (now Eastern Florida State College) to provide the courses required for technicians, inspectors, and engineers. However, as time went by, the agreement with the local college withered away and was only replaced by sporadic training events organized by the headquarters in Brazil that would either require individuals from the Melbourne site to travel or a team of experts from Brazil to travel to Melbourne to provide the training. Considering that this solution was not continuous and certainly not cost effective, EEA decided to hire a Technical Trainer who was transferred from EAMS (Embraer aircraft maintenance site in Nashville that was previously mentioned) in 2015.
At first, the Technical Trainer’s main responsibilities were to review training records and ensure they were up to date. As a result, this individual was not able to fully engage in training evaluation or development for at least one year. To add to the complexity, the Technical Trainer position was switched back and forth from being under the responsibility of Quality Management and Production Management only to be placed back under Quality Management. In addition, the number of shop floor employees and the volume of aircraft built at the Melbourne plant continues to increase steadily every year rendering the single point of failure Technical Trainer position insufficient to keep up with the training needs of the organization.

It became clear at the end of 2017 that the situation was dire and required attention from management. Working with the Technical Trainer, I began detailing the activities that need to be performed to maintain the level of training and what set of activities would be needed to grow the training offerings at EEA. Quickly, both Quality and Production Management agreed that additional dedicated trainers would be needed to support the growth of the organization.

Ensuring that the training environment is conducive to effective learning is of paramount importance in any training endeavor. Based on the information gleaned from Project 1, the training team reviewed the existing training environment. The room had the following issues and limitations:

- Converted from an aircraft paint shop supply room with no climate control system.
• Room size could only accommodate 12 students at a time due to the large workbenches present in the room.

• Metal stools previously purchased were extremely uncomfortable as mentioned by several individuals on the course evaluation surveys for basic training offerings.

A photo of the current training room is shown in Figure 39.

3.4.3. Ideating (Round 1)

In Project 2, the first round of ideation consisted in justifying the need for additional positions to be added to the training team. This was accomplished through a series of meetings with Quality Management, Production Management, and Human Resources Management. During these meetings the Technical Trainer and myself presented the information we had gathered regarding the activities and their associated execution times.
With this information, the management team agreed that two additional heads should be added to the training effort at EEA.

With regards to the training environment issues, the management team was approached about considering a larger and better equipped room to provide a more comfortable atmosphere for trainees. Initially, one of the requests from the training team was to have the new training room as close to the shop floor as possible to support any need for demonstrations on an actual aircraft or subassembly equipage work station. Unfortunately, this was not feasible due to organizational constraints.

The space for the new training room was validated by the management team. At first glance the new room appears to be a downgrade from the existing room since it is a 7-minute walk further away from the main production shop floor and is approximately 50 square feet smaller than the current room. After several discussions about these additional constraints imposed, it became clear to the training room that due to budgetary limitations, this was simply the only option that was feasible from the management team’s standpoint. As a result, the training team adopted a “silver lining” philosophy and worked hard to develop a plan to fit more people into a smaller room in a more comfortable classroom arrangement. Working with a blank canvas was a stimulating factor for the subsequent prototyping phase. Photos of the new training space allocated are shown in Figure 40.

Figure 40 EEA new training space - empty
3.4.4. Prototyping

In terms of expanding the training team, the management team felt that the training team would know best what type of skills and know-how would be needed in the prospective trainer positions. An agreement between Human Resources Management, Quality Management, and Production Management was found to place the two additional trainers under Production Management and dub the positions Production Trainers. This emphasized the management team’s perception that the additional training resources should be dedicated to more hands-on training.

The training team was asked to draw up a job description including all the requirements needed for a good Production Trainer. Because we were looking to expand on aircraft systems training eventually, we decided to focus our attention internally on individuals that had extensive experience working at EEA a knowledgeable with as many Phenom and Legacy aircraft systems as possible. In addition, we felt that being an FAA certificated airframe and powerplant technician would help provide credibility and build the trust of the trainees that would interact with the new trainers. In addition, we wanted the prospective Production Trainers to have a good understanding of adult education principles either through higher education and certificates or through prior successful experience as trainers. Ultimately, the candidates were also required to have strong social and communication skills in order to develop and deliver training presentations as well as hands-on bench training workshops and live demonstrations. The prototype job description was presented to EEA Human Resources and was accepted with minor modifications.
The Technical Trainer and I were heavily involved in the interviewing process. With the help of one of EEA’s Human Resources Business Partners, we interviewed eight individuals for two positions. We recommended four individuals for a second-round interview with the Production and Quality Managers – two Production Trainers were selected and confirmed in their promotion from shop floor lead technician positions.

In terms of improvements to the training environment, the now four-man strong training team had an uphill battle due to the constraints mentioned in the previous section. We began by focusing on optimizing our use of the new space. In order to do so, we had to inventory and measure all useful equipment in the current training room as well as rid ourselves of any extraneous items.

An effort to design and build training boards to be used for lab exercises like practicing how to route a wire harness properly and swaging hydraulic and fuel tubes in place had been initiated in January 2018. These training boards have two hinged sides that can be opened or closed to create several different variations of training exercises with different difficulty levels. A basic prototype of these boards is shown on Figure 41.
Immediately, it became clear that the largest amount of space wasted in the current room was from the large high-top workbenches seen in Figure 39. Considering that the space in the new room is less than the current room, the training team had to find a more compact solution for seating. As a cost avoidance measure, we also need to reuse as much furniture and equipment from the existing room as possible. Reusing the metal shelves at the bottom of the workbenches seen in Figure 39 as table tops and some recuperated metal tubes previously used to make part storage carts, we determined that we had enough material to build eight tables that could each seat two learners. We added some recuperated casters with brakes to allow us to move the tables easily and reconfigure the seating arrangement in the new room effortlessly. Unused regular cafeteria chairs were preferred to the high stools that had led to lower scores on our course evaluations. Figure 42 shows a prototype of the tables that we are currently assembling at no added cost to EEA.

Figure 42 EEA new training table prototype
The final prototype developed by the training team in Project 2 was a virtual walk-thru first-person game developed using Unity3D. The purpose of this prototype was to provide a 3-D visualization of the intended layout to the management team. Snapshots from two different angles are shown in Figure 43. A 2-D layout was also provided to the facilities team to provide specifications for required electrical work needed in the room (see Figure 44).

Figure 43 EEA new training room virtual walk-thru snapshots

Figure 44 EEA new training room 2-D layout
3.4.5. Ideating (Round 2)

In the last design thinking stage utilized in Project 2, one simple contribution was made. After the two new Production Trainers had been selected it was important to establish a strong synergy between all four members. At the request of the Production Manager, and in the interest of establishing and agreeing on roles early on a training team responsibility matrix was developed. A redacted version of this document can be found in Appendix H.

3.4.6. Project 2 – Looking Forward

The efforts presented in Project 2 were pivotal in the establishment of a people qualification framework at EEA. Going forward, it will be key to complete the prototype of the training lab boards and design actual training exercises to be performed. One suggestion that was given by a senior shop floor employee was to create work cards with wiring and tubing patterns to follow. The trainee would complete the installation and an inspector in training could practice looking for discrepancies using the same inspection standards as those applied to the aircraft build. Transitioning to the new room will surely be an exciting moment as the team has worked hard to cope with constraints and limitations. As the organization grows even more, justification for further expansion of the training team will be needed to convince the management team to commit more personnel to training.
Chapter 4
Future Work

The following contributions did not reach a high level of maturity and therefore were not included in the main portion of this thesis. These projects are still ongoing at EEA.

4.1. Project 3 – Essential Training and Shop Floor Qualifications

Project 3 featured a deep exploration of the various technical shop floor qualifications and how these are managed as well as the development of aircraft systems courses to increase knowledge. Table 17 presents the highlights of the project and Figure 45 shows the natural progression through the design thinking cycle as this project unfolded.

Table 17 Highlights of Project 3 – Essential training and shop floor qualifications

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<th>PROJECT 3</th>
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<td><strong>What?</strong></td>
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<td><strong>When?</strong></td>
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<td><strong>Why?</strong></td>
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<td></td>
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<td></td>
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<td></td>
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<tr>
<td><strong>How?</strong></td>
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<tr>
<td></td>
</tr>
<tr>
<td><strong>Who?</strong></td>
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In the needfinding stage for Project 3, we set out to answer two important questions:

- *What is the current level of technical competence and knowledge of our shop floor?*

- *What is the minimum level of technical competence and knowledge that EEA needs to meet its business goals?*

At EEA, shop floor technical certifications are called “buyoffs”. They are defined by the set of skills that are needed to accomplish the various assembly, testing, repairing, sealing, and painting the aircraft and are assigned to work order and maintenance order steps by the process engineering team. In the first ideating stage of Project 3, we studied the existing buyoffs in EEA’s manufacturing execution system (MES). We analyzed the existing
requirements and curricula in the company’s learning management system (LMS) for obtaining each certification. Through a series of semi-structured interviews with senior technicians and quality inspectors as well as brainstorming sessions with quality assurance supervisors, we mapped the buyoffs out workstation by workstation and made initial decisions on potential additional buyoffs to establish. These included supplier rework certifications that would help restrict operations that are required to be performed by on-site suppliers as well as specialized certifications required by law like the Environmental Protection Agency’s (EPA) certification for technicians servicing and handling air conditioning refrigerants.

Through our analysis of the existing spread of required and assigned certifications in the aircraft build process at EEA, we uncovered the following problems:

- Approximately 20-30% of planned work steps need buyoff adjustments.

- No existing buyoff decision tool is in place to assist the process engineering team in making buyoff assignment decisions.

- No existing buyoff levels map to support individual development and technical evaluation.

- Not enough awareness training with ongoing or recurring quality issues.

- Lack of understanding of aircraft systems from the shop floor individuals.
In the first prototyping stage of Project 3, we began developing a workstation competence map that showed both the required technical certifications listed by expected hours of work (as a percentage of total planned work hours within each given workstation) versus the percentage of workstation team individuals’ respective certifications. This prototype was successful in identifying certification gaps which also represent specific competence gaps that can further be targeted by adjusting the training schedule dynamically to address these gaps. These workstation competence maps were well received based on supervisors’ informal qualitative feedback. It is recommended to continue fine tuning this tool with the supervisors and to conduct an actual usability study of this tool to ensure that it provides all the information necessary.

The second ideating phase of Project 3 featured a high-level look at aircraft systems training. In aviation maintenance environments, this training is typically conducted via general familiarization courses that can take anywhere from 40 to 80 hours total depending on the complexity of the aircraft model as well as the level of depth of understanding required. While this is desirable in most aviation maintenance environments as all shop floor individuals could be faced with a troubleshooting situation where they need to be familiar with multiple aircraft systems, the scenarios in EEA final assembly and testing are different. At EEA, in theory technicians and inspectors are only interacting with the systems for which they have already been certified unless they are pursuing a new buyoff via on-the-job training. Hence, we felt the need to consider segmented aircraft systems familiarization training that could be integrated into the curricula for each system-related certification. In today’s evolving training industry, virtual, augmented, and mixed reality (VR, AR, and MR)
solutions have become the benchmark in terms of method of delivery for aircraft systems training content. This type of solution relies on technological devices that are becoming more and more accessible to companies as enterprise solution providers have multiplied over the past two decades. They offer immersive and scenario-based training offerings that have the potential for improving knowledge retention as well as detection of errors. During this the master’s program, I was invited to explore various existing VR, AR, and MR applications at the 2017 and 2018 Interservice/Industry Training, Simulation and Education Conference (I/ITSEC) in Orlando, Florida. I watched and participated in several product and solution demonstrations seeking to gather insight into strengths and weaknesses of this new mode of training. Much of the information collected was passed on to EEA and recommendations were made for future development projects of more immersive and engaging training offerings at EEA.

4.2. Project 4 – Structuring the On-the-Job Training (OJT)

In Project 4, we sought to add structure to the existing OJT process for training shop floor employees in their every-day activities. The goal was to achieve a more reliable and detailed way of dispensing training related to specific aircraft assembly or testing tasks. Table 18 lists the main highlights of the project and Figure 46 retraces the design thinking steps taken throughout the project.
Table 18 Highlights of Project 4 – Structuring the on-the-job training (OJT)

<table>
<thead>
<tr>
<th>PROJECT 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>What?</strong></td>
</tr>
<tr>
<td><strong>When?</strong></td>
</tr>
</tbody>
</table>
| **Why?** | * To eliminate subjective training and “tribal knowledge.”  
| | * To focus on developing habits of excellence rather than habits of shortcuts. |
| **How?** | * Task prescriptive training specific to each workcenter.  
| | * Restrict OJT to only be dispensed by "subject-matter experts." |
| **Who?** | * Supervisors  
| | * Leads  
| | * Training Team  
| | * Potential OJT Coaches  
| | * Individuals testing new process |

Figure 46 Main Design Thinking Sequence for Project 4

*Structuring the on-the-job training (OJT)*
4.3. Project 5 – Cognitive Modeling of Aircraft Inspections

The last contribution presented in this thesis, Project 5, deals with aircraft inspections. Stemming from repeated late detections of discrepancies that delayed final airworthiness approval on several aircraft, EEA Quality Management felt it was necessary to work on improving a specific type of inspection procedure referred to as close-out inspection or OK-to-close (OKTC) inspection. Table 19 highlights of the project and Figure 47 retraces the design thinking steps taken throughout the project.

Table 19 Highlights of Project 5 – Cognitive modeling of aircraft inspections

<table>
<thead>
<tr>
<th>PROJECT 5</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>What?</td>
<td>Improving detection of non-conformances and foreign objects during OKTC inspections.</td>
</tr>
<tr>
<td>When?</td>
<td>Spring 2018 – present</td>
</tr>
</tbody>
</table>
| Why?      | To reduce the risk of critical discrepancies being detected late or not being detected at all.  
           | To increase inspector awareness and develop more useful approaches to complex inspections. |
| How?      | Think-aloud task observations.  
           | Developing a list of relevant functions.  
           | Mapping using Rasmussen’s SRK.  
           | Evaluating outcome to make training and inspection procedure recommendations. |
| Who?      | Quality Inspectors  
           | Quality Engineer |

Figure 47 Main Design Thinking Sequence for Project 5
Cognitive modeling of aircraft inspections
Chapter 5
Conclusion

In this thesis we introduced the global corporation Embraer and its subsidiary, Embraer Executive Aircraft, Inc. Embraer is currently the third largest aircraft manufacturer in the world. EEA is Embraer’s business jet division that is one of the facilities that delivers the most business jets in the world every year. The flagship model of Embraer’s business jet lineup is without a doubt the Phenom 300 of which the Melbourne operation recently delivered the 500th unit. This makes it the most delivered business jet of the current decade according to GAMA (35. Spruce, 2019). We explored some of the key organization aspects of EEA and justified the need for a holistic people qualification approach.

We then dove into fundamental principles of technical training and provided an overview of the training industry today. We also highlighted the importance of training as it relates to some defining human factors principles such as the complexity of human error analysis and the need for improved situation awareness in both aircraft maintenance and manufacturing environments. Common human factors and error management models in aviation were presented and discussed in terms of their strengths and weaknesses.

The role of training in different aviation regulatory environments was reviewed. Under 14 CFR Part 145, the regulatory requirements as well as the extensive research and recommendations were looked at as a resource for best practices. A paucity of research was observed, on the other hand, as it relates directly to training in aircraft manufacturing
environments. This is echoed by several discussions the researcher had with EEA’s FAA principle inspectors that acknowledge the reality of this situation. We observe that the lack of standardization across the global industry for aircraft manufacturing limits the sharing of best practices within this segment of the industry. It is arguable that the FAA (and other regulatory agencies) adopt the approach to evaluate a PAH’s internal procedures carefully and audit closely to ensure that the intents of both regulatory and company requirements are met. While this has been the approach for many years, it appears that the manufacturing side of this industry could benefit from at least some additional training standardization. However, we do recognize here that considering the complexity and large variety of operations that fall under 14 CFR Part 21 (and similar regulatory chapters under other regulatory bodies) make these types of research efforts a tremendous undertaking that could surely take years and would require significant financial investments. While these efforts would surely be welcomed by the various OEM’s and other industry actors as it would provide guidance, it does seem unlikely that they will be undertaken.

The movement towards implementing a Safety Management System (SMS) is another trend that was reviewed in this thesis. We looked herein specifically at the establishment of a SMS in Part 21 facilities. Currently, this can be done on a voluntary basis as is the case at EEA, but the expectation is that having a SMS in place will be mandatory soon for PAH facilities just as it is for approved repair stations. We found that while SMS does have a strong potential to help mitigate all types of risk within an organization like EEA, it does not address aspects of technical knowledge and competence that we were most interested in for the contributions presented in this thesis.
Finally, we reviewed trends in training gamification and the use of disruptive
technologies to create more realistic and immersive training environments. As the training
industry continues to grow rapidly and new technology integration for training purposes
matures, we see a myriad of opportunities to further enhance people qualification. Many
examples of VR and AR-based training applications were explored at I/ITSEC during the
2017 and 2018 editions and the researcher was able to gather valuable information that is
being used to make recommendations for future training development at EEA.

We presented an elegant integration of the scrum framework with the design thinking
philosophy. Both methods offer the agility needed for the success of complex design
projects. They are both currently being used iteratively to help EEA in the people
qualification continuous improvement journey. The EEA training program road map was
presented, and each contribution was detailed with respect to the design thinking stages of
Meinel and Leifer.

Targeted improvements in basic training offerings were developed relying on the three
socio-technical dimensions of content, presentation, and interaction. A Kirkpatrick Level 1
training effectiveness evaluation survey method was used to measure trainee satisfaction and
identify further areas of improvement. From an organizational standpoint, we managed to
expand the training team and transition into a more suitable training space. We described the
efforts to diversify and grow the essential technical training offerings with a more hands-on
approach. In addition, we developed an approach for the creation of self-paced aircraft
systems training as well as a proof of concept training game that EEA can build upon to
create an immersive and entertaining experience. This work has been started in partnership with Embraer’s disruptive innovation division. A complete overhaul of EEA’s on-the-job training process. New roles and requirements were created, and an integrated dashboard application is currently under development. Finally, we studied the cognitive aspects of certain quality inspections being performed at EEA and developed a model observing and mapping cognitive functions as a knowledge elicitation tool for improving inspection procedures, checklists, and training.

Future work perspectives were considered in relation to each contribution. In addition to these, it will be key for EEA to continue investing in training to achieve its cost-of-poor-quality (CoPQ) reduction goals as well as to help control the turnover. Higher employee retention rates can be achieved through improved training that educates, motivates, and challenges employees. In order to continue improving training effectiveness, it is recommended that EEA utilize Kirkpatrick’s full four-level approach. It will be particularly important to measure initial knowledge retention (level 2 – learning) and how the training program impacts the performance of individuals and teams (level 3 – behavior).

Overall, conducting research, designing training offerings and artifacts, and instructing at EEA was an excellent experience. The work accomplished in the past two years was extensive but only lays the foundation for what is to come and what could be in terms of people qualification at Embraer Executive Aircraft, Inc.
References


Avoid the Dirty Dozen

12 Common Causes of Human Factors Errors

About 80 Percent of Maintenance Mistakes Involve Human Factors ... and if Not Detected... Would Lead to Accidents.

1. Lack of Communication
   - Failure to transmit, receive, or provide enough information to complete a task. Never assume anything.
   - Only 30% of verbal communication is received and understood by either side in a conversation. Others usually remember the first and last part of what you say.
   - Improve your communication—
     - Say the most important things in the beginning and repeat them at the end.
     - Use checklists.

2. Complacency
   - Overconfidence from repeated experience performing a task.
   - Avoid the tendency to see what you expect to see—
     - Expect to find errors.
     - Don’t sign it if you didn’t do it.
     - Use checklists.
     - Learn from the mistakes of others.

3. Lack of Knowledge
   - Shortage of the training, information, and/or ability to successfully perform.
   - Don’t guess, know—
     - Use current manuals.
     - Ask when you don’t know.
     - Participate in training.
Avoid These Common Causes of Mistakes in the Aviation Workplace

4. **Distractions**
   - Anything that draws your attention away from the task at hand.
   - Distractions are the #1 cause of forgetting things, including what has or has not been done in a maintenance task.

   **Get back in the groove after a distraction**
   - Use checklists.
   - Go back 3 steps when restarting the work.

5. **Lack of Teamwork**
   - Failure to work together to complete a shared goal.

   **Build solid teamwork**
   - Discuss how a task should be done.
   - Make sure everyone understands and agrees.
   - Trust your teammates.

6. **Fatigue**
   - Physical or mental exhaustion threatening work performance.

   **Eliminate fatigue-related performance issues**
   - Watch for symptoms of fatigue in yourself and others.
   - Have others check your work.

7. **Lack of Resources**
   - Not having enough people, equipment, documentation, time, parts, etc., to complete a task.

   **Improve supply and support**
   - Order parts before they are required.
   - Have a plan for pooling or loaning parts.

8. **Pressure**
   - Real or perceived forces demanding high-level job performance.

   **Reduce the burden of physical or mental distress**
   - Communicate concerns.
   - Ask for extra help.
   - Put safety first.

9. **Lack of Assertiveness**
   - Failure to speak up or demand concerns about instructions, orders, or the actions of others.

   **Express your feelings, opinions, beliefs, and needs in a positive, productive manner**
   - Express concerns but offer positive solutions.
   - Resolve one issue before addressing another.

10. **Stress**
    - A physical, chemical, or emotional factor that causes physical or mental tension.

    **Manage stress before it affects your work**
    - Take a rational approach to problem solving.
    - Take a short break when needed.
    - Discuss the problem with someone who can help.

11. **Lack of Awareness**
    - Failure to recognize a situation, understand what it is, and predict the possible results.

    **See the whole picture**
    - Make sure there are no conflicts with an existing repair or modifications.
    - Fully understand the procedures needed to complete a task.

12. **Norms**
    - Expected, yet unwritten, rules of behavior.

    **Help maintain a positive environment with your good attitude and work habits**
    - Existing norms don't make procedures right.
    - Follow good safety procedures.
    - Identify and eliminate negative norms.

Visit us at: www.FAASafety.gov
   Your Aviation Safety Web Site
Appendix C
EEA Training Team JIRA Dashboard
### Opportunities for Improvement

<table>
<thead>
<tr>
<th>Category</th>
<th>Comments</th>
<th>Delivery</th>
<th>Interactions</th>
</tr>
</thead>
</table>
| **Quality Engagement** | *Poorly translated from Portuguese.  
  *Several misspelled words.  
  *Poor attention to detail regarding a serious subject.  
  *No real structure, merely a series of vague statements and definitions. | *Instructor presentation template.  
  *No videos or other type of media - dry presentation. | *Instructor could not wait to get it over with.  
  *Very little group involvement, discussion, or questions.  
  *Interaction was virtually non-existent. |
| **Introduction to Phenom and Legacy Aircraft** | *Relevant and to the point.  
  *Well-suited for new hires and individuals new to the aviation industry. | *Poorly shot video of an instructor presenting using a slideshow.  
  *There’s a plane on the presentation screen in the video which prevents us from seeing a part of the slide.  
  *Low volume of instructor’s voice. | *Interaction between the instructor and the individuals in the class while the video was being taken appears to be excellent.  
  *Very little interaction due to the delivery method.  
  *Recommend finding a new instructor that can match the level of interaction from the instructor in the video. |
| **M3C/E5P Systems Overview** | *Parts of the content are outdated and irrelevant to the target learners’ jobs. | *Presentation is dry. | *Target learners not interacting with the systems being explained.  
  *Content better suited for an interactive demo/practice of system use case scenario. |
| **Aircraft Corrosion Prevention** | *Content is mainly composed of slide titles and pictures from the FAA Maintenance Technician Handbook.  
  *There are no explanations given of the different types of corrosion and how they can occur.  
  *Video at the end is from a competing OEM’s corrosion prevention and control program. | *Instructor lacks knowledge about corrosion types and only vaguely addresses consequences of corrosion. | *Very little group involvement, discussion, or questions.  
  *Interaction was virtually non-existent. |
| **Squash Lift (CST)** | *Parts of the content are irrelevant to the target learners’ jobs. | | |
| **Squash Lift (Practical)** | | | |
| **C פוס** | *One size fits all OSHA training content is not adequate for the target learners’ jobs.  
  *Content is not broken up into digestible pieces. | *Delivered via CST with a very monotonous voice.  
  *Very few engaging videos. | *Computer-based delivery method is not engaging for this subject.  
  *Learners appeared to check out during this section and only paid attention when there was a quiz. |
| **Foreign Object E505** | | | |
| **Extraverted E565** | *Poorly translated from Portuguese. | *Presentation is dry. | *Interaction between instructor and learners was excellent.  
  *Learners took turns driving the squash lift around a small obstacle course and found it more difficult than expected.  
  *Section extended to allow for questions, and more practice to reach higher comfort level with this ground support equipment. |
| **Embassy Drawings** | *Lacking content about how to properly read Parts Lists. | *Presentation could use some improvements to highlight common pitfalls and confusions with Embassy’s drawing conventions. | *Subject is quite dry and interaction between instructor and learners was limited to individuals that had previous experience working with 3D assembly and instruction drawings.  
  *Individuals with no experience appeared to be left behind or unentertained.  
  *Recommend providing multiple practice scenarios with questions and training “recipes” to close to help increase proficiency. |
## HIRING & EMPLOYEE RETENTION

<table>
<thead>
<tr>
<th>Viewpoint</th>
<th>Rank</th>
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</thead>
<tbody>
<tr>
<td>Hire staff focused on quality.</td>
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<tr>
<td>Change hiring perspective to question candidates on technical and quality-related topics.</td>
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<tr>
<td>Retain your best employees - they set the example.</td>
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## TRAINING

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<thead>
<tr>
<th>Viewpoint</th>
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<tbody>
<tr>
<td>Promote objective training - teach them how to fish rather than giving them a fish.</td>
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<tr>
<td>Introduce and drive consequences more frequently during training.</td>
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<td>Assess competence and knowledge before assigning responsibilities.</td>
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<td>Educate about non-compliance drivers and consequences.</td>
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<tr>
<td>Incorporate lessons learned into training.</td>
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<tr>
<td>More actual DoD training workshops for all SIE employees.</td>
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<tr>
<td>More frequent leadership engagement in training.</td>
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<tr>
<td>Stress how each job is important, how all systems work together - one weak link breaks the value chain.</td>
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<tr>
<td>Ensure training resources.</td>
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</table>

## LEADERSHIP

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<th>Viewpoint</th>
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</thead>
<tbody>
<tr>
<td>Promote leadership development more events.</td>
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<tr>
<td>Leadership engagement in problem resolution instead of following day today.</td>
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<tr>
<td>Leadership engagement in problem resolution instead of following day today.</td>
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<tr>
<td>Leadership promoting and enforcement of compliance.</td>
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<tr>
<td>Leadership in training.</td>
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<tr>
<td>Leadership establishing goals that promote company values.</td>
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<tr>
<td>Leadership as a mentor to empower employees.</td>
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<tr>
<td>Recognition of employee successes - leadership skills create a strong culture.</td>
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<tr>
<td>Recognition for quality/safety at all hands meetings.</td>
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<tr>
<td>Employee fights they can understand what is at stake.</td>
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</table>

## COMMUNICATION

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<th>Viewpoint</th>
<th>Rank</th>
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<tbody>
<tr>
<td>Explain how individuals can contribute to company goals.</td>
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<tr>
<td>Aviation fines &amp; penalties should be posted throughout the facilities regardless of consequences.</td>
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<tr>
<td>Share customer experiences with teams.</td>
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<tr>
<td>日常焦点on fundamentals such as FOE.</td>
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<tr>
<td>Describe the role of FAA &amp; Part 121, regularity.</td>
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<tr>
<td>Knowledge is power, the more feedback for everyone the better the loop is closed.</td>
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<tr>
<td>More self audits (spot checks) with consequences and rewards.</td>
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<tr>
<td>Have pilots talk with staff so they understand the techs’ perspective.</td>
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<tr>
<td>Improve communication about quality between all departments, teams, shifts, and areas.</td>
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<tr>
<td>Have the quality team spend more time interacting with the installations.</td>
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<tr>
<td>Improve criteria to be more easy to inspect.</td>
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<tr>
<td>Dictate and enforce quality from our suppliers. Stop buying cheap parts.</td>
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<tr>
<td>Improve the morale of the assembly jobs so they can understand what is at stake.</td>
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## CULTURE

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<th>Viewpoint</th>
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<tbody>
<tr>
<td>Do not sit around. On the right things even when it takes more time.</td>
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<tr>
<td>Deal with violations quickly and fairly.</td>
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<tr>
<td>Highlight significance of signing something off as completed.</td>
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<tr>
<td>Team building activities across functional groups.</td>
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<tr>
<td>Implement lessons learned into recurring training.</td>
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<tr>
<td>Have more actual DoD training workshops for all SIE employees.</td>
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<tr>
<td>More frequent leadership engagement in training.</td>
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<tr>
<td>Stress how each job is important, how all systems work together - one weak link breaks the value chain.</td>
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<tr>
<td>Ensure training resources.</td>
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</table>

## EXPECTATIONS & RESOURCES

<table>
<thead>
<tr>
<th>Viewpoint</th>
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<tbody>
<tr>
<td>Raise the bar on compliance.</td>
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<tr>
<td>Discipline for noncompliance has to be enforced.</td>
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<tr>
<td>Don’t put people in impossible situations.</td>
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<tr>
<td>Give employees the resources they need to succeed.</td>
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<tr>
<td>Remove the excuses to be non-compliant.</td>
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<tr>
<td>Ensure roles, responsibilities, and expectations are well defined.</td>
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<tr>
<td>Hold every leader and every employee accountable.</td>
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</table>

## SCM & PRODUCTION PLANNING

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<tr>
<th>Viewpoint</th>
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</thead>
<tbody>
<tr>
<td>No test procedure should be implemented in production without us validating it, including revisions.</td>
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<tr>
<td>Compliance has to be put in front of delivery.</td>
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<tr>
<td>You can plan, check, at the end of the year and expect compliance.</td>
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<tr>
<td>Step planning to make more AOC’s then production can reasonably produce.</td>
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<tr>
<td>Reduce pressure by better planning, costs, and remaining skills.</td>
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<tr>
<td>Dictate and enforce quality from our suppliers. Stop buying cheap parts.</td>
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<tr>
<td>Drive/improve supplier quality.</td>
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</table>

## PROCESS ENGINEERING

<table>
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<tr>
<th>Viewpoint</th>
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<tbody>
<tr>
<td>5W3H should operate by the same processes and rules.</td>
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<tr>
<td>How can you compare costs between facilities when processes are not the same.</td>
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<tr>
<td>Have planners and ME’s perform inspections of the assembly jobs so they can understand the techs’ perspective.</td>
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<tr>
<td>Develop more Gantt charts to promote quality engagement.</td>
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<tr>
<td>Improve work instructions that are unclear.</td>
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<tr>
<td>Improve drawing details.</td>
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<tr>
<td>Improve criteria to be more easy to inspect.</td>
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<tr>
<td>Improve parts for use. Put in more process controls.</td>
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<tr>
<td>Use more technology to help technicians.</td>
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## RCCA & CONTINUOUS IMPROVEMENT

<table>
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<tr>
<th>Viewpoint</th>
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</thead>
<tbody>
<tr>
<td>Find ways to review quality issues in a positive way to invite new ideas (current process is all negative and employs fear-based management).</td>
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<tr>
<td>Random audits to ensure staff are following work instructions.</td>
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<tr>
<td>Involve support personnel into the process improvement.</td>
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<tr>
<td>Develop more Gantt charts to promote quality engagement.</td>
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<tr>
<td>Focus on standardizing processes rather than assigning blame to individuals.</td>
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<tr>
<td>Learning from mistakes; allow employees to contribute to correcting their own NCR’s.</td>
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</tbody>
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Appendix F
Project 1 – Visual Shop Floor Reminder Examples
Appendix G
EEA Course Evaluation Survey

EEA Training Course Evaluation Form
Our records indicate that you recently attended or completed a training course at EEA. We would like to invite you to provide some feedback on your training experience to help us improve our offerings.

* Required

Informed Consent Form

The purpose of this research project is to identify areas of potential improvement in the EEA training program. This is a research project being conducted by Yassine Rayad at Florida Institute of Technology. Our records indicate that you recently attended one of the EEA training offerings and your feedback is very valuable to us.
Your participation in this research study is voluntary. You may choose not to participate. If you decide to participate in this research survey, you may withdraw at any time. If you decide not to participate in this study or if you withdraw from participating at any time, you will not be penalized.

The procedure involves filling an online survey that will take approximately 5-10 minutes. Your responses will be confidential and we do not collect identifying information such as your name, email address or IP address. The survey questions will be about the content, presentation, and interaction aspects of the training you recently completed.

We will do our best to keep your information confidential. All data is stored in a password protected electronic format. To help protect your confidentiality, the surveys will not contain information that will personally identify you. The results of this study will be used for scholarly purposes only and may be shared with Florida Institute of Technology representatives.

If you have any questions about the research study, please contact Yassine Rayad (yrayad@fit.edu). You are welcome to take a snapshot of this page for your records. This research has been reviewed according to Florida Institute of Technology IRB procedures for research involving human subjects.

**Electronic Consent:** Please select your choice below.

- You have read the above information
- You voluntarily agree to participate
- You are at least 18 years of age

If you do not wish to participate in the research study, please decline participation by clicking on the "disagree" button.

1. *
Mark only one oval

- [ ] Agree
- [ ] Disagree

Stop filling out this form.
2. Select the course you attended from the drop down list below.
   *Mark only one oval.*
   - Quality Engagement
   - Aeronautical Culture
   - Human Factors Awareness
   - Introduction to Phenom & Legacy
   - Oxygen Servicing and Handling
   - Torque and Safety Wire (Lab + Theoretical Combined)
   - Phenom SIT (WebSIT version)
   - Electrical Harness Installation (Lab + Theoretical Combined)
   - Theoretical Torque and Safety Wire
   - Lab Torque and Safety Wire
   - Theoretical Electrical Bonding
   - Lab Electrical Bonding
   - Theoretical Permaswage
   - Lab Permaswage
   - Theoretical Electrical Harness Installation
   - Lab Electrical Harness Installation
   - Theoretical Phenom 100/300 Thermal and Acoustic Insulation System
   - Hydraulic Line Installation and Torque Refresher
   - Legacy Hydraulic & Landing Gear System
   - Phenom and Legacy Interior Systems

3. Select your position / title from the drop down list below.
   *Mark only one oval.*
   - Production Technician
   - Quality Inspector
   - Manufacturing Engineer
   - Methods Planner
   - Quality Analyst / Engineer

4. How many years of experience in aviation do you have?
   *Mark only one oval.*
   - None
   - 0-2 years
   - 2-5 years
   - 5-10 years
   - more than 10 years
5. The material covered in the training course was relevant to my job.
   Mark only one oval.
   ![Survey Response Options]

6. The material was presented in an interesting way.
   Mark only one oval.
   ![Survey Response Options]

7. The instructor was an effective communicator.
   Mark only one oval.
   ![Survey Response Options]

8. The instructor was well prepared.
   Mark only one oval.
   ![Survey Response Options]

9. The audiovisual aids were effective.
   Mark only one oval.
   ![Survey Response Options]

10. The handouts will be of help to me.
    Mark only one oval.
    ![Survey Response Options]

11. I will be able to apply much of the material to my job.
    Mark only one oval.
    ![Survey Response Options]
12. The facilities were suitable.  
   Mark only one oval.

   1  2  3  4  5  6  7  8
   Strongly Disagree   Strongly Agree

13. The schedule was suitable.  
   Mark only one oval.

   1  2  3  4  5  6  7  8
   Strongly Disagree   Strongly Agree

14. There was a good balance between presentation and group involvement.  
   Mark only one oval.

   1  2  3  4  5  6  7  8
   Strongly Disagree   Strongly Agree

15. I feel that this training course will help me do my job better.  
   Mark only one oval.

   1  2  3  4  5  6  7  8
   Strongly Disagree   Strongly Agree

16. What would have improved this training course?

   ___________________________________________
   ___________________________________________
   ___________________________________________
<table>
<thead>
<tr>
<th>Responsibilities</th>
<th>Production Trainer 1st Shift</th>
<th>Production Trainer 2nd Shift</th>
<th>Technical Trainer</th>
<th>Quality Engineer-Training Project Lead</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interface with Station Leads and Supervisors to identify in-station training gaps.</td>
<td>XX</td>
<td>XX</td>
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<tr>
<td>Conduct OJT on the shop floor with new technicians and technicians requiring additional training.</td>
<td>XX</td>
<td>XX</td>
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<tr>
<td>Monitor the OJT Coaching process to ensure best practices are respected when performing OJT.</td>
<td>XX</td>
<td>XX</td>
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</tr>
<tr>
<td>Establish new structured process for OJT, complete the testing phase, and implement the new process.</td>
<td>X</td>
<td>X</td>
<td>XX</td>
<td>XX</td>
</tr>
<tr>
<td>Conduct classroom essential training (theoretical and lab) with new hires and backlog of technicians missing training.</td>
<td>XX</td>
<td>XX</td>
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<tr>
<td>Conduct relevant Weekly Quality Dialogues including review of recurring workmanship issues and critical findings.</td>
<td>XX</td>
<td>XX</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Develop new shop floor reminders.</td>
<td>XX</td>
<td>XX</td>
<td></td>
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</tr>
<tr>
<td>Develop new training aids, lab training devices, and exercises.</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Training planning and scheduling</td>
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<tr>
<td>Training supplies and equipment procurement</td>
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<tr>
<td>Training records keeping</td>
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<tr>
<td>People Qualification doc and maintenance.</td>
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<tr>
<td>Develop aircraft systems training</td>
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<tr>
<td>Attend staff meetings with Production Manager.</td>
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<tr>
<td>Participate in weekly/biweekly Training Team meetings to plan projects and review progress on training actions (SCRUM).</td>
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<tr>
<td>Participate in RCCA focusing on training related potential causes.</td>
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<tr>
<td>Participate in Kaizens for process improvements and new process requiring additional technician training.</td>
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</tbody>
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XX: Main Responsibility
X: Support Responsibility