Digitization of a Component Repair Facility

A Major Qualifying Project

For General Electric - Aviation

Submitted to the Faculty

of

Worcester Polytechnic Institute

In Partial Fulfillment of the Requirements for the

Degree of Bachelor of Science

By

Connor McGrath

Kurt Schebel

Paul Trimby

Date: October 17, 2008

Approved By:

Professor Kevin Rong	**Primary Advisor**
Professor Sharon Johnson	**Co-Advisor**
Mrs. Michelle Babb	**GE-Liaison**

Abstract

Documentation such as Engine Manuals and specific planning materials exist at engine repair facilities to provide work instructions when performing component repair. Recent audit findings and the use of legacy systems at Services-Cincinnati demonstrated reasons to organize these instructions in easily accessible locations on a computer. The team researched current systems of this shop and the available IT-supported systems to control documentation. With this information, the team developed systems for the floor to access all documentation, in addition to a tool to flow documentation through the shop.

Acknowledgements

The team received help and guidance from numerous sources during the course of the project. These individuals were knowledgeable sources who the team looked to for information, advice, and support. First, the team would like to recognize the advisors, Professors Kevin Rong and Sharon Johnson, for pushing the team to succeed throughout the course of the project. From GE, the team would especially like to thank the main project advisors, or the Quality Business Leader and IM Leader at Services-Cincinnati for their continuous help and support during the team's seven-week stay at the office. This also extends to one engineer, who provided support as a project champion at Symmes Rd.

Again, the team would like to acknowledge all those who contributed to the research and execution of our project. Special thanks to:

Blades Cell	HR Personnel
Caledonia personnel	IT team
Cell leaders	McAllen personnel
CPL & Symmes Operators	Plant Leaders
DCAs	Quality team
Document Center	Strother personnel
Engineers	Sumps and Seals Cell
Facilities Managers	Tri-remen personnel
GE Aviation business team	VSLs
General Manager	Wales personnel

Table of Contents

Table of Figures

Table of Tables

1. Introduction

Working in an aircraft engine-repair shop poses difficulties through both engineering problem solving and organization, as structure helps define all operations. Document control is essential to any repair shop because regulatory and internal instructions are the driving factors behind every operation. Without a regulated system to control the organization and flow of Engine Manuals (EMs) and planning, a component repair shop would be unable to follow the standard procedures linked to any given engine part. General Electric (GE) Aviation owns 16 service facilities throughout the world and each one deals with a wide variety of repairs on a variety of GE turbine engines. With arguably the widest scope of repairs, Services-Cincinnati is a component repair shop that currently depends on controlled paper documents to guide each operation. As GE Aviation makes a push for digitization of the shops around the globe, Services-Cincinnati seeks a centralized area to house all EMs and planning. The team was tasked with developing such a system, in addition to guiding the implementation of a digitized floor. In addition, GE Aviation challenged the team to determine an IT supported system to control EM flow through the hands of the Technical Coordinators (Engineers) and the Document Center (Document Center).

The challenge of digitizing all of Services-Cincinnati calls for a thorough understanding of two repair shops, comprehension of a wide variety of documents, and an understanding of how documents affect the ability to work efficiently. Each document that flows through a repair shop goes through many hands before the floor uses it. Once on the floor, maintenance is a difficult task, especially if paper copies supply the information. The goal was to eliminate paper copies of all paperwork except routers and travelling data sheets (Chapter 2.2). To do this the team explored different facets of the business. In order to analyze the problem at hand and gain the knowledge necessary to make a switch to paperless, the team performed a literature review, interviews, and discussions with GE Aviation professionals who know and understand the problem, and tested different theories to determine best practices. This methodology separated the two components of the project and distinguished between understanding the problems and actually forming solutions.

Altering the review process and use of EMs on the floor has a drastic effect on a repair shop. With regard to document flow, the Document Center currently receives manuals for each engine model, both GE and customer specific (Delta, American, etc.), and must inform Engineers of the new revisions so that they may revise their planning accordingly. After engineer review, the Document Center receives back EMs for distribution for use on the shop floor. In the current system, a legacy program controls the issue of different sections that the Engineers are "subscribed" to, or supposed to review. These are reviewed by the relevant Engineers, who view their changes in a weekly report and a separate legacy workflow application. The Document Center (DC) controls document flow tools, though they are not always updated in parallel, since the upkeep is difficult in numerous locations. Therefore, the team's goal was to use one system to generate a weekly report automatically and subscribe Engineers to entire EMs as opposed to the smaller sections. This system must also incorporate some logic, such as having all Engineers approve the review of the document before distribution to the floor.

In the current system; once approved, each revised EM section is printed and distributed manually to satellite libraries across the shop by walking the copies onto the floor. Satellite libraries are areas on the shop floor where there are currently shelves of binders, which house all documentation for floor use. They are specific per cell, based on the needs of that area; there are 17 satellite libraries at one repair shop, called Container Place (CPL) alone; there are over 400 binders throughout these libraries. CPL is the primary component repair shop in Cincinnati, excluding airfoil work. Its sister shop for these operations, Symmes, has roughly one planning binder per workstation, due to the specifics of each individual job and the quantity of parts that flow through the shop. Generally, this system is inefficient because of excess costs, audit risks, and a high level of non-value added work in retaining planning. The idea of a digital format has led to the exploration of setting up one centralized location for work instructions instead of multiple satellite libraries. In addition, the new system should allow numerous users at once to access each EM to eliminate the need for multiple copies of the same section. To help the Document Center, digitization should define uploads as the main form of distribution so that all can access new documents as soon as they enter a directory. This includes Symmes, which allows both shops to work using one main system for controlled documentation. Finally, the project influences the floor because they will have a different place to locate work instructions, which will be closer to their immediate workstation and easy to access.

This document discusses the background of GE's engine service shop in Cincinnati and the documentation that proposed systems control. In addition, this background information highlights the roles affected by digitization, potential areas to improve the shop, and the technical aspects of the project. Next, the team elaborates on an intense methodology, which used interviews and focus groups to gage comfort levels and opinions of all employees affected by the project. In addition, the methodology covers the steps taken to determine document control systems and test proposed systems on the shop floor. These methods lead to the results section, including successful systems that flow documentation and house it for all employees to access, as well as the tools necessary to implement computers on the shop floor. In addition, the team found gaps within the company of miscommunication and uncovered a new twist in document flow from the technical publication team. Finally, the team explained the conclusions of the project and provided recommendations for the company to further the idea of digitization.

2. Background

To provide a complete background of GE Aviation Engine Services (with Cincinnati as the focal point) and the problem with document control, there are many topics to be covered. These subjects include:

- An overview of Services-Cincinnati
- Forms of documentation
- Review and control of technical publications
- Potential measurable effects
- Roles to be affected by the project
- Technical aspects of document control

This report documents each of the above and provides the reader with an overview of the current problems with document flow at the specific engine repair facility. Once these topics were examined in the project, the team began to develop solutions.

2.1. GE Aviation, Services – Cincinnati

Established in 1951, Services-Cincinnati is one of the first repair sites in the history of GE Aviation. It is a component repair shop, meaning the shop receives an extremely wide variety of parts from all different engines in service; Structures, Combustors, Boosters, Airfoils, Sumps, Seals, Ducts, etc. Two local sites divide these: Container Place (CPL) and Symmes (SYM). SYM repairs all airfoils, or blades and nozzles, while CPL handles all other hardware. Since any two repairs may vary, work instructions for CPL are specialized to account for the condition of any incoming part; SYM typically sees high-volume, less-varying repairs. The differences in repairs also make control of work instructions a necessary function of each repair site.

Separated from the new-make GE Aviation headquarters in Evendale, OH, the repair facility has its own management structure to operate the site. There is one general manager to oversee both CPL and Symmes, with many different departments underneath him/her, led by business leaders as shown below in Figure 1:

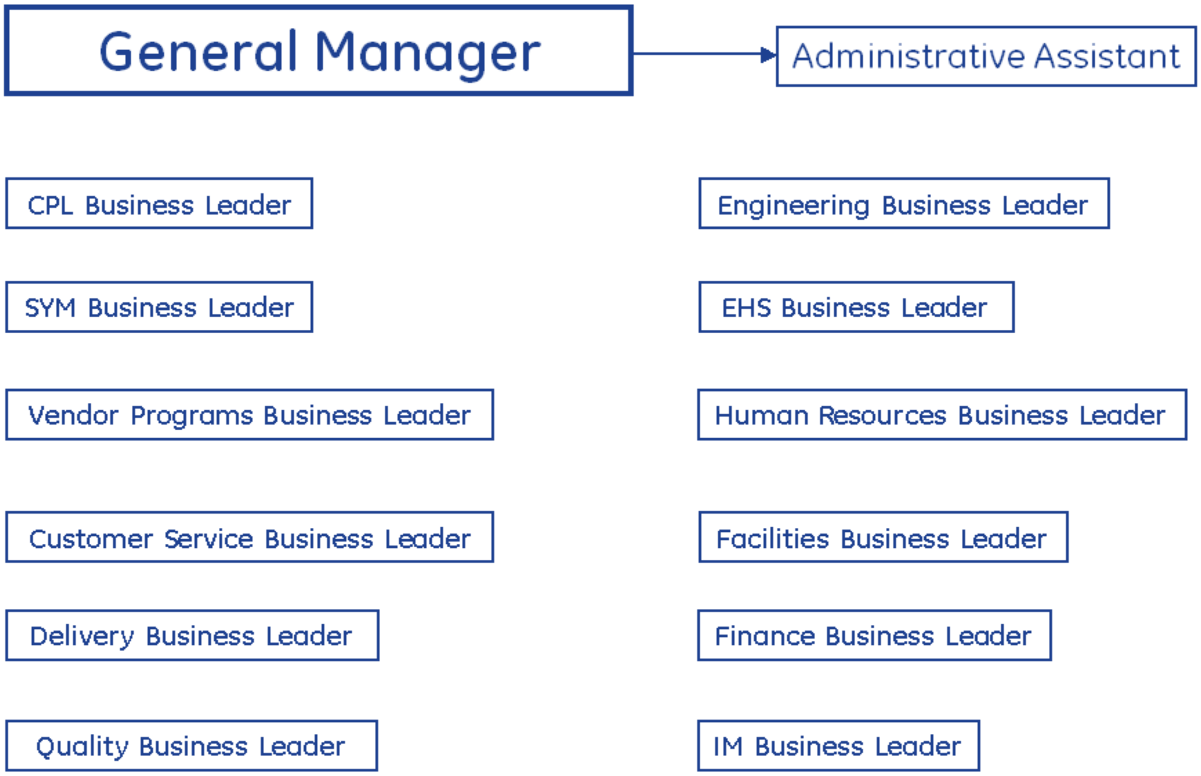


Figure 1: Services - Cincinnati Staff

Each leadership position in Services-Cincinnati serves across both shops. Each leader has a team to work with them in order to account for production and issues at CPL, Symmes, and Vendor Programs. Vendor Programs work directly with GE to perform repairs, which creates more capacity for work at GE facilities. In this case, Services – Cincinnati sends the parts to vendors, who work directly with GE to perform a repair before sending it back to the customer. These main positions handle all facets of the business: quality, technology, safety, production, customer service and capital. In order to flourish, the repair shop must have the supervision of an excellent general manager.

Within each shop, cells have been created to repair specific components; there also exist a set of Central Service cells that perform operations, such as metal spray and shot peen, for other cells. All components that enter the business go through a specific route once received at Services-Cincinnati, as outlined below:

1. Receipt and order entry, performed on the CPL dock for parts at CPL, SYM, and Vendor Programs
2. Site docks, where each part is arranged so that it is ready for repair
3. Cleaning; either water-jet or chemical cleaning
4. Inspection in the form of either FPI or an NDT process, where the parts receive a temporary fluorescent-chemical coating that permits the inspectors to identify flaws under a black light. This process uncovers cracks that the eyes cannot discover through typical visual inspection.
5. Repair in its specified cell (Tubes and Ducts, Hot Section; whichever section of the engine it pertains to). The part is inspected in the cell and benched/machined to repair the damage where specified. Within the main repair of the part, Central Services may apply a metal spray, or perform grit blasting, etc.
6. Final inspection, where it is issued an 8130 tag (confirming the repair)
7. Finally, the part is shipped and returned to service

Once Services-Cincinnati performs all repairs on a part and is confident the part is serviceable, the customer is shipped the part for use. Overall, the repairs are setup to run most efficiently and with minimal quality concern.

To oversee the repairs performed on the floor, Value Stream Leaders (VSLs) manage groups of cells. One VSL may cover anywhere from one to three cells, depending on the abundance of work there. Underneath these VSLs, Technical Coordinators, also known simply as Engineers, work directly with given cells to define technical processes, tool and fixture design, and to produce work instructions. VSLs own the individual product lines in each cell. These include:

- Blades
- Cases and Frames
- GE-90 Combustors and Turbine Center Frames
- Hot Section
- Nozzles (Energy, High Pressure Turbine [HPT], LPT)

- Rotating Parts
- Sumps and Seals
- Tubes and Ducts

Engineers also help to leverage best practices when unknown circumstances occur. For example, an engineer may have to work with a Repair engineer to construct a Departure Record (DR) for a part if it has a new and unexpected condition, or if it is a new and/or uncommon part in the shop. Otherwise, the engineer is responsible for controlling any work instructions that the floor uses.

2.2. Forms of Documents

Three document groups define the processes and operations aircraft engine-component repair shop relies on: technical publications, regulatory documents, and planning. The technical publications, commonly called tech pubs, are primary documents that define the specifications of serviceable parts for an engine. Regulatory Documents are primary documents that define safety standards and specify the qualifications and requirements of repair technicians and inspectors, as well as other various roles; regulatory documents also define the control and use of technical documents. Planning encompasses a wide variety of secondary material used directly by the repair technicians through daily operations and reflects the two primary forms of documentation.

2.2.1. Description of Primary Documents

Technical publications cover the range of documents expressing the limits, tolerances, and procedures used in the aviation industry. It is through the obtained technical publications that Engineers create substantiated planning and work instructions facilitating component repair operations. The component repair shop obtains these from a variety of sources, as shown in Table 1. In all, SERVICES - CINCINNATI receives technical publications from more than 20 sources; SERVICES - CINCINNATI utilizes over 58 regularly updated technical publications.

Table 1: Technical Publication Sources

Internal	GE Aviation Engineering GE Aviation Quality
Partner Corporations	SNECMA Pratt & Whitney
Airframe Manufacturers	Airbus Alaska Bell Boeing Continental Embraer McDonnell Douglas SAAB Sikorsky Aircraft
Airlines	American Airlines Delta Airlines Japan Airlines United
Military	US Department of Defense
Regulatory Agencies	Civil Aviation Administration of China Department of Civil Aviation (Thailand) Federal Aviation Administration Joint Aviation Authorities (Europe) Transport Canada

Most technical publication sources provide their documents electronically on disc media or make provisions to allow downloading from the Internet. Two sources have not upgraded to electronic media, with their technical publications received in hardcopy via paper and microfilm.

The tech pubs received are predominantly public information, with a handful of GE Aviation documents being of a proprietary nature. Technical publications may range from a several thousand page Engine Service Manual to a single-line Service Bulletin. The types of documents include:

- Engine Manual (EM)
- Engine Service Manual (ESM)
- Illustrated Parts Catalog (IPC)

- Customer Engine Service Manual (CSM)
- Temporary Revision (TRs)
- Incremental Change Notice (ICNs or ICs)
- Standard Practice Manual (SPM)
- Repair Document (RD)
- Service Bulletin (SB)
- Advisory Circular (AC)
- Airworthiness Directive (AD)
- Federal Aviation Regulation (FAR)

2.2.1.a Document Breakdown and Relationships

Service Manuals

Specific to each engine model, EMs provide information for the service of the entire engine as designed by GE Aviation, meeting regulatory, airframe and customer requirements. EMs provide serviceability characteristics governing the reparability of a component, indicating acceptable repair procedures, and describing the characteristics of a repaired part sufficient for entry into service. The EM is made up of sub-manuals, which include the ESM, specific to regular service and repair processes, and the IPC, providing visual references for assembly/disassembly and service operations. Each manual has a unique GEK Number for numeric referencing.

A regular schedule exists for new ESM revisions. The TRs and ICNs exist to provide for changes to the manual occurring between ESM revisions. TRs update large portions of the manual and are considered part of the current ESM revision upon release. ICNs update small sections of the manual, such as adding a Repair Page Block or, more often, overriding a section of the most current ESM revision. ICNs are typically included as part of subsequent ESM revisions.

For customers preferring specific service operations and criteria are met for their engines, Customer Engine Service Manuals may be issued specific to an engine model, mostly or wholly replacing the GE ESM for that customer's repair work.

A standardized numbering system divides all common flight service manuals. Known as ATA numbers, the standard specifies sections through a "Chapter – Engine Section – Component" numbering system (ex, 72–40-01, referring to Engine Overhaul – Rear Combustor – High-Pressure Turbine Nozzle). Providing further break down, Page Blocks are used to divide ATA sections into subsections specific to Tooling, Repair, Inspection, Cleaning, etc; each subsection is given a standard page number (ex, 800 being Repair in the CF6-50). Electronic versions of the EMs divide the manual into single files for each Page Block.

It is important to note that EMs specific to Land-Marine (LM) and Military engines do not follow the typical ATA breakdown, but rather feature a "Chapter – Section – Paragraph" breakdown. The electronic versions of these LM and Military manuals exist as a monolithic file or file-per-chapter.

2.2.1.b Other Tech Pubs

SPMs exist for the CF6, CFM56, and GE90 engine lines. Each describe best practices for the engine lines, ranging from standards used, interchangeable parts listing and standard assembly or repair processes.

RDs provide critical repair information, often of a proprietary nature, to successfully rejuvenate a part. These contain information regarding tooling, chemicals, operation parameters, etc, specific to the repair.

SBs, or more formally, Special Airworthiness Information Bulletins, are notifications issued by GE, a customer or a regulatory body that "alerts, educates and makes recommendations to the aviation community" (Special Airworthiness Information Bulletins (SAIB), 2007).

ACs provide information regarding compliance with regulations as set forth by a National Aviation Authority such as the FAA.

ADs are notifications by a regulatory body that identify "those products in which the Administrator has found an unsafe condition [in a product or procedure] and, as appropriate, prescribes inspections and the conditions and limitations, if any, under which those products may continue to be operated." These are legally enforceable directives with a set completion date (Code of Federal Regulations, 2008).

FARs indicate requirements and laws for the aviation community, as presented by the respective National Aviation Authoirty – FARs are specific to the FAA, whereas the JAA uses JARs. FAR 145 pertains to Repair Stations, specifying the general terms of a repair station, necessary certifications, facilities, equipment, personnel and operating rules. FAR 145 Subpart C – *Housing, Facilities, Equipment, Materials and Data,* as well as FAR 145 Subpart E – *Operating Rules*, specify the requirements of Technical Document use and control; the primary takeaway of FAR 145 relevant to this project is that repair technicians must review their planning prior to beginning an operation (Federal Aviation Regulations, 2008).

2.2.2. Description of planning

Planning is a generic term encompassing internal documents that facilitate the repair process, derived from tech pubs. On the most basic level, Engineers develop planning during the review process of technical publications; it is during this review that they update the planning to reflect the most recent applicable documents. Planning includes Production Process Routers (PPR), Datasheets, Standard Operating Procedures (SOP) and Work Instructions (synonymous with Technical Plans, Repair Instructions and Operation Instructions).

The primary element of planning is the PPR. Specific to each engine component, version and customer, the PPR is a page or set of pages that travels with a part listing required operations. It provides a location for machinists and inspectors to certify the completion of an operation.

Where a part is measured and large amounts of information collected, repair technicians record the data on Travelling Datasheets. The Datasheets reference the ESM for acceptable values or limits. The IPC provides any required visual references.

Standard Operation sheets, or SOPs, describe any practice that must occur for multiple product lines. They specify safety information, machine use instructions, handling procedures, etc. These may pertain to the shop as a whole or a specific workstation.

2.2.2.a Planning at Container Place

Due to the low-volume, high-variability nature of components repaired at the Container Place location, Engineers typically opt to specify instructions for each operation directly on the PPR. The lengthy repairs lend to multiple-page PPRs containing SOPs and Work Instructions. GEK and ATA numbers reference pertinent EM sections for each operation. The exception to this practice is in Central Services, which utilizes planning in the manner typical of Symmes.

2.2.2.b Planning at Symmes

Due to the high-volume, process-line nature of components repaired at the Symmes location, machinists and inspectors rely on PPR and 'planning books'. Engineers create PPRs that state standard operation numbers and names; when necessary, these include blanks for measured data. At each workstation there exist planning books containing detailed SOPs and Work Instructions created by Engineers, with Work Instructions being specific to that operation and PPR. RDs and EMs provide the majority of information contained within these planning books.

2.3. Review and Control of Technical Publications

The current system of review and control of Tech Pubs at Services – Cincinnati relies on legacy software not supported by the internal IT community as well as physical auditing of all controlled documents. The Quality Business Leader has flagged both processes as being of concern. Due to the assumed risk present in the current system and the potential for cost-savings, there is a desire for an improved system.

2.3.1. Review Process

FAA regulations require the completion of repairs to the most current technical publications (Federal Aviation Regulations, 2008). As changes to tech pubs often lead to alterations of the repair process, the Engineers must adjust any planning to reflect these changes. Through agreement with the FAA, there exists a 30-day period, from receipt of the new tech pubs, for Engineers to adjust any necessary planning. To ensure this process happens within the time allotted, it is desirable to use an automated control system.

There are four landmarks through the review process:

1) Receipt of the new document by the Document Center,
2) Distribution of the new document to Engineers,
3) Review of document by Engineers, necessary Planning changes made,
4) Release of new document and Planning to floor.

It is required by the FAA that all work be completed according to the most recent technical documents (Federal Aviation Regulations, 2008); failure to comply with this regulation risks possible civil penalties or loss of repair license.

2.3.1.a Current System

The review process previously relied on custom systems designed by an external contractor specifically for Services – Cincinnati. The two primary systems are "Master Distribution" and "Tollgate," both legacy systems no longer supported by IT. A manually created "Weekly Report" lists all new and pending-review Tech Pubs. Appendix 0, Appendix C: Current Tech Pub Workflow, shows the high-level steps required for this process

Master Distribution

Designed specifically for the task, Master Distribution runs off a Microsoft Access Database, offering a front-end application to enter new documents and to mark the review of the documents. Engineers check for documents pending review through the same front-end app. Upon completion of their review, clicking a checkbox adjacent to the item denotes it as reviewed.

Master Distribution relies on a Subscriber Matrix with over 5000 subscriptions relating Engineers to specific ATA sections. The application's subscription-based nature cannot take into account an Engineer's needing a new section without some direct human interaction, and does not provide indication of all sections that are new or changed.

Engineers have described situations where items known to be pending do not display. Similarly, they have indicated that items already checked as reviewed may reappear as pending.

Tollgate

While documents are pending review, they also exist in a system known as Tollgate. This program's function is to hold up the start of repairs on components when the necessary Engineers have not reviewed a document. This is a wholly separate program from Master Distribution used in parallel by the Document Center

Weekly Report

Distributed every Monday, the Weekly Report provides notification of all pending-review documents as well as any new "No Subscriber" documents. It is the assumed responsibility of Engineers to review this weekly to ensure that they are not delinquent on any reviews, they know of all reviews assigned to them and that they do not require a subscription to any No Subscriber documents. VSLs, Plant Managers and Quality Leaders also review the weekly report to make certain there are no delinquencies.

This manually generated report assumes the risk of human error in processing the up to 50-page report. It also assumes human error in reviewing all pages for No Subscriber items that may pertain to an engineer.

2.4. Control of Technical Documentation

The tech pubs and planning used by the floor exist in three-ring satellite libraries placed around the shop floor. These documents, used by the repair technicians, exist as stamped, controlled copies separate from the master copies in the Document Center. In CPL alone there are 17 satellite libraries, with over 400 three-ring binders across the shop – this presents a significant risk for uncontrolled copies remaining on the floor and for new documents not to be properly disseminated to their respective binders. Manual auditing of each binder is the only definitive method of determining the binders are correct.

In order to develop a plan to manage the control of document flow, the team must first establish the technical aspects of the project and understand why it is beneficial to an engine service shop. From a project standpoint, the requirements must be defined in a manner that portrays the tasks as engineering-specific. This section will illustrate the technical applications of:

- Understanding of EM and planning uses
- Reasoning for EM flow and use
- Project management

Why does the floor possess the technical documents, such as EMs and planning? Technical documentation governs every task performed on the shop floor, no matter where or when. All tasks must be defined by some regulated documents. In addition, these documents require attention before the start of every operation, due to the variability of EM revisions, which could affect any SOP or set of planning. There are various regulatory agencies around the world, as listed in Table 1: Technical Publication Sources, which all provide different standards for GE to meet with regular activity. Each one helps to govern the technical documents and, therefore, a system must be installed to flow documentation logically through the hands of various employees.

In addition, these regulations create a need for a safe and secure method for housing documents for floor use. This aspect of the project required the team to understand where and when technical documents are used on the floor. On the floor, current and up-to-date documentation must be readily available for every job because of the importance of these instructions. In other words, the floor would be restricted from all production without a regulated system to flow documentation correctly through the facility. Although some operations only require the viewing of EMs or planning before starting, most floor employees use their instructions during an operation. Currently, due to the nature of satellite libraries on the floor, documents are printed in the DC and physically delivered to the floor as updates. As the audits performed by the worldwide regulatory agencies illustrate, the flow does not always run properly, due to system glitches and human error. As a result, the team was tasked with designing a process to flow documentation through Engineers in a way that all current revisions exist on the floor for immediate access. The idea of a digital system and the proposed set up for it should constitute as an effective solution.

The main engineering focus on the project stems from the project management requirements of the tasks at hand. The team has been asked to form one process, which results in the logical flow of documentation and convenient storage of these instructions for all to use. Framework and logic of this process are for the team to determine and analyze until a plan can be set for the repair shop. Therefore, the team has been required to work directly with engineering and hourly employees to understand the uses of this documentation and convince them that a change will benefit the shop. Developing an understanding of the entire flow process serves as a challenge to the team, due to the depth of document control and the lack of technical understanding that exists at Services-Cincinnati with regard to current control systems. The ultimate task to monitor the success of this project is to understand current systems, develop ideas to improve, and implement in an efficient and convincing manner across the facility.

2.5. Roles Effected

Using standardized systems to flow documentation and to house all instructions for the floor will have a massive impact on many roles within the shop. Anyone who encounters an EM for review will experience a change in the way that they access the documents. In addition, those who are responsible for work instructions and ensuring that the floor works to most current revisions will also be affected by the change from satellite libraries to an encouraged centralized location. Lastly, some group will need to drive the changes that are desired and continue the implementation. These roles are the:

- Shop floor (operators)
- Engineers
- VSLs
- Document Center (DC or Document Center)
- Cell leaders

- Information Management (IM)

The shop floor will experience the largest culture change on the digitization side, since they deal with the manuals and any planning/standard operating procedures (SOPs) daily. The operators at CPL and Symmes combined have over 12,500 years of experience between roughly 520 operators (Quality, 2008). With this, many of the operators are comfortable working with the instructions as they currently do, using paper copies to navigate through manuals and planning. In order to gain their compliance, the team must develop the digital system to be simple and easy to navigate through. The team must also have a full understanding of the technical uses for these documents, so that they may be organized in a way that operators can easily select the desired files.

Engineers will be affected because they must adjust their planning online in the potential new system and upload it into a central directory instead of printing and distributing to satellite libraries. Ideally, the digitization project will decrease the time necessary to update planning files and allow the floor to access these quicker than ever before. In addition, the Engineers will be dealing with the culture change on the floor, since the operators voice their concerns to the management within that cell. The nature of a new system will shape the way which Engineers are required to adjust.

In addition, the DC currently replaces EM sections in the satellite libraries as they are received. The team hopes to develop a system to eliminate this distribution method and provide timely EM uploading for all employees who need them. Initially, a change will be time consuming because all engine manuals will require initial uploading to a central system. The hope is to ultimately decrease work on the Document Center side by eliminating steps taken to release documentation to the floor.

The last foreseeable role being affected by digitization is Information Management (IM) because of the need for computer set-up and network drops on the shop floor. In order to provide work instructions online, the aim will be to install hard-wired desktop computers for use on the floor. In addition, this will require extra power, Internet network drops, and the actual establishment of the computers. As the technical "gurus", the IM department should assist in these steps. Once a layout plan has been developed for computers, they can bring the requests to IM for help with ordering the assets and installing them. The IM department should also serve as the technical experts for solving network problems on the floor as they evolve.

For technical publication flow, Engineers will be influenced by the technical publication workflow project, since they receive the requests to review EM changes and adjust other pertinent documents accordingly. As seen in the current system, there are numerous ways to view manual changes; none of which are standardized or IT supported. The goal is to create one flow, which would send workflow requests to each engineer who is subscribed to an engine line when a revision is distributed within that engine. For example, if a engineer is responsible to review a section of the CF6-50 EM, they would be notified of a change in that manual once the DC receives it.

Currently on the Document Center side, the Document Center receives EM changes and distributes them individually to different Engineers. Ideally, the tools used for a new standardized workflow will automatically populate the responsible Engineers when an engine model is selected in the workflow. This would decrease the work on that end, and also decrease the number of inputs for revisions, since the DC currently informs Engineers of individual ATA changes.

2.6. Potential Measurable Effects

To weigh the effectiveness of the project, the team established measures to capture potential benefits of using digital documents to support operations. The ability to show how a project has affected the subject is crucial for success. With this, there were a few different ways to determine potential effectiveness of the digitization project:

- Cost benefits
- Changes in audit findings
- Compliance with GE Aviation standards, worldwide

2.6.1. Cost

The cost analysis for physical materials involves calculating potential annual savings by eliminating the need for excess paper, ink, binders, and the other office supplies that contribute to paper copies throughout the floor. Since the team's research indicates that over 400 binders are currently on the floor, some with hundreds of pages in them, these figures become a real measure of possible value for a switch from paper to digital.

For operators, three time-based metrics exist. The first is the time to walk from workstations to planning/EM books, since this time is best described as non-value added work. Each machinist must walk to a satellite Document Center, located at 17 different places on the floor (1-2 per cell) and locate their book in order to perform their operation. Some of the machines are over a hundred feet from the satellite libraries, allowing for distractions to and from the books. This illustrates the advantages of multiple points of access. The second time-based metric comes from work vouchering: with several computers, vouchering is more readily available, decreasing lines at the end of the shift to clock-out. The ability to have planning and vouchering together at individual workstations should increase productivity on the shop floor.

A related measurable result is the number of access points available to view the planning and EMs from an operator to access point ratio; machine to access point ratio.

Another way to measure the cost savings from going digital is the possibility of cutting down the workload in the DC and, therefore, eliminating one technical librarian. Currently, there are three non-GE employees working in the DC, contracted through a vendor company. This includes one main librarian who is teaching two others the tasks and responsibilities of the DC. Much of this contributes to non-value added time in the Document Center, devoted to training. In addition, the opportunity to eliminate one librarian poses a savings of roughly $46K per year for the company.

2.6.2. Audit Findings

A long-term variable to measure will be the effect on audit findings. The current systems for document control have led to audit findings, by both the Quality team and external regulatory agencies. For definition, an audit finding for document control is a flaw within the process that shows the floor may not be working to current revisions of EMs or may not be complying with other airworthiness regulatory standards. The issues that surround the current control methods concern both legacy computer applications and the points of access on the floor. To illustrate some of these, the team researched some of the findings that are relevant to document control, as shown in Table 2.

Table 2: Audit Findings

Note: *all of the following audit findings were located using an internal IT system used to track GE audit findings.*

Project Component	Audit Finding	Instances	Description
Technical publications – flow of documents	Expired technical plan; Master Menu, April 2008	1	Master Menu was causing the expiration date to show previous to when a document was printed for both cases. Current date should be listed to show an expiration after 24 hours.
	Printing error with expiration date; Master Menu, May 2008	1	
Shop floor digitization	Table of contents doesn't indicate newest revisions to planning; May, 2008	1	Binders should show which revisions are latest in book; was not indicated on front
	Additional books needed on floor; Nov. 2003	1	Books were being shared for two separate operations, so one was unable to view the EM where it was needed
	Uncontrolled documents at workstations; April-May, 2008	2	All documentation for floor use needs a "controlled copy" stamp – not present on papers being used by the floor

Legacy systems are those that were developed to serve a specific purpose in the past and no longer have direct IT support. This is just the case with the Master Menu application, which is a Services-Cincinnati system that was set up to house Engine Manuals and several other applications used by operators, Engineers, and business leaders alike. An employee who is no longer with the Document Center created this system and, while the design fit the needs at the time, no training was left behind to maintain the system. Glitches have caused errors within the system and led to audit findings. For example, a technical plan in Metal Spray cell was expired during an audit in April, 2008 – caused by the "FPS," a Master Menu application failing. In addition, in May of the same year, a system error caused planning to print out with an expiration date predating to the date of print. This is important because printed controlled documentation should indicate that the paper is only valid for 24 hours of use. With the wrong date on the sheet, operators could use the outdated planning past the expiration date, leaving the opportunity to work to old revisions of the manual. In addition, the team has been with GE during numerous instances where Master Menu systems have crashed for days at a time; one system (Metal Spray's FPS) has never properly been restored. The goal was to eliminate the need for these systems.

As far as document control is concerned, the distribution of paper copies to 17 different locations serves as a risk, since there is no definitive way to ensure the distribution of all copies. With this, books are not always updated to show when changes were made. For example, a finding in May 2008 showed that the table of contents in one binder did not indicate the correct and updated revision numbers for EM ATA sections within the book. This is a mistake on the side of the Document Center when distributing the documents and regularly involves misplacement of documents in relevant books. Another finding in November of 2003 illustrated the need for additional books on the floor, since copies of the same section were needed elsewhere while one operator was performing his job. This shows the need for one central repository for information, where numerous employees can access the same documents at one time. Lastly, two findings in April and May of 2008 revealed uncontrolled documents at workstations in use as work instructions. In order to use a document for a job, it must be a signed and controlled copy, marked usually with a special stamp. If they are not controlled copies, then no assurance is available to show their integrity as updated instructions.

A main goal of the project is to eliminate these audit risks by forming one location for all technical documentation and data. With one location, distribution will be less of a risk, eliminating the chance of uncontrolled documents. These findings help scope the project because the team must now find a solution to the option of printing documents, displaying an expiration disclaimer on documentation that may require printing and a tool that displays the date on which the document was last modified

2.6.3. Compliance with GE Standards

As GE Aviation Services makes a push for digital shop floors, it is important for Services-Cincinnati to stay compliant with the direction of the company. The plans of the company show two main systems to control all documentation in GE Aviation: eManuals and SAP. Both are very expensive systems seeing slow implementation across the different shops. Although exact implementation dates are unknown, Services-Cincinnati has sought to study different avenues of digitization to prepare for these systems on the horizon.

The system known as eManuals is currently in use at repair facilities in Wales, England and Strother Field, KS. It shows promise to easily review changes to EMs and include planning directly within EM sections as add-ons and notes. This would eliminate the need for separate controlled documentation and allow Engineers to access one system to review changes and then revise planning accordingly. In addition, the DC work would decreased because EM updates are to be generated automatically with eManuals, eliminating the need to upload all manuals and inform Engineers of the changes that have been made. Currently, Cal and Strother have partially paid for the cost of the eManuals system. In order to implement in the rest of the business, a fee of $50K is required up front from each site, not including the costs to adapt the system to each individual repair shop.

The long-term goal, set now for 2011, is the implementation of SAP. Companies such as Nortel, Nestle, and Hewlett-Packard are examples of large scale, international companies that have embraced SAP for ERP implementation. Exact details about this application on the GE side are minimal, but many large-scale companies have been using it as a standard of process control. One advantage of SAP is it will centrally locate router generation and traveling data sheets as digital documents, which is outside the scope of the MQP. A team is in development at Services-Cincinnati to own SAP and learn about the facets of the system.

With these new projects on the way to further digitize GE Aviation Services, the team is attempting to prepare the shop for larger changes. By introducing digital documents now, a transition to either system down the road will be less of a culture change. One of the largest challenges of the project is convincing the floor that this change is beneficial, along with developing the system structure to match the technical needs of the shop.

3. Literature Review

Before exploring the GE-specifics of this project, the team performed a literature review to understand the history of implementation projects and key aspects of integration. A literature review helps to show points of previous projects so that the team may measure the project against the literature. In this section, the team researched project management, technical document control, and the aviation industry as a whole. As a result, the team gained knowledge regarding all topics and used ideas from this section to guide the project.

3.1. Project Management

In order to qualify as an acceptable senior project, the team examined problems from a project management standpoint. In doing so, there were numerous tasks to delegate within the group and a number of people to include when implementing. Any project that calls for change involves a level of resistance from those affected. Therefore, the scope of a digitization project raised the possibility the team would face with resistance from operators and even the managers that own certain product lines. In order to analyze the methods used to manage a project successfully and deal with different personalities in the workplace, the team performed a literature review to examine how to manage projects and resistance from the main users.

3.1.1. Developing a Plan and Managing

Motivated managers drive project management with regard to implementation techniques. Any implementation project must include five functions (Bradley, 2008). These factors include:

- Planning – detailed plan with thoroughly defined tasks
- Organizing – feasible workload with full-time managers
- Staffing – training those involved and teamwork
- Leading – change management (Laughlin, 1999)
- Controlling – consider feedback and improve

Logically, the idea of a successful project stems from the management behind it. The creativity of management to develop and plan an assignment for improvement helps to spark the interest of other roles involved. An article in the Journal of Information Systems (Nicolaou, 2004) states that involvement in systems development and assessment of business needs have a strong impact on the outcome of an implementation project, since the plan must be elaborate. Without proof of business needs, the project cannot be defined as a potential success for a company. In addition, the planning piece proposes specific goals for a project, which are necessary to staying on track and indicating milestones.

Another important factor when planning a project is matching the IT perspective with the business vision. Ensuring that these parties are in parallel with project plans is vital because, with IT bought in to a project, the management team may use those technical resources as competitive tools (Bradley, 2008). IT knowledge for many applications, including the current plan of shop digitization, can be extremely beneficial to the company and the outcome of any project proposal. Using business plans in addition to available systems with which IT is familiar has proven to be a best practice, which helps to "outperform the competition" (Das & Warketin, 1991). With this knowledge, the team has tapped into the IT resources available at the repair shop in Cincinnati.

When organizing a project, the manager should have an absolute understanding of the business and the reasons for change, even if they do not fully understand the systems proposed to solve the problem (Bradley, 2008). This results from the definition of manager responsibilities, which are to make difficult decisions and delegate responsibilities to those groups affected by the changes. Without the ability to make tough decisions, others either progress slowly with project ideals or resist the changes, due to a lack of strength in the driving forces. For example, Bradley states that Cisco Systems only advanced in their ERP (Enterprise Resource planning) project when the CIO and VP of manufacturing conquered the responsibilities of the organizational tasks. Although the current project does not deal with ERP, the concept of implementing a digital tool for work instructions parallels ERP ideas. Instead of encompassing an entire company with this project, the team deals with document control and the necessary electronic wave to implement. Every implementation project requires a strong manager who can firmly act on different aspects of furthering the project.

To surround the manager, the company must provide knowledgeable employees to act as the project team. In addition, the project manager must be qualified for the task, possessing plenty of prior experience in leading projects (Maciarello & Kirby, 1994). The strength of a project team will contribute to success, since the team knowledge helps to continually scope the project and solve problems along the way. These project management teams should meet at least every four weeks, says Bradley, but no limit is set on the frequency of meetings for progress (Bradley, 2008).

Literature suggests that leading the project is most successful when corporate officials and "project champions" are actively involved with the project, instead of passively approving the goals (Bradley, 2008). A project champion is one who fully supports the project, will do anything to help the cause, and promotes it as a beneficial idea in order to generate support. Bradley also proposes that "CEO participation in the planning and implementation of ERP systems is positively related to implementation project success" since the support is from such a powerful figure. Heavy support and morale for a project are important for the leadership aspect.

All of the above factors contribute equally to the overall success of an implementation project, since the pieces must fall into place in a logical order with compliance on all fronts. For example, a project was undertaken at Drilling International, Inc. to eliminate a legacy software application and replace it by Oracle, a standard software package to perform operations on an open platform for drilling services (Bradley, 2008). The author described the project using the following parameters:

- Discrepancies between IT and business visions
- An external vendor as the project manager, possessing project management skills without an understanding of Oracle
- Weak training for employees with little CEO involvement
- Extreme resistance with skepticism from manufacturing
- No defined project champion(s)

Because of these factors, the project outcome was "successful, but painful." Although productivity and performance initially suffered, the project soon changed this so that ERP improved the production in drilling operations. The gap is believed to be a result of poor planning, based on initial ignorance of the prep needed for Oracle. This project illustrates the troubles that occur because of poor preparation of the five-implementation functions. As evidence to support a very successful case, a similar project took form at Mudco, a global energy services company. With regard to the same parameters bulleted above, the company met all of the functions successfully with no recorded resistance. As a result, the project was a complete success and the project team completed all tasks on time (Bradley, 2008).

One of the most difficult barriers to any project is the resistance piece, which the team discusses in the next section. Resistance plays a role in project management because teams and champions must deal with resistors and capture all concerns to provide solutions. The success of a project depends on resistance and vice versa, as shown below.

3.1.2. Resistance to Change

During any project that adjusts the culture of a company, the project team will feel resistance from various sources affected by changes. At Services-Cincinnati, the demographics of the workforce show minor areas of potential resistance upon project rollout. The following literature illustrates the main causes of resistance, the resisting groups, and suggested solutions to work around the culture change. The team has used this advice to deal with the challenges provided through the implementation project.

Resistance is a factor caused by initial user feelings of a possible change. Companies must plan for this, since "half of ERP implementation failures occur because companies significantly underestimate the efforts involved in change management," as shown in a study in surviving ERP (Appleton, 1997). The project management team must work to define the resistant users early because of the damage they can impose on implementation. For example, in a study to oversee ERP implementation at a small university, Furumo and Melcher noted that failure was due to lack of communication with uneasy team members (Furumo & Melcher, 2006). Some resistance occurs due to employees being "set in their ways" and uncomfortable with the general idea of changing practices. In addition, individuals are identified because of the following reasons (el Ansari, Russel, Spence, Ryder, & Chambers, 2003):

- Poor staff understanding of the material being implemented
- Change fatigue, due to a quick change
- Misunderstandings and lack of respect for management
- Availability and depth of training materials for new systems

Another important factor related to resistance is technology acceptance and the usability of the systems. Technology can be a daunting factor for many users, even when it shows evidence of being a useful tool. Oreg says "individuals with higher resistance to change are expected to be disinclined to try out new things such as new technologies, because even when a new technology can bring significant benefits, the act of learning and using a new technology is psychologically difficult for them" (Oreg, 2003). Especially older users fall under this category, due to recent technological advances. In addition, the two dominant resistance measures in one study were perceived ease of use (PEOU) and perceived usefulness (PU). A group introduced a new digital Document Center to 244 students in order to view the resulting perception of usability (Ye & Nov, 2008). A survey helped to demonstrate these results, which asked the users about the usability of the system and their experience when using it. Each question used a seven-point scale to weigh usefulness, with "1" indicating low usability and "7" as high. Results showed that users are strongly against systems that are difficult to use and create excess work for the participants, based on the spread of response mean-values from 2.55 to 5.40.

In order to fight resistance in a project, several methods can be used to prepare and mediate. First, sufficient project preparation helps to calm the anxiety and concerns of users (Bradley, 2008). When all points of interest and potential problems appear before the team introduces the project then the implementation becomes smoother and easier. It is when users try using ill-prepared methods that they become frustrated and resistant against the management team.

Next, a company should use the aforementioned champions to alleviate resistance levels. As stated previously, champions exist to support the project and sell the product in a positive manner. Generally, champions spend the majority of their time "communicating the vision, maintaining motivation in the project team and the business, fighting political battles, and remaining influential with the stakeholders, including senior management" (Willcocks & Sykes, 2000). These actions help to capture concerns early and present the project in a beneficial way.

Lastly, ensuring the simplicity of implemented systems may reduce usability concerns. When introducing new material to users, the change needs to flow smoothly and the project must be convincingly beneficial. Therefore, the system must be easy to use from the start, proving that the switch will not substantially affect the operations governed by said system. Understanding the need for simple systems will "create a better fit between users' personal characteristics and the systems' design, look, and feel" (Ye & Nov, 2008). The usability of a system ultimately depends on the design of interfaces (in the computer-system discussion) and the training available for users. Without these main components, perceived ease of use will suffer and the management team will deal with increased resistance.

3.2. Mutually Dependent Processes: Tech Pubs Review

The Process

The use of technology to track and assist group processes is known as Computer Supported Cooperative Work, or CSCW (Grudin, 1994). Two issues are apparent with the current system: Of primary concern, the current Workflow Management System (WfMS), Master Distrib, is setup as an ad-hoc workflow system supporting only the single, highly-routine organizational process. Second, as is typical with evolving workflow systems (Keen & Morton, 1978), any new system must be able to handle cooperative control of dynamic, individual processes.

While a fully dynamic, interactive workflow system is not needed as depicted in some research (Bernstein, 2000), the Workflow must retain control of each step in the timeframe of the individual review processes as well as provide direction for individuals throughout the process.

As each Engineer is assigned to work with a specific product and a specific work cell, their work output is unique and loosely defined on a group level. The cooperative group process defines only the timeframe of these individual processes, a limit which must be met by all for any to proceed. Several external software packages exist suiting this need: ProZessware (ONEstone, 1998), Bramble (Blumenthal, 1998) and FreeFlow (Dourish, Holmes, MacLean, Marqvardsen, & Zbyslaw, 1996), among others. The specification of an internal program eliminates such options

As benchmarked with the Caledonia, Scotland - Engine Overhaul Shop, the option exists to use an E-mail based system (Halliday, 2008). Though using E-mail distribution and Microsoft Outlook's "Vote" buttons supports an ever shifting, non-standard process, users are required much preparatory and organizational work: a list of subscriptions must be physically maintained, the correct users must be E-mailed, and the end-users must track their own in-process status.

The Culture Change

There are two facets to the culture change: prior experience and ownership/ responsibility. The main driving force of the change is a benchmarked standard from Wales and Strother, as well as the new digital manual system: Engineers will begin being notified of any revision to a manual rather than only those sections they are subscribed to. Prior experience, as predicted in "The Role of Prior Experience," (Taylor & Todd, 1995), has led the majority of resistance to stem from users experienced with the old system; minimal resistance comes from those newest to the system.

To drive the culture change, a Technology Acceptance Model may be used to aid in the design of the utility to properly suit the end-user, as well as promote the acceptance of the end-user through cooperative design. (Davis, 1989). The key driver is to increase perceived ease of use and usefulness, which permits an increase trending individuals to use the system, allowing them to see the actual system use (Venkatesh, Morris, Davis, & Davis, 2003).

3.3. An Always Changing Aviation Industry

Aviation is a constantly changing industry that depends on a wide variety of variables. Some of these variables include price of oil, FAA regulations, restrictions of gas emissions and an unpredictable aviation market. Currently, the main and most noticeable effect that has influenced most industries is the rise in the price of oil. Also known as "the Bush boom", the price of oil has increased from under $21 per barrel in February 2002 to easily surpassing $100 per barrel setting an all time inflation record (The Price of Oil, 2008). With this, the maintenance, repair and overhaul (MRO) companies of aviation services continuously merge and create partnerships to be competitive. A quote from Snecma's CFM Executive Vice President,

> *"Also, a difference in our strategies on that bigger segment, the narrow body application, is our partnership with GE for CFM. We already are preparing together the next generation of engine. On the high side, Snecma is not the size to be able to manage such an engine program on our own, so our preferred partner is and will continue to be GE. On the regional and business jet side, we have a goal to be an engine maker. Of course, we are looking for partnership because in today's world nobody is designing and manufacturing an engine 100 percent on its own. We have been doing that with SaM146, with NPO Saturn, and we will be looking for partners on the Silvercrest, as well. But on the Silvercrest, we want to retain the majority of the engine." (Tegtmeier, 2008)*

In the US airline industry alone, there have been more than 22 merges. One of the largest merges was between American Airlines, British Airways, Canadian Airlines, Cathay Pacific, Quantas, Iberia and Finnair to create the Oneworld alliance. This alliance alone carries 206 million passengers a year with a fleet of 1,783 aircraft (Aharoni & Nachum, 2000). This shows an industry strategy that will continue for some time to come.

Competition is strong and companies continue to find ways to lean out their current processes to find cost reductions. Outsourcing has continued to grow while shops are trying to cut costs. Sometimes it is more cost efficient for a company to outsource, also called vendor programs, to another company that already has the proper overhaul equipment for that particular engine component. The use of vendor programs alone increases this idea of alliances between companies (Aharoni & Nachum, 2000).

The three main OEM companies are General Electric, Pratt and Whitney and Rolls Royce but there are still many more competitors. Competitors continue to emerge challenging the costs and services of the major competitors. There are two main threats that every OEM must be aware of. The first threat, mentioned previously, is the growth of competitors. The second threat comes from the reliability and efficiency of newer and more technologically advanced engines. As the engine's run longer hours before overhaul, the less engines the shops will have to repair.

Staying in business is becoming quite difficult as the aviation industry is enduring difficult times. North America has the largest aviation industry and most affected by these changes. Aviation has always been a cyclical industry, but this down-cycle has been the most severe in aviation history. " The U.S. major airlines have over $100B of debt, with a market capitalization of only $3.7B. In the last two years, the global airline industry has lost approximately 30 billion dollars, another $2.5 billion this year." (Brandt, 2004)

With an industry in a lull, it is important to identify the leaders in the business and the companies that continue to survive economic hard times. Looking at the pie chart below, one may easily notice the world leaders for regional jet engines and the great shift in market share units in just ten years.

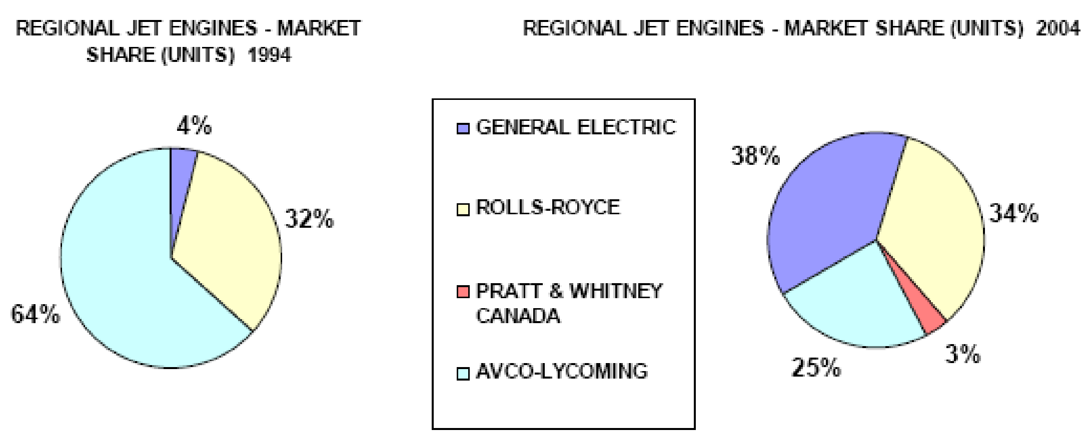


Figure 2: Market shares over the last 10 years

Predicting such an industry is difficult, but it is important to try and understand what the future has to hold to make obvious changes and stay competitive. There are many consulting companies that are dedicated to predict such an industry. This helps both smaller and larger companies stay in business. The Figure 3 shows such predictions that companies will use.

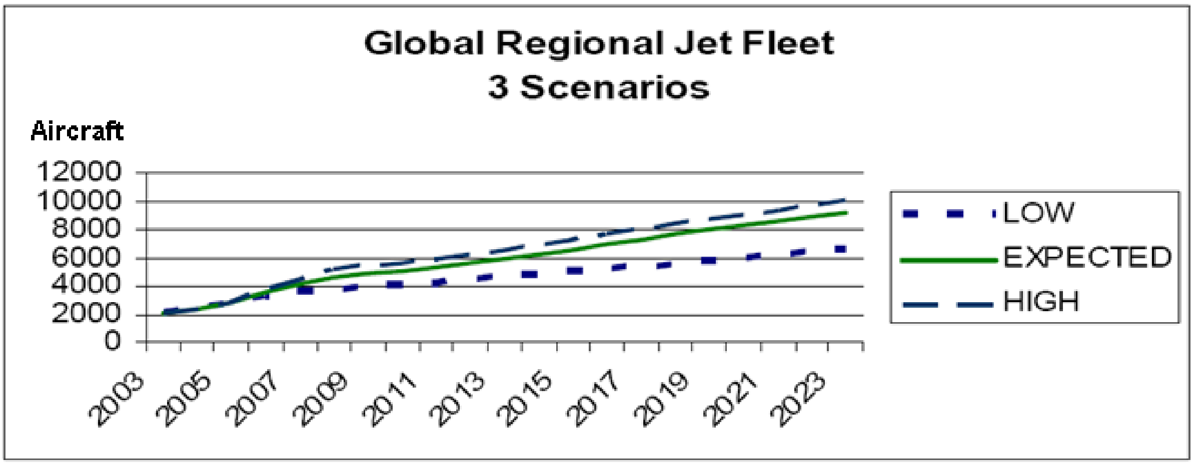


Figure 3: Predictions for Regional Jet Fleets

The graph lays out the global regional jet fleet number predictions in three different scenarios. An expected number of regional jet fleets plus both a high and low number that this industry may see in the years to come. This particular graph will help MRO companies predict the jet fleet to come, so they will be best suited and prepared to handle the future, while either increasing or decreasing their own resources for the industry.

Attempting to predict the future is not the only way MRO shops stay competitive. Advancements in technology and software also help. Numerous companies are going digital, eliminating paper and thus eliminating inefficiencies in their operations (Elsner, 2004). With this as technology advances, so will the digital equipment available to all operators. Taking a look at some of these advancements helps us understand the effects these tools will have and help shops stay in business.

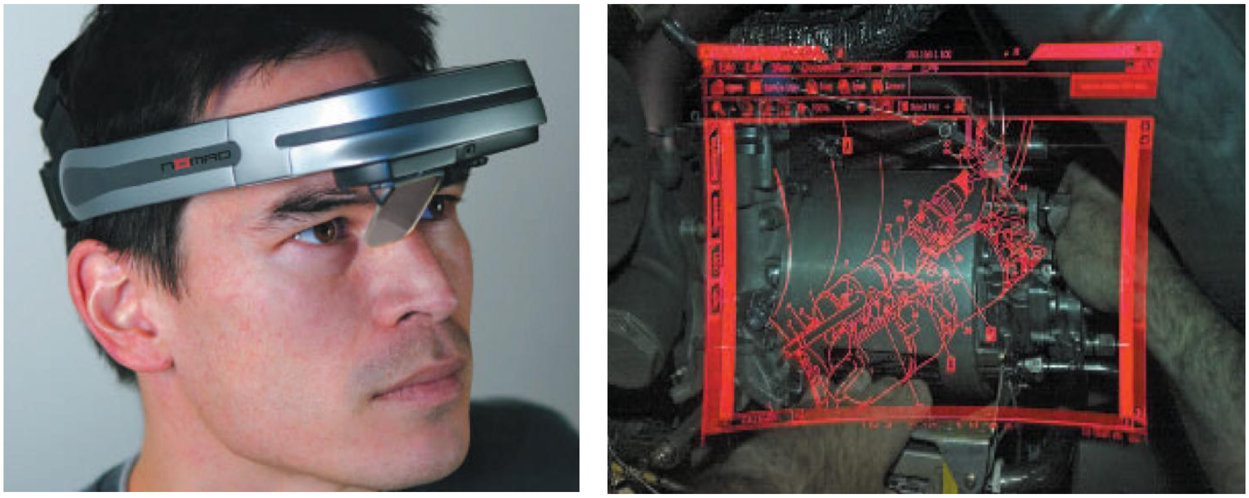


Figure 4: Headset optical display device

"The Nomad Expert Technician System allows technicians to superimpose text and diagrams from electronic service manuals directly over their workspace," says Martin Elsner, a field service director for aerospace and defense. "Weighing only 4.5 ounces, the Nomad head-worn Display Module can either be mounted under the brim of a cap or integrated into a headband (Elsner, 2004)

This is just a glimpse of some technology available to shops. Although it may not work for all, this is just an idea of where technology is today and a thought of where technology will go in the future to come. With technology advancing at a fast pace, the first step for MRO companies will be to take the initial steps of becoming digital. Having a plan for the future will require companies to plan ahead for digitization.

This brings the team to the digitization plans for GE. The project entails the initial steps a company will take for the start of a digitized shop. SAP, eManuals and other systems are also in the future to come, but companies should take smaller steps towards the future. Becoming digital involves a lot of work, but is a step in the right direction to remain competitive with the other modernized MRO shops.

4. Methodology

The goal of this project was to set in motion a culture change toward a digital shop floor and sustainable technical document review workflow. The success of the project depended on realizing both goals independently; thus, the project has been split into two components: Shop Floor Digitization and Document Flow Control. Within each component, the team has broken down the project to 3 steps: plan development, testing of selected systems, and long-term implementation. Due to the layers of analysis for each component, the team had to plan for continued use of these systems after the project period, including the roles responsible for certain tasks. In addition, the methodology includes a section that describes the steps taken to measure the impact of the project. This methodology explains all steps taken to gain necessary information and mold the project successfully.

4.1. Shop Floor Digitization

4.1.1. Developing the Plan

In order to form the plan for shop digitization smoothly and using best practices, the team first developed a thorough understanding of the subject matter. The process of document control and the flow of documentation through the shop started as a foreign topic, requiring the team to discuss the details of the project in depth with numerous sources. In an attempt to gain full knowledge of the Services-Cincinnati document control systems, the team utilized people, potential systems for use, and benchmarking with other shops. Utilized methods to determine this information for both portions of the project are listed in Table 3.

Table 3: Developing the Plan – Strategies of Gathering Information

Strategy - *Who*	Contact – Reasoning
One-on-ones, discussions - *Individuals having general knowledge of problem; closest affiliates to project; affected by potential changes*	Quality Business Leader – Project manager; provided guidance coming into company and direction for project goals. Responsible for initial project kick-off, she served as the main source for systems knowledge, problem information and expert contact information. Regular meetings served to continually adjust scope and plan the next steps.

Table 4: Developing the Plan – Strategies of Gathering Information (Ctd. – ii)

	DC Specialist – Key individual for document control; alternatively known as "main technical librarian." First-hand knowledge of the systems influenced by the project. She proved to be a crucial piece of the project as her input for the new system was of concern, as she had to understand it and use it for continued document control once the team departed from the shop.
	IM Leader – Project contact and lead for IT related matters. Aided in analysis of system options, computer availability and technical matters. He possessed a thorough understanding of GE IT systems leading regular meetings to develop sensible system as well as strategies for implementation of the systems.
	Engineers (see below)
Focus groups - *Main roles being affected; spark discussion about digitization; share initial feelings*	Engineers – Particularly affected by the culture change of both components. Initially pulsed individual Engineers to gauge comfort, ideas and opinions, considered during systems planning. Meeting held with all Engineers; risk analysis performed; "threats vs. opportunities matrix" completed; all questions, comments and concerns captured for further review; end of discussion risk analysis performed to measure comfort level shift after discussion.
	VSLs – As a whole, own the function of the shop, along with Plant Manager (also included in meetings); ultimately oversee the culture change across the shop. With all gathered, initial risk analysis performed; "threats vs. opportunities matrix" completed; feedback captured; end-of-discussion risk analysis performed. Discussed rollout plan, decided on pilot cell.
Floor discussion – Focus groups and One-on-ones - *End users; Individuals most likely to voice concerns and questions early; must ensure preparedness for the change*	Operators, DCAs – Digitization here had the most profound culture change effect. Kick-offs at cell production meetings were held emphasizing the project scope; what documents will and will not be involved; the complete one-on-one training to be provided; the deliberate, reserved transition timeline. Feedback varied greatly from positive to negative, with proponents noted as potential assistors or leaders and those with concerns noted for continued discussion. In prepping for implementation, one-on-ones aided in realizing individual training needs, terminal placement, and naming conventions for files.
Walkabouts - Mapping computer placement - *Best understand needs for computers, hardware, net-drops and power needs*	VSL – As owner's of the production cells, each VSL was given the final say with regards to computer placement through a walkabout on the shop floor. Operator suggestions previously attained proved helpful if not essential; space concerns were worked out as necessary; special needs (monitor arms, dual monitors, etc) were considered case-by-case. Locations were marked on a flop map.

Table 5: Developing the Plan – Strategies of Gathering Information (Ctd. – iii)

	IM/IT – After finalizing computer layouts, a walkabout with the IM/IT leader to facilitate the location of network and power drops. Visual aids, short sections of tied caution tape (network) and colored tape (power), hand-noted locations with references, and a marked floor map provided the necessary information for contractors. After confirmation of expense and budget information, aided in placing necessary orders.
	Maintenance/facilities – Followed through process of installing power drops, necessary computer hardware and furniture; ensured Environmental, Health and Safety concerns were met.
Testing systems - *Front-end users able to best determine most effective systems; End-users to provide initial test of functionality, ease-of-use*	IM – Preliminary testing completed in conjunction with IM Leader to test basic level functionality of both systems. Electronic Document Center system tested using dummy files, terminal server access. The Tech Pub Workflow was tested for functionality by placing project members into "Engineer" positions within Workflow; each routing option tried to ensure functionality.
	Document Center – Tasked with uploading manuals into electronic Document Center for test purposes. Dummy document workflows submitted in Tech Pub Workflow to further test functionality of loop and "wait-for-all" functionality.
	Operators – End-user test with specific users, then single cell; during test, one-on-ones and focus groups used to develop understanding of user needs, perceived usability and behavioral intention.

4.1.1.a Benchmarking and Leveraging

- GE Aviation repair facilities around the world have been exploring similar projects to this idea of shop floor digitization. While some shops are still in the planning phase of such a project, others have already implemented computers and have their floors working on electronic manuals and planning. For this reason, the team benchmarked with other shops about the systems used for document control and the methods used when incorporating computers;

Table 6 explains who the team spoke with and about what.

The other shops that the team contacted, listed by location:

- Caledonia, Scotland
- McAllen, TX
- Strother, KS

- Tri-Remen, IN
- Wales, England

Table 6: Developing the Plan - Benchmarking

Benchmarking - *Contact with other GE Aviation repair shops to understand the systems which they use for document control*	Benchmarked with three groups across 5 other service shops Quality – Description and understanding of each shop, including roles and procedures. Proved vital as liaisons in contacting individuals knowledgeable about specific systems (IM/IT and Document Centers). IM/IT – Relating current GE Engine service software utilized at each shop. Aspects of functionality, support necessitated, and procedure discussed. Future GE Aviation-wide systems discussed to ensure any developed systems will be compatible or require minimum rework. Document Centers – Practices of other shops analyzed: number of documents processed, number of persons handling document control, specific process (predominantly Tech Pubs Review) and audit control considered. Us-them discussion with each shop realized comparative strengths and faults.

Through discussion with these locations, the team was able to develop an understanding of the current systems elsewhere and, for those digital shops, gain tips on implementation strategy. The team started by sending other shops meeting requests over e-mail or Sametime, a GE internal messaging system. During interviews, the team inquired about the current tools used for control elsewhere and the steps taken to develop a practical method. Outside opinions and ideas helped to shape the project and clearly demonstrate problems to be aware of when setting up for an electronic floor.

Tools

Since the team had no prior experience with document control or the available systems to suit the needs of the project, they had to determine the best system available for storage purposes in various steps. In addition, the team was required to provide standard guidelines for computer placement on the floor, the programs that operators should have access to, and any other access topics which the project illustrated. As a shop within GE Worldwide, an enormous corporation, the IT team is required to thoroughly examine GE IT systems for use. In addition, the team had to provide EMs/planning so that the shop can be compliant with FAA regulations. These factors helped to shape the project for the team.

IT Support

As part of regular discussion with the IM Leader, the team was provided advice on available GE systems to serve as the main document housing programs. These systems would help with maintenance and also provide security if required to use personal GE accounts. For advice on this topic, the team met with IM about the potential systems that exist, and also dissected the options of shared drives and extra servers at Services-Cincinnati for document storage. This meeting left the team with one storage tool for floor use.

Computers

In order to provide all operators with a convenient way to view planning and manuals, the team created a layout for computer placement on the floor. Although this did not require a computer at each individual workstation, the terminals should be placed wherever an operator currently needs to view their planning. To determine this ratio, the team visited each cell separately and found out where the operators bring the binders to perform jobs. The team used floor maps to indicate placement, provided by a contractor at CPL who controls the floor layout. Also, the team discussed the floor plans with Engineers to receive their input about terminal location. Once these numbers were determined per cell with a layout, the VSLs had the ultimate say in where computers were placed. VSLs are responsible for the assets in their cells, which includes the computers.

Additional hardware for use on the floor were also mapped out for the selected test areas and used to test functionality during the pilot sessions. To run computers through a shop, extra accessories are always required. Needs across the shop determined the placement for these, as some workstations required computers but need a moveable arm to place them where needed. The goal was to develop standard factors that constitute the need for extra hardware. With this, hardware has been included in an implementation plan.

4.1.2. Setup for Continued Digitization Implementation

In order to completely digitize CPL and Symmes, the team developed a continued implementation plan in the form of a timeline that covers:

- Delegation of responsibilities

- People involved
- Resources available
- Methods used to solve problems involved with digitization per cell

Initially, the team performed a digitization pilot to underline any problems along the way, different situations that could possibly appear while keeping a record of the different variables that involve digitizing a given cell. This timeline covers all tasks addressed during a given number of days within the overall time. Initial pilots at both CPL and Symmes helped to form a strong plan for the ensuing cells. A post-mortem and analysis helped to improve and finalize the overall cell implementation timeline and procedures. With a plan to implement each individual cell, the team developed an overall timeline and plan to digitize each cell completely at CPL and Symmes.

4.1.2.a Individual Cell Implementation Gantt Chart

The team created a detailed Gantt chart that describes all of the roles involved in the implementation plan. In order to develop this chart, the team took note of all tasks performed in initial pilot cell. Due to the intense interaction with the floor during this pilot and the knowledge of a general implementation plan, the team was able to explain this process in depth. The Gantt chart includes the initial introduction to the cell, all the way to the removal of binders from Satellite Libraries. The format is a timeline that places tasks for a given role and the number of days an individual role has to complete the responsibility. In addition, the chart illustrates the various tasks that overlap. Various tasks include activating user names and resetting passwords, uploading planning, ordering computers, network drops, and other specific computer needs. Using this Gantt chart, the team conducted a second pilot in order to view the accuracy of the implementation plan and any gaps that existed. This "implementation pilot" focused mainly on the delegation of tasks, since the employees associated with each cell must drive the changes. The Gantt chart assigns these responsibilities based on the roles that the team determined to be best fit for the different tasks. In addition, the input of the QBL and the roles affected helped to develop a strong plan for the different employees to implement. These factors helped to improve the plan that the team formed initially.

4.1.2.b Future Cells

After developing the timeline for an individual cell implementation, the team needed to choose the future cell strategically. The future implementation cell was selected in an effort to not interfere with company productivity, while still performing the operations to thoroughly test the new system of work instructions. In order to avoid implementation during highly productive periods, the team made an effort to eliminate piloting during weeks at the end of months. Each month, the repair shop must meet certain shipping requirements and, therefore, is busiest during this time. The team had to look at the number of cells, days to implement a given cell and delegated tasks. Working with the assigned management, a timeline outlined the entire digitization process for implementation elsewhere.

4.2. Control Flow of Documentation

There was a need for a new system to control flow of documentation because of legacy issues, IT support, and constant functionality problems involved with the outdated legacy system being used at the repair facility. Due to this, the team looked to create a system with IT support that maintains the same basic ideas of the old system used. The team held discussions with VSLs, Engineers and the Document Center to gather enough information about the functionality and problems involved with the current outdated system. With enough knowledge of the outdated system, the team searched for a solution through benchmarking other GE Service Shops and other GE supported systems that IT would support.

4.2.1. Developing the Plan

4.2.1.a People

In order to determine the individual roles in the documentation workflow and the different functions those roles are responsible for, the team held discussions with the following groups:

- Document Center
- Engineers
- Value Stream Leaders
- Quality

This was necessary to fully understand the current system before the team could search for a completely new system. After discussing the project goal with these individuals, the team was able to form an idea of what a deliverable system should include and the functionality that it needs. Next, the team moved on to further the understanding of these document control systems.

4.2.1.b Benchmarking

After developing a strong understanding of the technical publication flow at Services-Cincinnati, benchmarking with other GE service shops was necessary to find other GE supported systems. The team compiled a list of GE engine service shops and started interviewing employees elsewhere. The purpose of these interviews was to link the practices of service shops to see which given systems had the functionality to hold the requirements of our own shop. In addition, leveraging best practices was key for developing the project. When contacting other facilities, the team aimed to reach Quality Leaders and technical librarians where available. These two groups possess a thorough understanding of document flow tools at their shops. To understand document flow at other shops, the team asked the following questions, in addition to others which arose within the conversation:

Interview questions

- What Engine Manuals are you subscribed to?
- What are the types of incoming documents that you receive?
- What are your overall steps with incoming documents?
- What system are you currently running to flow technical documents?
- Are you currently on a paperless system?
- What is your level of digitization on the shop floor?

- Do you guys currently have a distribution list? If so, how is it controlled?
- How do the Engineers sign off on documents?
- Do the Engineers have a set time to update their planning?

4.2.1.c Systems

The new IT supported system was required to hold all functionality of the old system, as well as suit the needs of a service shop that is subscribed to every GE Engine Manual, in addition to various others. With this, the team held group discussions with all the people involved and lay out all of the positives and negatives to find the best system. The purpose of these discussions was to evaluate the necessary steps for a potential system. Certain aspects of the current flow should not change, based on the best logic for revisions to reach the floor. To capture these stages and include them in a new system was a crucial step in developing the new document control process.

After ensuring that all of these functions were feasible, it was necessary to create a Threats vs. Opportunities chart (see s) while brainstorming during our focus group with the people involved in the work flow. This tool helped to weigh both the positives and negatives gathered. The last step in defining a system for GE internal use was a discussion with the IM Leader about available systems for the purpose of document control. This role helped due to his expertise with IT systems and overall knowledge of the company, including the need for such a process. The team used a Decision Making Worksheet (see Appendix B: Decision Making Matrix) to lay out the choices available and the criteria with both the givens and wants. This tool allowed a quantitative measurement of all the current systems for a better decision-making process. After performing the stated actions, the decision was made for the system which would be best suited for Services-Cincinnati.

4.2.1.d Develop Flow Template

Given the selected system, the team was required to develop a test for document flow through the shop. The test included sending fake notifications of new revisions between the three-team members, in order to test the functionality of a control application. In order to form this template, the team met with the IM Leader and determined the necessary facets of the system. This involved the functionality to inform multiple individuals of a new revision and the ability to recognize when all responsible Engineers have approved their sections for review. There were various concerns to be captured by a tool to control the flow of documentation through the company. Since IM assisted in defining a system to fit these needs, his knowledge and expertise was valuable in explaining the program and it was therefore created to fit the project needs.

In addition, the leveraging done to explore available systems aided in forming a standard for document control. When benchmarking, the team explored document control systems at other sites and were able to highlight some that would work similarly for Services-Cincinnati. Once identified, the team reached out to those shops for help in understanding the program. With the cooperation of other shops, a similar system was created to serve as a solution to the technical publication flow.

4.2.1.e Introduce to Document Center

Once a plan was developed and the team had a document control system ready for testing, the DC was given the opportunity to review. In addition, the team delivered a training packet to the DC early for review and feedback on the clarity of the instructions. Due to the involvement of the DC, the main librarian was able to explore the system and point out areas where it would clash with a system called tollgate, which the DC uses to keep track of received EM changes. She also provided feedback to establish a more user-friendly system layout for any technical librarian to use. With this responsive information, the team was able to rework the document flow system to work for all pertinent GE employees and roll it out to the business.

4.3. Potential Measurable Values

As explained in the background, there are different measureable factors that the team wanted to evaluate by the end of the project. These values help to show the effectiveness and reasoning for the project, which is ultimately to cut costs and improve the quality of document control within the repair shop. In order to whey the effects of the projects, the team must analyze what impact digitization has on the following:

- Cost
- Audit findings
- Compliance with GE Aviation

In studying these different effects, the team was able to determine the amount saved by GE in making this switch.

4.3.1. Cost Analysis

Cost for document control accrues from various sources, depending on the system used to control the process. Due to the system of paper distribution, costs include office supplies used to print the copies and then distribute them in directories on the floor. These costs also include the time used to locate said paper documents and the work in the Document Center that controls all of these operations. As a result, the team took on the task of comparing the costs involved with the current system and the proposed paperless floor format. To calculate an actual number for savings from locating documentation, the team formed spaghetti charts and took note of time for floor employees to walk to satellite libraries and select necessary instructions. In addition, the paths for the DC to the 17 different libraries were mapped in order to highlight the time taken to distribute these documents. Then, using the number of EM sections revised weekly for shop use and Document Center compensation, the team was able to calculate an estimate for costs saved.

In addition, the team attempted to measure Document Center productivity as a result of the digitization and document flow. The change in systems has altered the work scope of the DC and, therefore, the new system should in theory cut down the amount of labor for the technical librarians. With enough evidence, the team could suggest to release one out of three librarians, since this seems to be standard at other repair facilities. This measure is over a long period of time, since immediate effects cannot suffice as the sustained workload. Instead, immediate work illustrates tasks done to maintain two systems while the transition from paper to paperless is in process. The company will be reminded to monitor the activity in the DC and make a decision on the Document Center staff. The guidelines to base this on are defined by the DC workscope, as defined in the contract between GE and the vendor.

4.3.2. Audit Findings

Another long-term measure of success is the effect of the project on audit findings. As observed earlier in background, the current systems cause numerous regulatory issues and, as a result, the company must take action to stay compliant. In order to solve this, the project components are being exercised through the repair shop. Although it is difficult to measure audit risk as an immediate effect, the long-term impact on audit findings will illustrate the success of the project from a regulatory standpoint. Once again, the QBL will be on notice to weigh the sustained effect on audits that the project causes.

4.3.3. Compliance

The direction of GE Aviation - Services shows a digital horizon where all operations and documentation are accessible via the computer. As previously discussed, the two main systems in the future will be eManuals and SAP; both of which are used to control documentation for the use of all employees. Because of these future programs, GE must prepare for changes with a project to convert to digital shop floors. The digital standard has reached Services-Cincinnati and, as a result, the project may be evaluated by its level of compliance with the industry. When considering the costs included with new computers and network drops, the future must be considered, since eManuals and SAP will require implementation of more computers on the floor. The electronic age for EMs and work instructions is coming and, as a result, this project proves as an excellent stepping stone for the future. The level of implementation when complete has evaluated this variable, since the goal is to stay compliant and make a strong push for a digital format.

5. Results

In this section, the team discusses the digitization and workflow results, providing specific instances to support the conclusions and recommendations for GE. Mainly, the results outline the following:

- Discussions with various focal groups
- Tools used to help plan the project structure
- Firm decisions with reasoning
- Different functionality pilots
- Plans for continued implementation

As the previous sections illustrate, the results split into the two main project components to distinguish between the processes. In addition, a section has been included to describe the steps taken to determine metrics and project measurable effects.

5.1. Shop Floor Digitization

5.1.1. Systems for work instructions

Work instructions (planning and EMs) require a specified system for control and maintenance because of their importance on the shop floor. In order to decide on a system for storing all technical documents, the team first researched the instructions and their vitality to all operations. As per FAA regulations, the EM section or planning operation associated with each job must receive review before the start of that operation. The reasons for this are to ensure no recent revisions and to understand the requirements of the operation beforehand. Without a system to control the use of updated work instructions on the floor, no evidence supports the maintenance of current documentation. Therefore, the project team and IT worked to define and strengthen a control system.

Discussions with IT professionals and other engine repair shops helped the team to evaluate the different available directories. After understanding the problem, the team determined two possible solutions for document control: GE-IT supported systems or an independent shared drive, much like the current system at Services-Cincinnati. The IM Leader explained that the current shared drive had insufficient space to house all necessary documents and that the IT department wanted to eliminate the drive. In addition, the IM Leader justified the use of IT systems by specifying the level of security ensured through a Single Sign On (SSO) number and password, and corporate support to protect the system and keep it running as often as possible.

When determining the best IT system for document control, the team explored different options for file uploads and the ability to create specific folder architecture for all work instructions. The IM Leader provided advice to investigate SupportCentral, which includes several systems within and the company uses as the main document control tool. IT guaranteed that GE Libraries had "infinite" space and the ability to contain all necessary documentation for both CPL and Symmes. The ideal situation was to upload all instructions onto one centralized system for all relevant Services-Cincinnati employees to use, which GE Libraries provided. Therefore, in order to begin learning the system and developing appropriate folder architecture, SupportCentral's **GE Libraries** was chosen as the choice system for shop floor digitization.

5.1.1.a Folder architecture

GE Libraries has the functionality to develop directories, folders, and upload files to specified locations: much like the folder set-up in a drive on any computer (ex: C:\ drive). In addition, it allows one to form the desired folder architecture on the hard drive of a computer and upload the entire directory to an explicit location in the system. This is beneficial for document maintenance, as the Document Center and Engineers are responsible for providing EMs and specific planning to the floor, respectively. These groups, using this feature of GE Libraries, may form this architecture initially and then mirror it with the system to ensure all pertinent documentation is current and available for floor use.

Upon entering the GE Libraries homepage, users view the main directories that they have permissions to access. For Services-Cincinnati employees, this directory is **eDocs**, named to abbreviate electronic documents, as shown below:

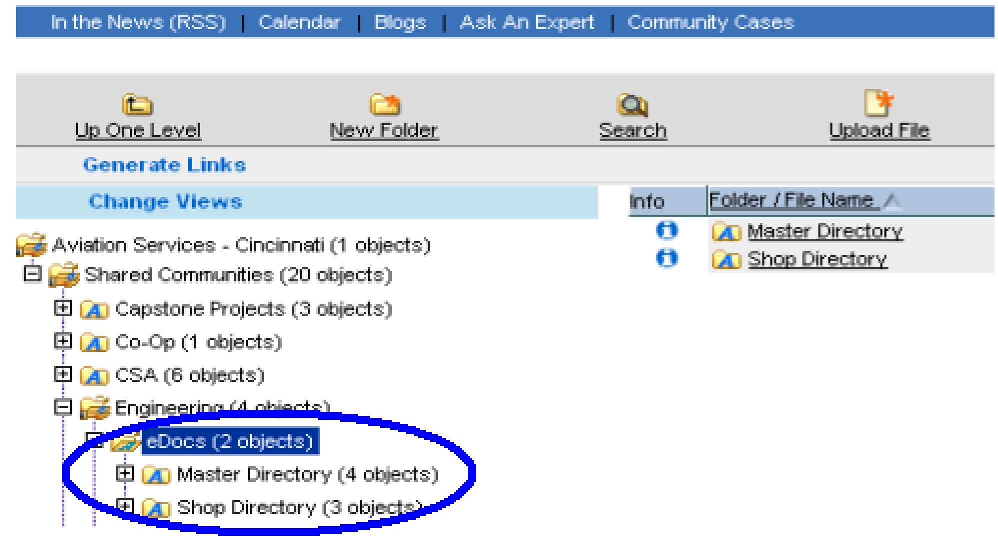


Figure 5: Main eDocs folder in GE Libraries

This main directory contains many layers, demonstrated in Figure 6. The architecture shown illustrates the directories used separately by Engineers and the shop floor. They mirror each other to ensure that all documentation resides neatly in the same location on both directories.

This sample architecture helped to differentiate the responsibilities of the Engineers/DC and the shop floor, as their use of the system is completely dissimilar. The team developed the Master Directory as the "working" directory, used to check out an item so that a file modification may occur. Once there is an adjustment, the Engineer or DC is to replace the old, outdated file with the current revision on the Shop Directory, which is accessible to the entire floor for access. Since these two main directories match each other, managers can easily guarantee that they have supplied current revisions in both places.

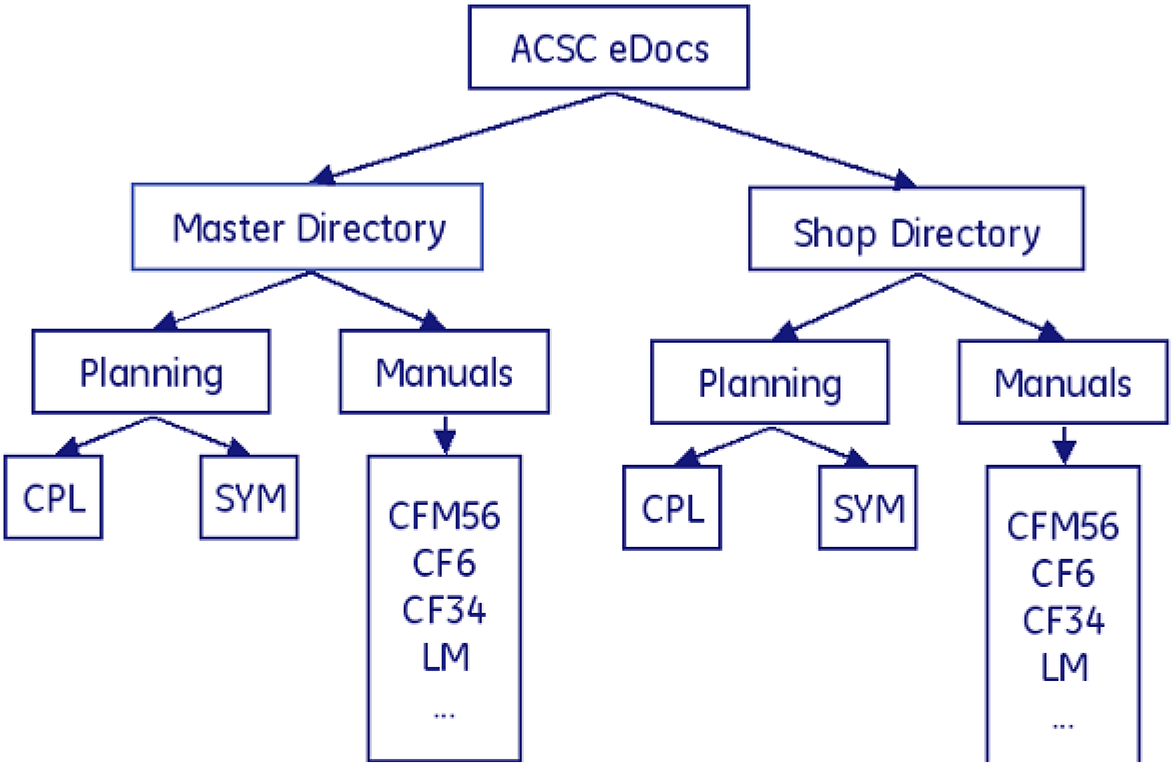


Figure 6: Original folder architecture

The planning side of GE Libraries includes all specific work instructions that derive from different EM sections. Each cell has its own planning folder, which may contain SOPs, data sheets, or no documents depending on the cell. On the other hand, the EMs were to be input by engine model instead of matching different ATA sections to individual cells. This decision helps the DC, since the technical librarians can simply upload the entire EM at once straight from the CD, or neater folders developed on the librarian's hard drive. The initial plans were for the Engineers to control planning maintenance, while the DC would preserve the EM section.

5.1.1.b Shortcuts

Accessing the Shop Directory from the GE Libraries homepage involves navigating through many levels, which are irrelevant to the project. In order to help the floor and increase the ease of use, the team explored avenues to creating desktop shortcuts to different folders within the system. As a result, the team was able to form shortcuts to any level folder on different desktops, depending on the most frequently used folders at each individual computer. For example, the Sumps and Seals planning folder contains all data sheets for that area. Therefore, the team helped all operators in S+S to form the shortcut to this set of data sheets. The use of shortcuts allows operators to navigate directly to desired folders without causing confusion en route to reaching the necessary files.

5.1.1.c Management of member rights

Another benefit of this IT tool is the management of member rights, controlled by the administrators of the main directory. GE Libraries allows delegating rights on four levels for anyone with a GE SSO login:

- Browsers (Browse only)
- Readers (Read only)
- Editors (Read, write)
- Managers (Read, write, modify access lists)

The team granted management responsibilities to the IT department at Services-Cincinnati, the Quality team, and themselves as the WPI project team. Engineers and the Document Center possess Editor rights on the overall eDocs folder, since they need to edit on both the Master and Shop folders. All operators have Reader access to the Shop Directory only, in order to eliminate the use of the Master Directory while Engineers are updating their work instructions. Table 7 below illustrates the hierarchy:

Table 7: Access rights to digital Document Center

Rights	Group(s)	Folder applicable
Browser	NONE	NONE
Reader	Operators	Shop Directory
Editor	TCs, DC	eDocs
Manager	IT, Quality, WPI team	eDocs

The ability to delegate these access rights creates a level of security for the folders, since managers may control the ability to view different sections. For example, the shop floor should not use the Master Directory at any point and, therefore, they lack access to this level.

5.1.1.d File types

The folders and directories in GE Libraries have the ability to house various file types. Initially, the team planned to use the system specifically for PDF files and Microsoft Office tools: Word, PowerPoint, Excel, etc. Engineers use these file types to create and adjust planning/SOPs because of the ability to include disclaimers, such as an expiration date for a printed document. In addition, most EMs were received by the DC in PDF format; individual files representing ATA sections, Service Bulletins, Incremental Changes, etc. The task of uploading EM sections to GE Libraries became difficult for the DC, since each EM upload lasted anywhere between two and four hours. In addition, the files cluttered each folder, leaving the operators to skim through hundreds to thousands of documents until they found the desired section. In an effort to fix this, the team tried a method of forming folder architecture for each EM on the hard drive of the main librarian, which mirrors with GE Libraries as the new appearance of the manual. Within an EM, the ATA sections are arranged as three main numbers, separated by a dash (-). To reduce clutter, the plan encompassed separating folders by the first two of these three numbers, as shown in Figure 7:

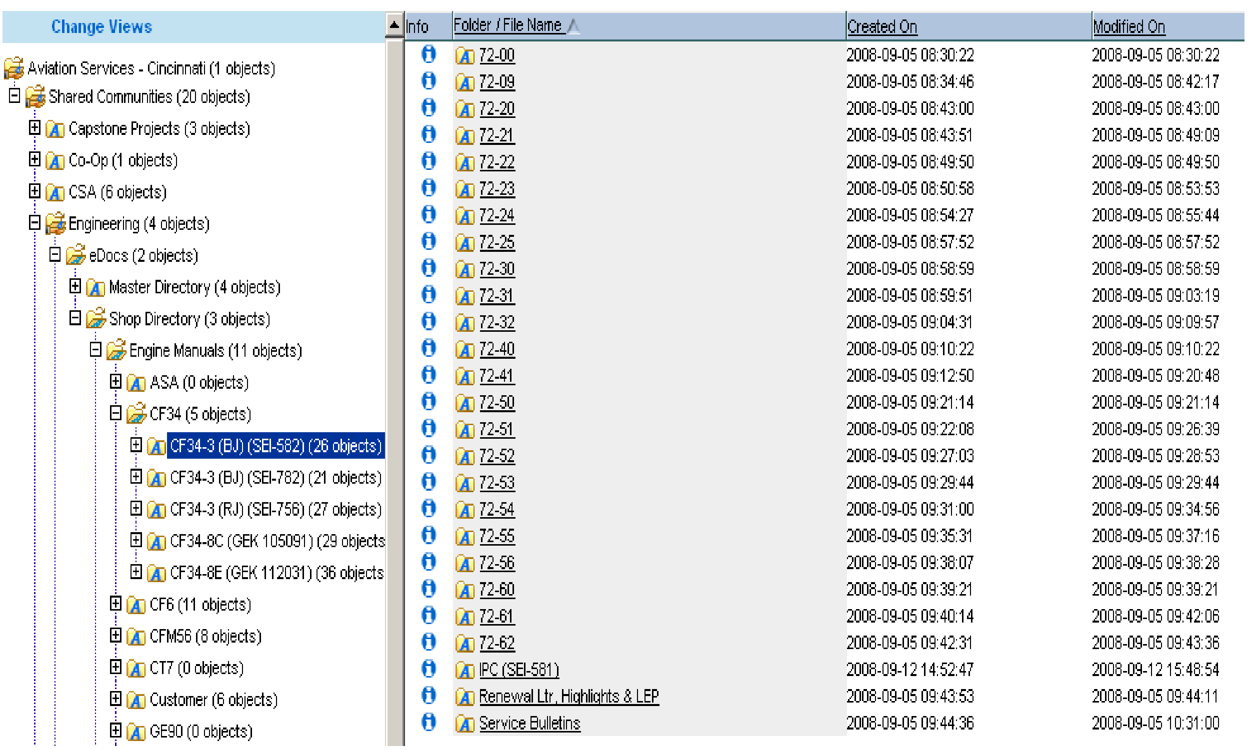


Figure 7: Screenshot of manual architecture

Changes in format for the GE technical publications group caused the team to develop new plans with regard to the housing of EMs.

5.1.2. Hardware Placement

In order to implement a digital system for use on the shop floor, the team sought out to determine computer placement around the repair facility. Locating computers depended on communication with floor employees, Engineers and VSLs, and the IT department to determine best placement for network drops and power supply. The placement of computers depended on the locations that operators need to view planning and the frequency of planning review in that area.

First, the team walked around with maps of each area in the shop to ask operators about locations for computer placement. Discussions occurred with each cell separately in order to give each cell undivided attention. All operators present at a given time had the opportunity to provide input to computer placement that would best fit the cell. They did just that, as floor workers helped to emphasize necessary terminal locations on the floor. When asking about strategic locations, the team was sure to emphasize the removal of planning books from the Satellite Libraries completely and, therefore, computers were to be located where necessary. In addition, the team marked the placement of additional hardware on these maps, such as articulating monitor arms and computer stands, depending on the need in a given area.

After mapping out the initial thoughts, the team went back through each cell with each VSL and the IM Leader to ensure that the places were correct and would be feasible for network drops. The opinion of the VSL mattered most for computer location because they "own" the hardware as assets under their watch. On the final floor layout for all computers, the team indicated all necessary hardware, including:

- Computers
- Articulating arms
- Computer stands
- Moveable carts

- Network drops
- Power drops

Cincinnati Bell is the company responsible for installation of network drops, while the Facilities Manager installed the additional power sources. Once the team developed the overall placement plan for all hardware, the General Manager received the budget plan for the project and approved the implementation. At this point, the team began ordering computers for different pilot cells.

5.1.3. Training on Digital Systems

In an attempt to introduce the digitization plan without flaws, the team generated a training package to illustrate the key points of GE Libraries and the other systems used to retrieve documentation. This training evolved for two separate parties: Engineers/Document Center and the shop floor. They differ in that Engineers and the Document Center needed the editor's version for document creation and uploading, while the floor simply required training on document retrieval and use. Some of the similar training pieces in these different packages were:

- Accessing the "eDocs" section of GE Libraries
- Folder architecture for each directory
- Forming shortcuts to GE Libraries folders
- Using the "page over" function for GE Libraries folders with more than 50 files
- Using the "Find" function in PDF files
- Resetting the SSO password

These topics were generic and all users found the information essential to accessing the system. Although many facets of the training packages are similar, each had a handful of independent pages.

5.1.3.a Engineer/DC Training

The training for Engineers and the DC focuses mainly on uploading files and updating those that currently exist, using the Master Directory. This is important because the adjustments must come from these groups and they need to continually mirror the current revisions on the Master and Shop Directories. In addition, this training includes information about rights management and audit trail. Rights management affects all on this level, since they need to have Editor status on the overall eDocs section. With regard to audit trail, GE Libraries tracks the dates when individuals, using their SSO login as the proof, update files. Therefore, the system is effective in tracking changes to work instructions.

5.1.3.b Floor Training

On the other hand, the shop floor training involved a slow and simple breakdown of GE Libraries and even overall computer usage. The team supplied specific directions for logging on and off the computer, entering the GE Libraries system, and user functions that help the employees, such as:

- Opening files from GE Libraries
- Zooming in/out within files
- Using the designed shortcuts
- Assuring the latest revision (checking the "modified date" of a file to view the last date of changes)

This training assumed users with little to no computer knowledge and challenged the floor to learn one basic system. Presentation of this training occurred with individual operators during the pilot, in order to create a comfortable environment for users to learn the system at their own pace. The team was readily available for any user issues and responded to the problems by creating further materials for the floor to reference.

When the HTML formatting arrived, the team included some key aspects of the server for EMs and the use of GE Libraries for RDs. Use of the EMs through the server is easy because there is no requirement to login to view these documents and the usability is much higher. To incorporate this training, the team studied the server capabilities and instructed users on how to use the functions available through the new EM software. For example, the new software allows individual users to bookmark ATA sections that they use regularly. This function decreases the time needed to find sections that an operator may use often. In addition to the user aspect of the server, the team created extra training to discuss replacement of EM sections for the Document Center, who is responsible for the maintenance of the EMs. Although the information is now located in two separate locations, the training helps to distinguish between the access needs for each document housing system. As a result, the floor is aware of which system to enter for specific information.

The main training for RDs simply demonstrates the fact that RDs appear on PPRs, referenced as the number and not the specific EM to which it pertains. Therefore, these documents meet the eye under one main directory. Once the team adjusted the original training tools, the next steps included creating extra pages to introduce the server.

5.2. First Digitization Pilot – Sumps and Seals

The team performed the first digitization pilot in Sumps and Seals at CPL, hoping to prove the functionality of GE Libraries. Through the pilot, the team encountered different obstacles to overcome in order to continue the implementation here. The first sets of problems appeared before the actual pilot, while operators expressed other concerns during a post-mortem session. This pilot occurred in Sumps and Seals for a variety of reasons; they handle a wide variety of engine parts and, therefore, subscribe to several different engine lines. Testing an area of high production helped test the feasibility of the project in a diverse cell and helped convey the results of computer usage on production.

5.2.1. Fishbone Plan

First, the team developed a plan for necessary materials and personnel for the pilot. The fishbone diagram shown below (Figure 8) defines these necessities and illustrates Six Sigma tools used to implement.

The fishbone includes a description of the five basic steps needed to begin the pilot. The five steps include materials needed, the training involved, documentation coverage, shifts involved, and a finalization plan to review before actually beginning the training. Details of the fishbone are covered in this particular section of the paper. The fishbone mainly covered the overall layout and plans moving forward, while making a clearer image of all that is involved with the Sumps and Seals pilot.

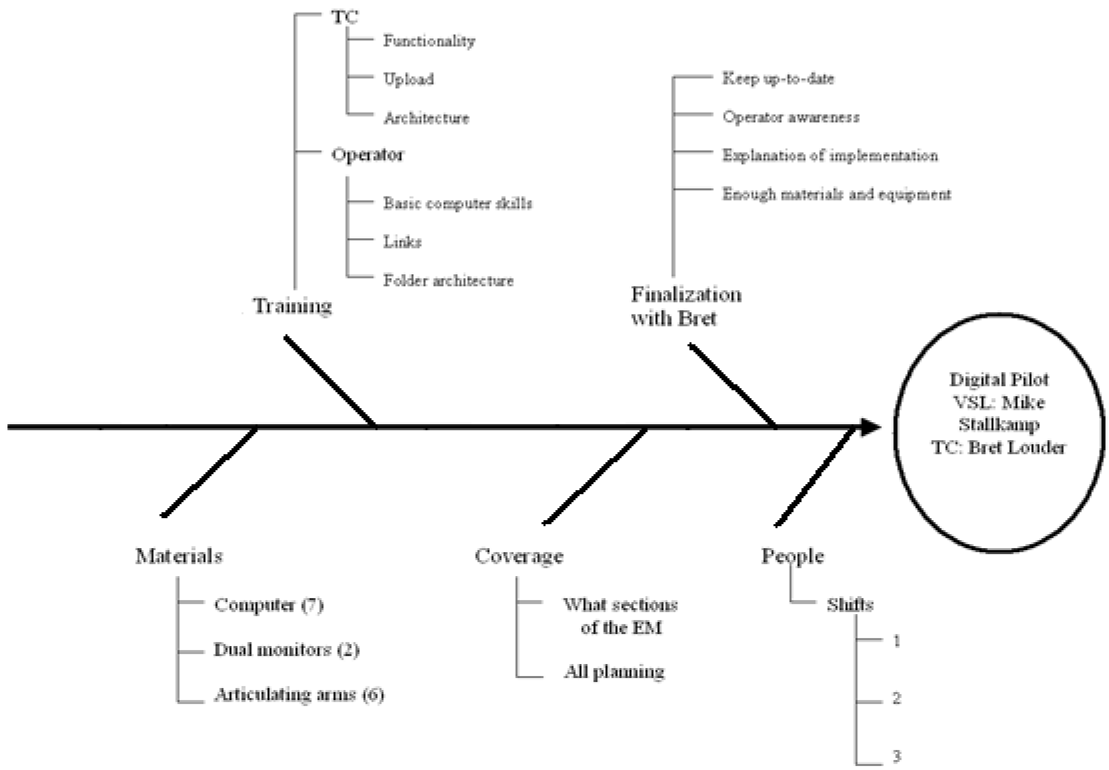


Figure 8: Fishbone diagram

5.2.2. EM Upload and Naming Convention

Initially the team planned to upload only a few EMs to GE Libraries, since the pilot wanted to test feasibility of the system and result in no effect on production. It also meant to ease operators into the new system with only certain sections and help with the resistance of a culture change. Therefore, the team loaded the following engine lines into the system:

- LM 1600
- LM 2500
- LM2500+
- LM 5000
- LM 6000
- CF6 SPM
- CF6-6
- CF6-50

While uploading PDFs of EMs into GE Libraries, the team uncovered a problem with the naming convention. A sample ATA-section file name should read: 72-34-01 Repair 001. However, the documents displayed numbers to indicate the different sections for repair, inspection, etc. as shown below.

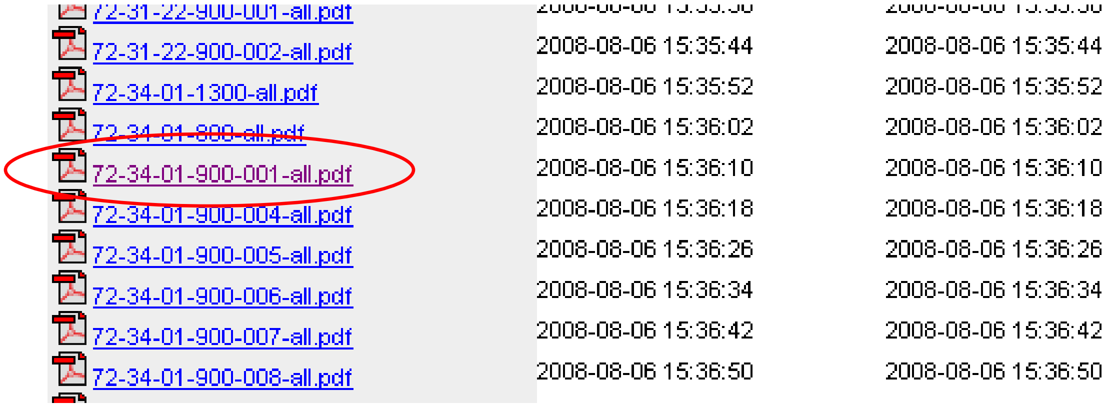


Figure 9: Naming convention for EMs on GE Libraries

"900" represents repair in the GE Libraries system for the CF6-50 EM. This naming convention changed between certain engine lines, where either 300 or 800 could represent inspection while repair could be represented by either 400 or 900 as well as various other sections were represented by various numbers. In order to inform operators of the discrepancy, the team created the cheat sheet shown below to exist at all workstations.

Table 8: Cheat sheet

EM Page-Section Reference

Manual filenames are formatted as such:
"ATA - PAGE - # - ALL" (eg, "72-32-05-800-01-all")

PAGE SECTION

CF6-50	
800	INSPECTION
900	REPAIR
1300	TESTING
CF6-6	
300	INSPECTION
400	REPAIR
600	FITS AND CLEARENCE
700	TESTING
1000	SPECIAL TOOLS

5.2.3. Computer placement and hardware needs

In order to implement computers in S+S, the team developed a layout to work around the tight workspace of the area. This cells working area consists of various lathes with small desks, available for some inspection and benching work before an operation. Due to the nature of work in this area and the specialization of parts to different machines, the team concluded that each workstation required a separate computer. The Figure 10 shows the layout of machines and different workstations.

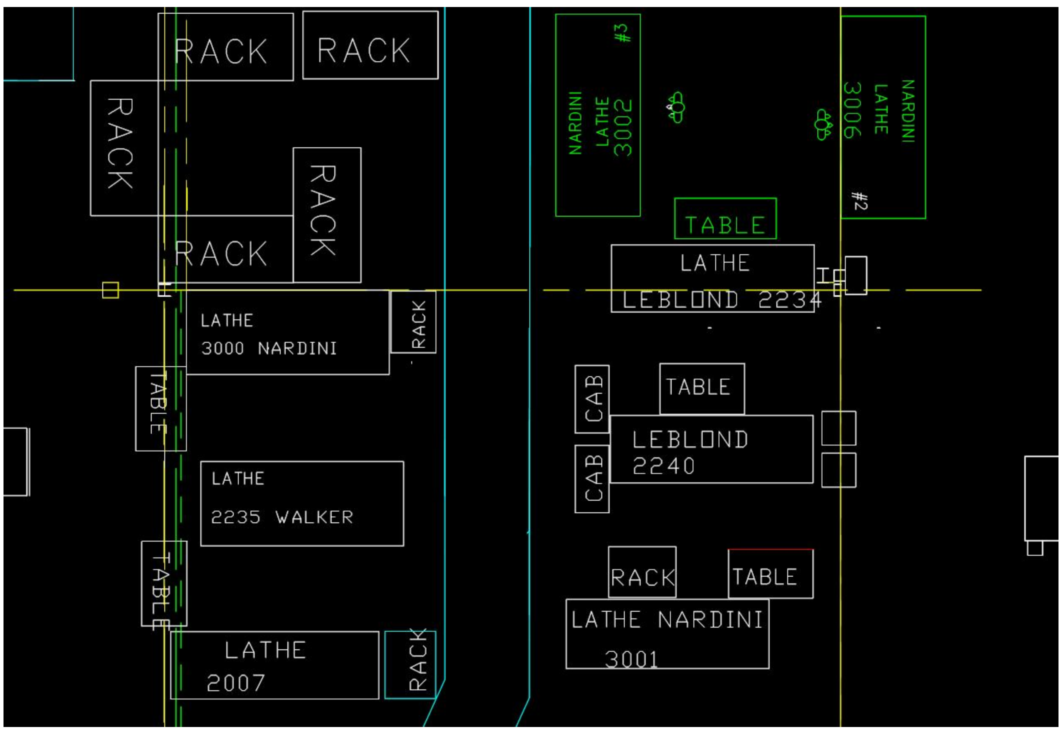


Figure 10: Layout of Sumps and Seals

In order to avoid computer placement on benching tables, the team explored the use of moveable monitor arms with a horizontal range of 360 degrees of motion. The monitor arms also had the functionality to move vertically and rotate the monitor to resemble an 8.5" and 11" sheet of paper for work instructions, shown in Figure 11.

With the monitor arm, the operator can move the screen closer to the lathe so they can continue their normal operations while having the planning in the immediate proximity of the machine.

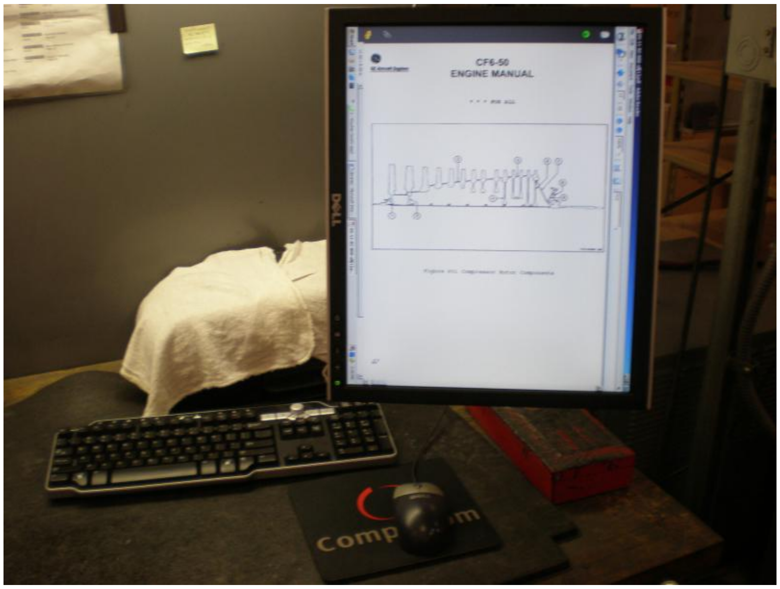


Figure 11: Rotated monitor on arm

Another concern of operators was having the ability to view two different EM pages at once. The facilitator of Sumps and Seals normally references two pages at once, and can simply flip pages to view the content. This showed potential to affect productivity and user speed since a normal monitor would not have the capability to display two files at once for the use of an average operator. The team installed dual monitors, seen below, for this particular facilitator and one other inspector in the cell. Plans for digital implementation consider this option as well.

Figure 12: Dual-monitor setup

5.2.4. Access rights

Next, the team needed to grant access rights to all employees. Some of the operators did not have access to Intranet and/or e-mail, so the team requested this through a GE internal system called Identity Manager. The screen appeared as follows:

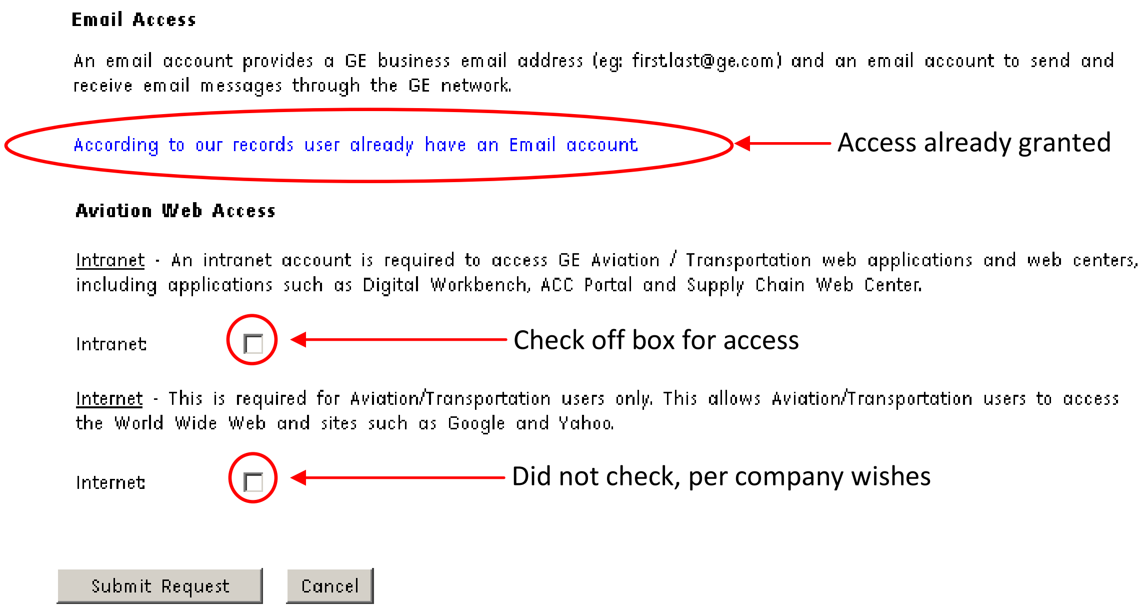


Figure 13: Request access for operators

As seen from the screen shot above, the team completed the form for each operator and submitted the requests. If the operator already had access, Identity Manager would indicate so. Internet was not granted to the operators for the threat of productivity loss and an unfocused work environment. However, if the operator already possessed Internet access, the team could not remove it. After submitting the forms, the cell leaders approved to complete the requests.

With 12 operators in Sumps and Seals with a team of three implementing, it was necessary to keep a record granted access rights. This record also includes a list of completed training. This record resides Table 9.

Table 9: Access rights and training record

Name	Shift	SSO #	NT ID	NT password	SSO password	Email	1 on 1	Basic computer training	Log on/off	Homepage	Library log-in	Folder organization	Navigation through libraries	Shortcut usage
John Doe	1st	11111	ABCDEF	X	X	X	X	X	X	X	X	X	X	X
John Doe 2	1st	11111	ABCDEF	X	X	X	X	X	X	X	X	X	X	X
John Doe 3	1st	11111	ABCDEF	X	X	X	X	X	X	X	X	X	X	X
John Doe 4	1st	11111	ABCDEF	X	X	X	X	X	X	X	X	X	X	X

5.2.5. Pilot Kick-off

To initiate the pilot, the team attended the morning production meeting in Sumps and Seals to introduce digitization. In addition, the team presented to the second shift employees upon their arrival. The team announced that this was the first day of the pilot, the plans for a digitization project, and reasons for said project. To express full availability during the pilot, the team offered cell phone numbers and work numbers to the operators to field questions.

During the initiation, the team expressed the use of each employee's Single Sign On (SSO) ID to enter GE Libraries. This personal ID allowed the team to place proprietary information on the GE Libraries system. However, operators use this ID for their benefits information, covering all savings and security for their time at GE. After informing the operators of this requirement, the team received great resistance. As a result, the team and the IM Leader were asked to explore different options for document housing or a generic sign-on for all shop employees.

After research with no feasible solutions, the team decided to inform all operators of the security behind the SSO login. The team met with Sumps and Seals cell, along with the business team, to address the concerns. The IM Leader fielded all questions and provided feedback about the IT security surrounding an individual's SSO login information. This gathering helped to settle the concerns from the initial kick-off and, as a result, led to smoother implementation.

5.2.6. Training the pilot work cell

Once all necessary documentation resided online, the team trained each Sumps and Seals operator separately. Training packets existed at every workstation for operators to reference anytime. GE Libraries also stored a copy of this training, accessible to all employees with "eDocs" access. Some operators required more time than others regarding basic computer knowledge. The team provided extra time and attention for these operators, training them until they thoroughly understood the system. Through this training, the team discovered different topics for training. As a result, the team adjusted the training package to include the following.

Table 10: Additions to training after pilot

Added Training	Description
1. Vouchering – IME Codes	This sheet can be referenced for the correct Indirect Manufacturing Expense (IME) codes involving operator training
2. Assuring the Latest Revision	In order to be sure that you are working to the most current revision in an Engine Manual, simply check the date on which the file was last modified before opening it. This is demonstrated in the training packet.
3. Page over within Engine Manuals	In GE Libraries each page can only show 50 objects (files or sub-folders) at a time. Therefore there are various pages within each EM folder to account for all of the files, or individual ATA sections. A section in the training packet was added to show how to maneuver throughout the various pages.
4. Zoom In and Out	When looking at a file (EM or planning/SOP), the size of the text may be too small to clearly view. In order to increase the size, you may zoom, by changing the percentage of which the page shows in one screen. A section was added to show how to zoom in the various documents.
5. Finding a Specific Place in an EM	The files are sometimes very large so finding specific parts of the documents may have been a challenge. A section was added to the training packet to show different ways to search through these documents efficiently.

Once all operators displayed confidence in using GE Libraries, the team removed relevant binders from the floor in this cell. At that point, the implementation pilot was complete and the team monitored the status of the cell.

5.2.7. During the pilot and post-mortem

Throughout the pilot, different issues arose for the team to identify and solve. Most notably, the operators expressed concern about the naming convention of entire EMs. Routers referred to the different EMs by either listing the engine model or GEK number. The team initially loaded the EMs with only the engine model name. With this, the operators were having issues finding the desired EM when the router referred to the GEK number. The developed solution involved indicating the engine model name with the GEK number in parenthesis, as shown below:

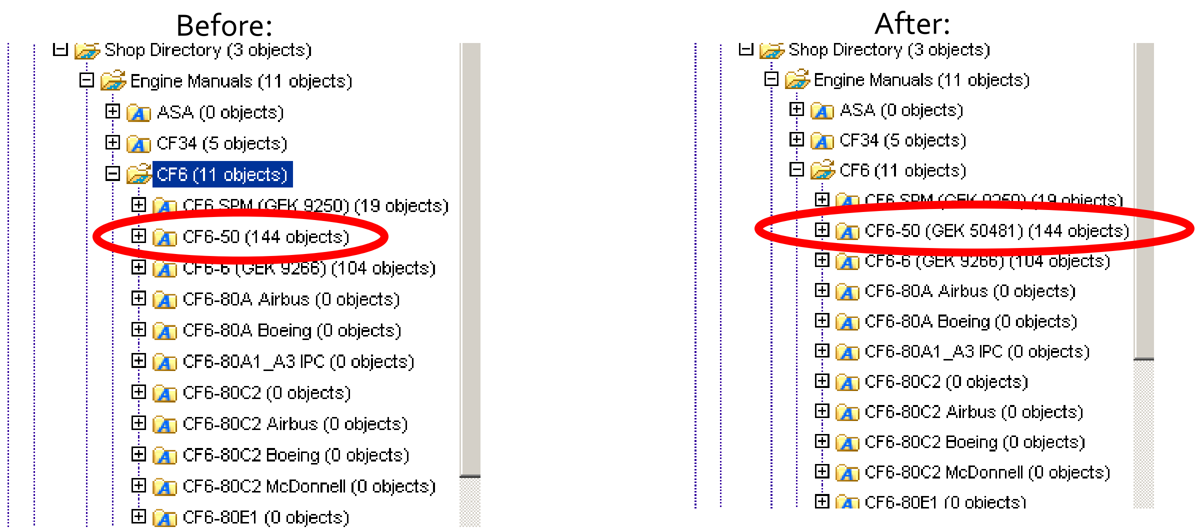


Figure 14: Switch to GEK indication

Lastly, the post-mortem for the cell concluded the pilot. During a session with all operators, the Engineer, and VSL, the team fielded all concerns and issues with the project. No major issued appeared and, therefore, the floor expressed high usability for the system. In fact, most operators preferred the digital method to paper instructions. With a successful pilot, the team prepared to stretch the project elsewhere in the shop.

5.3. Symmes Digitization Pilot – HPT Blades

Symmes differs from CPL in that workspace is tight and work instructions are much more specific to different machines and processes. In order to implement the digitization project at Symmes, the team strategically placed computers and gathered planning in each cell to upload onto GE Libraries. This planning evolves from EMs and, along with the routers, is the only instructions that the Symmes floor uses for operations. One obstacle was the age of the employees at Symmes, as approximately 45 floor workers have over 30 years of experience in the shop. All of the above factors contributed to an interested pilot session at Symmes.

Before conducting the Symmes pilot, the General Manager of Services-Cincinnati requested a thorough report of users with existing Internet access. He demanded this in order to assess the threats of allowing operators to access the Internet on terminals all over the floor. After the IT department generated a user list, the team could continue with the implementation of digitization in Blades.

5.3.1. Selection of cell

Other than the Central Services areas, Symmes is composed of four main cells: HPT Nozzles, LPT Nozzles, Energy Nozzles, and HPT Blades. In order to determine which cell would be best for piloting, the team explored the cells with the least current workload that could spend the time to train and understand the new system. After discussing the project with the plant leader and VSLs at Symmes, the group decided that HPT Blades would serve as a successful pilot area. In addition to having availability to train, the Blades cell posed a challenge in placing computers, since space is so tight. The team decided to pilot Blades and began the implementation process accordingly.

5.3.1.a Kick-off

Upon choosing Blades as the target cell, the team set up times to introduce the project to all shifts (3) and field any initial resistance from operators. These "kick-off" meetings covered the same topics: the project, use of computers for work instructions, training tools, and reasons for change. At all meetings, the team received comments and concerns from vocal shop workers and noted all feedback. In addition, the team confronted the vocal employees after the meetings to thoroughly understand their issues with digitization. Communication with the floor proved to be vital in the digitization process.

5.3.1.b Computer placement

In order to place computers logically in the Blades cell, the team studied the shop with the VSL, an Engineer, and one IT employee. The plan encompassed marking computer placement on a map of the shop, in addition to network and power needs, so that a hardware layout existed. The VSL possessed the ultimate authority in computer location. Because of the shop tour, Blades required 13 new computers. Based on their exact location and needs, most computers demanded either a moveable arm or a stand for convenient usage. In addition, the team spoke with operators directly once computers arrived to pulse their opinion on exact placement. Only the operators know exactly where they use their planning materials and, therefore, the team complied with their wishes where feasible.

5.3.1.c Access rights

Similar to CPL, the team needed to create a single e-mail list for all Symmes hourly employees, in addition to granting rights to e-mail and Intranet. Although these actions were only urgent within Blades, the team decided to work on granting all rights before a pilot began. First, the team used SSO numbers to request access for all employees to have e-mail and Intranet. Management at Symmes specifically requested that hourly employees did not receive Internet access and, therefore, the team neglected this option when granting other rights. After the cell leaders approved these requests, the team entered all employees into an Excel spreadsheet, showing name and SSO number, and requested a Symmes hourly e-mail alias through the GE Helpdesk. With this list, the Helpdesk created the alias in a timely fashion. The team added this alias for Reader access to the "Symmes" section for Planning and SOPs, located within the Shop Directory on GE Libraries.

5.3.1.d Upload the planning

Planning materials, the main form of work instructions at Symmes, played a crucial role in the effective rollout of digitization in Blades cell. At Symmes, planning binders are located everywhere and are vital to the operations performed all over the shop. The team approached the Engineers in Blades about their planning and the steps necessary to provide the floor with these instructions via GE Libraries. In addition, the team provided in-depth training on planning uploads and the necessary steps when adjusting any documents. Engineers used said training to learn the system and upload files with proper naming convention and in appropriate format (PDF). PDF format was crucial because of the shop floor ability to change documents in other formats. Using PDF, the Engineers are able to lock down their files to the floor.

In addition to approaching Engineers within Blades, the team utilized the services of one Central Services Engineer at Symmes as the project champion. He showed interest in the project from the start and volunteered to help gather all planning from other Engineers. The team met with this champion and Blades Engineers to ensure that all planning materials existed on GE Libraries.

5.3.1.e Training the cell

Once all planning resided online and the computers installed on the floor, the team began training Blades employees on the use of GE Libraries. As with CPL, the team offered desktop shortcuts to access specific folders quickly. In HPT Blades, the planning is so specific per workstation that these shortcuts helped all across the cell. Once the cell members knew which shortcuts to use for their planning, the training simply involved logging into GE Libraries and locating the desired file for use (naming convention). In addition, the team trained the Blades cell on computer basics and tips for using PDF documents. Each operator received one-on-one training in order to capture all skill sets and provide assistance accordingly. After all users showed competence with the system, the team removed all planning books from the Blades cell.

5.4. Implementation – Central Services

Throughout both CPL and Symmes, the Central Services (CS) possessed hardware and documentation that prepared them for easy implementation. Contrary to other cells, CS cells mainly operate using Standard Operating Procedures (SOPs) that are specific to each process. In addition, these documents already existed in different directories on computers within the shop. Therefore, the team decided to digitize the CS cells in order to create one practice for the entire shop.

5.4.1. Switch digital cells to GE Libraries

Two Designated Certifying Agents (DCAs) already established all SOPs on the computer for their cells at CPL, before the team's arrival. These cells include:

- Abrasive Blast
- Chemical Room
- Airfoils
- EB Weld

They used the Shared Drive, which IT wants to eliminate. However, their use of SOPs caused an easy switch to using GE Libraries, since all SOPs existed in logical folder architecture on the computer. To reform the cells, the team simply worked with these DCAs to organize all SOPs and upload them in desired folder architecture onto GE Libraries, located under Planning and SOPs. Once on GE Libraries, the team trained the four CS cells on use of the system and supplied them with shortcuts on all desktops. The smooth shift instilled confidence in the team and operators, as implementation seemed feasible with necessary hardware and organized documentation.

5.4.2. Rollout to other CS cells

In order to stay consistent with the implementation plan generated from Sumps and Seals, the team decided to approach digitization of CS by following all necessary steps. Instead of dealing with Engineers, the team would work with DCAs to ensure smooth rollout across all cells. First, the team introduced the project and objectives to all of CS at different morning production meetings. This allowed for immediate feedback and informed the team of initial resistors around the shop. Introducing the plan also helped to gain the attention and compliance of all DCAs. From the "kick-off" meetings, the team began planning for digitization.

To further the process, the team met with DCAs to discuss the use and location of SOPs in each cell. Although most documentation resided online, some only existed as handwritten papers in binders on the floor or in legacy systems on the local Document Center server. Therefore, the team began loading all SOPs by scanning documents into PDF formats and separating tech plans and other documents using Adobe PDF Creator. Eventually, all SOPs existed as separate documents that could easily be loaded into GE Libraries.

Next, the team visited each cell with DCAs and the two main VSLs in CS to determine computer placements and additional hardware for each workstation. This strategy followed the guidelines set by previous pilots and seemed best fit for each cell. Once the team created a layout, they ordered all equipment necessary to effectively implement the digitization plan in CS.

Once the necessary hardware arrived, the team started installation and, in the process, discussed the project with operators. These discussions allowed the team to capture instances of employees who did not know their SSO password. With this information, the team retrieved passwords for those employees without, allowing for smoother implementation. Finally, the team began training the CS employees, which simply entailed providing them with a desktop shortcut to their specific folder and showing them how to open desired files. The team provided the main training packet for all employees. Once all shop employees showed competence using GE Libraries, the team advised all DCAs to remove their paper SOPs from the floor.

Due to time constraints, the team was unable to implement the digitization in all CS cells. Ordering hardware became a lengthy process in some cells and there lacked availability of some DCAs. However, the overall implementation of CS at CPL and Symmes proved to be a success, due to the functionality of GE Libraries for the purposes of SOPs.

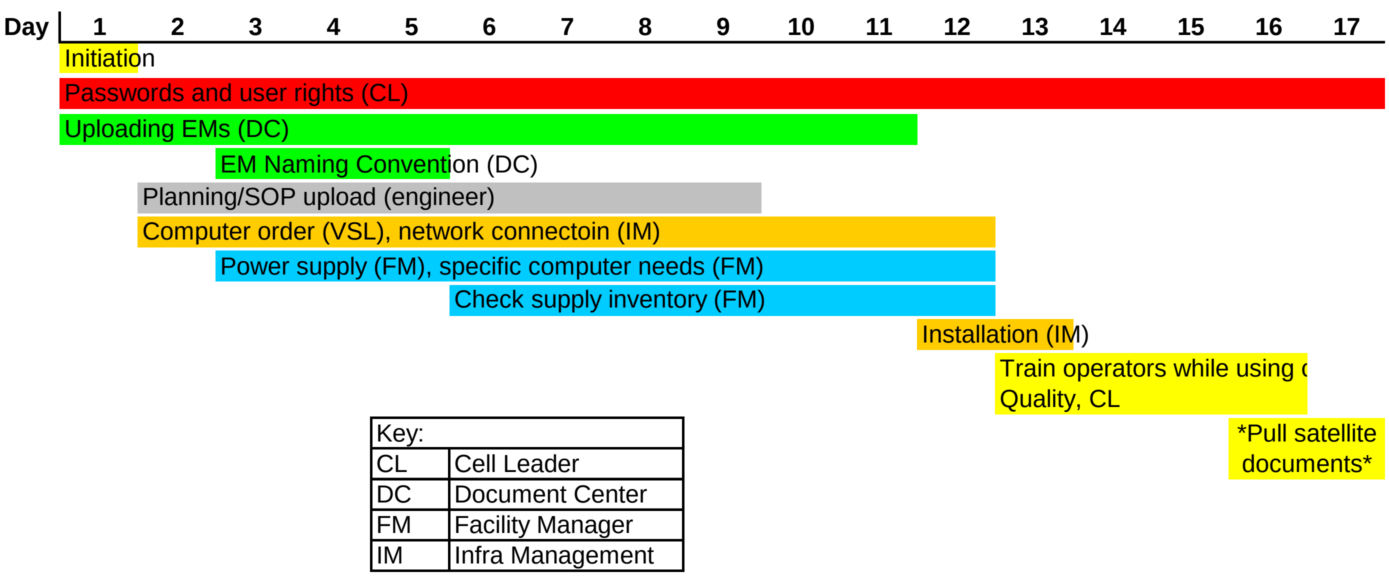
5.5. Continued Digital Implementation

In order to digitize Services-Cincinnati, the team needed to come up with a continued implementation plan that covered a timeline, delegation of responsibilities with roles involved, desired resources, and methods to guide the project. Initially, the team piloted Sumps and Seals to uncover any problems along the way; different situations that could possibly come up, recording the different variables. In addition, the team began a pilot in HPT Blades at Symmes to understand any new problems from another service station. A postmortem and analysis helped to finalize the individual cell implementation timeline and procedures. With a plan to implement each individual cell, the team developed an overall timeline and plan to digitize every cell at CPL and Symmes.

5.5.1. Individual Cell Implementation Timeline

The team created the following timeline to help guide digitization in each individual cell. It covers each assigned task, from the initiation to pulling the satellite documents from the shop floor. In addition, the timeline shows total time necessary for each task, allowing some room for delays. For example, the team found in Blades that ordering hardware became a lengthy process because of the placement of network and power drops. The team proposes this implementation timeline with flexibility built in.

Table 11: Implementation Timeline



The Quality Business Leader and her staff will use the timeline to ensure all the delegated tasks are completed within the given period and will help orchestrate assigning tasks during a single cell implementation. Colors indicate the different roles responsible for the tasks.

5.5.2. Delegating Responsibilities

The responsibilities for the digitization process were chosen so that each position could logically complete the delegated task within the allotted time. The numbers at the top of the figure indicate the progress of the pilot and show when each task should initiate. The tasks stretch across several days in order to allow for some flexibility. The delegated tasks, people responsible and specific instructions are as follows:

1. **Initiation: Quality, Cell Leader, Infra Management Leader**
   - Introduce yourself at morning production meeting
     - Describe plans of moving Satellite Documents into Libraries
     - Describe what Libraries is and where GE is going
     - Initially settle any SSO concerns and describe security of system
   - Walk through that particular cell
     - Get 1-on-1 times with operators to address concerns, explain process further, field any questions, and find their individual computer needs
     - Make sure to fully describe that the Satellite Documents will no longer exist and will need to be accessed through a computer
   - While walking through, use a map to place every computer needed
     - Use layout already developed by the project team to guide
     - Make a decision for the placement based on operator needs, machine spacing, machine usage, and operator interaction with Satellite Documents
     - Locate hardware needs such as a monitor arm, dual screens, and/or a mobile computer
     - Locate network drops and power supply
2. **Passwords and user rights: Cell Leader**
   - Start getting passwords and user rights for operators that need it
     - Email, NT ID, and SSO
     - Use IT Helpdesk
3. **Uploading EMs: Document Center**
   - Upload implemented Engine Manuals for specific cell
     - Ensure that the EMs in that cell already exist on client versions of server

- Allow entire manual to reside on operating side of server

4. **EM Naming Convention: DC**
   - Check the EM sections to identify naming convention that represents EM subheadings; provide cheat sheet for this convention
     - Ex. CF6-50: 05-11-02-800-4; 800-4 = Inspection #4
   - Modify cheat sheet if necessary for floor and engineer use
5. **Planning/SOP upload: Engineers**
   - Have Engineers upload planning and any other specific documents used by that individual cell onto GE Libraries
     - "Check out" file from the Master Directory and update the desired file once revisions are complete
     - The planning must be converted to PDF format to lock down the write access for the Shop Directory
     - Only latest revisions in Shop Directory
6. **Computer order and network connections (10,11): VSL, IM team**
   - VSLs own hardware in each cell, so they must order computers
   - IT place work order with Cincinnati Bell for network drops in designated locations (only for new locations that did not previously exist)
7. **Power supply and specific computer needs: Facilities Manager**
   - Ensure power supply at each proposed new workstation
   - Order specific computer hardware needs
8. **Checking supply inventory: Facilities Manager**
   - Make sure all hardware has been delivered
9. **Installation: Infra Management**
   - Set up computers in designated areas with additional hardware
   - Use help of FM if necessary
10. **Training: Quality, Cell Leader, Infra Management Leader**
    - Train each individual operator separately with training packet
    - Allow a few days to reiterate steps to accessing systems

11. Pulling satellite documents: Document Center

Remove all paper documentation from the floor once all employees in the cell have demonstrated competency with systems

5.5.3. Future Cells

With the timeline and delegation of responsibilities for individual cell implementation, it is important to pick the future cells strategically. Future cells must be chosen and laid out in such a way that will not interfere with company productivity, while still being implemented affectively and on schedule. The team eliminated implementation during weeks toward the end of business quarters to allow operators and management to work diligently toward meeting production goals. Amount of cells, days to implement a given cell, and delegated tasks contributed to an implementation plan for future cells. After working with the assigned management, a timeline exists that outlines the entire digitization process. The timeline includes the cell involved, amount of time for that cell to completely digitize, and the given persons responsible for that cell.

The current progress for the given cells is as follows. This maps out the additional work needed for complete digitization in the given cells. In addition, it highlights the order of cells for implementation. One major unknown is the arrival of a server to Services-Cincinnati and, therefore, this process of implementation may not be initiated until said server arrives. Regardless, the plan exists to kick-off shop digitization upon arrival of a server, as outlined in Table 12 and Table 13.

These figures indicate the cells for implementation in order, steps as indicated on the implementation timeline, and comments about the status of the cell. All green cells on the Excel spreadsheet show completed steps, while yellow indicates those tasks that are still pending. Again, tasks such as ordering hardware and network drops are complete for an overall floor layout, but VSLs possess the authority to request assets based on the needs of the cell.

Table 12: Current progress for Symmes cells

Milestones	ID Location for PCS	Order PC	Order Electrical Drops	Orders Data Drops	Order Arms	Request EE IDM access	Locate PC's	Load the Client SW for EM's	Train TC's / DCA's	Train EE	Pull Paper	Status
(Symmes)	Symmes is taken t	HOLD until Server timing is set.	ependent of the HTML conversion of tech pubs because the planning is in PPT format and content ech data, independent of the format.									
Pilot HPTB												Nick generating list of all EE and their current access to Intranet and Internet. Also if they have NTUser IDs.
Central Services												
A-Bar												Waiting for mobile cart equipment.
Chem Room												
VPA												Waiting for mobile cart equipment.
FPI												
Metallography												
Laser Drill/Weld												
HPTN												
LPTN												
Inf Energy												

Table 13: Current progress for CPL cells

Milestones	ID Location for PCS	Order PC	Order Electrical Drops	Orders Data Drops	Order Arms	Request EE IDM access	Locate PC's	Load the Client SW for EM's	Train TC's / DCA's	Train EE	Pull Paper	Status
Pilot S&S												Need to circle back on EM to Shared Drive. Decision: do we hold or continue with current EM rev in Libraries? Suggest loading remaining material for S&S on GE Libraries to get them fully digital...then learn.
Central Services												Finishing the loading planning. Need to Train EE's and DCA's on eDocs
X-ray												Waiting for computer and accessories. Need computer at machine due to planning interaction. Will place exactly where the planning is located now.
Heat Treat												Need to pull paper. In transition stage using both Libraries and books.
EMU												Need to load planning on GE Libraries
Met Lab												Pending while waiting for server. Work off of
Shotpeen												
Structures FPI												Waiting for additional computer.
RP FPI												Waiting for additional computer.
Chem Room												
Air Foils												
Metallography												Server
Abrasive Blast												
EB Weld												
HS		HOLD until Server timing is										Identify where to locate computers and EE IDM requests
T&D												
CF												
GE90												
RP												

5.6. Control of Document Flow

5.6.1. Chosen System and Features

In order to begin understanding the new abilities with a revised Workflow tool, the team first determined which system provides a logical flow for the purpose of document control. This section discusses the chosen tool, its functionality, and the issues that arose due to the nature of the system and the changes with technical publications.

5.6.2. Selecting a system

After discussing the Workflow issue with the DC and IM Leader, the team decided that an IT system best suits the needs of a document control tool. Similar to the digitization component, problems with the previous document control system involve a legacy system, known as Master Distribution. This system causes audit findings and, therefore, IT support seemed necessary. In addition, the team desired a system to flow through entire EM instead of individual ATA sections, since the Master Subscriber Matrix requires heavy maintenance. The Master Subscriber List is an Excel document that includes all matches of ATA sections to pertinent Engineers, showing almost 5,000 matches when broken down by individual repairs within the EM. The team aimed to eliminate the need for such a list and, instead, match Engineers to the different EMs. In addition, this vision complies with the eManuals system, which other shops currently use to test the functionality and convert EMs to the Sierra system. With these requirements in mind, the team explored different document control systems within GE IT to once again, find SupportCentral as the perfect tool. Within the GE SupportCentral (SC), the team decided to investigate "Workflows" to send the notification of new manual revisions.

Using SC Workflows, the team planned for the DC to submit each EM revision in the shop as a request for Engineers to revise. The submission step, or the first step of the Workflow, is "Document Input." The system would send notification to the Engineers responsible for sections in that EM, instead of only those affected by that particular ATA section. The next step in the Workflow becomes "Engineer Review" and it allows the form to stay with Engineers until all have approved the Workflow. Once each Engineer approves the

Workflow form as either an applicable section or not applicable, the DC receives the form in the third step, known as "Distribution," and the EM section becomes available for use on the shop floor. In addition, the Engineer sends any applicable planning changes to the DC, since this information cannot release until the matching EM section is available for use. All information on the shop floor must reflect the most current revision of the EM in use by operators and, therefore, planning needs to match the EMs on the floor. All pertinent documentation within each Workflow appears on the floor after the last Engineer approves and sends relevant documentation to the DC.

Step 1: Document Input

The input step initiates each Workflow so that the Engineers may begin to review pertinent revisions. To thoroughly inform Engineers of the changes to an EM, each Workflow form requires the DC to populate the following fields:

- Engine family and model (automatically populates Engineers from this)
- Data type (EM, SB, TR, etc.)
- Revision number and date
- Date received by shop
- Publication title and reference number (ATA)
- Location of revision
- Brief description of the change made

All of the above help the Engineer to understand the exact changes to the manual so that they may recognize the altered sections and determine the relevancy to their individual sections. In addition, the information allows them to quickly locate the affected section of the EM. Lastly, the input stage provides an organized record of the documents that flow through the shop and the accuracy with which the DC processes them. After Document Input, the Engineers are responsible for the timely completion of each Workflow form.

Step 2: Engineer Review

Each Workflow for an EM section change goes to all Engineers subscribed to that manual. The notification releases through e-mail and, therefore, each Engineer created a separate e-mail folder to receive all Workflows. This method received some resistance due to the concern with releasing planning before the EM release. Engineers feel somewhat punished by this system, since completing paperwork early does not affect the floor until all have sent the approvals. However, the window of 30 days for Engineers to approve EM revisions and supply work instructions for the floor is a firm timeframe and, therefore, the actual date of planning release only depends on the 30 day limit. This change became necessary later in the project.

One key aspect of Engineer review is the adjustment of other documentation. This includes all of the following:

- 8130 templates
- Planning
- Routers
- RSS packages

The SC Workflow tool is not capable of creating checkboxes for each of these documents, since individual Engineers share each form. In other words, the DC submits one form that all Engineers view and, therefore, all actions on that form (except approval) by one individual will complete that section for all. Without the use of checkboxes, the team still wanted to remind Engineers to adjust this documentation. Therefore, a disclaimer appears on each Workflow form, in addition to the e-mail notification that SC automatically sends to pertinent Engineers. The disclaimer reads as follows (bolded and larger font as in actual use):

> **"Please review the request, then check all of the following:**
> **Any applicable 8130 templates**
> **Any applicable planning**
> **Any applicable routers**
> **Any applicable RSS packages**
> **By clicking approve on the Workflow form, you have validated that you have completed the above reviews."**

By inserting this message, the team provides a visible reminder to adjust all relevant documents and leaves each Engineer responsible for their end of the work. Once the Engineers have all performed said actions and reviewed the EM revision, they select "Approve" on the form, which then routes back to the DC.

Step 3: Distribution

Finally, the Document Center receives the Workflow form and all planning documents to release to the floor. This step is vital because it must include the placement of planning materials on GE Libraries, while the EMs are released on the server repository. If Engineers send all documentation to the DC along with their approval, then this should not be an issue when releasing all instructions to the floor. Similar to Engineers, the main technical librarian established a separate e-mail folder for the Workflow notifications. Upon notification, it is her duty to release this information to the shop floor.

5.6.3. Training

Similar to digitization, the team developed a training package to instruct the Document Center and Engineers about SupportCentral Workflows. Two separate documents contain this information: one geared toward the DC for notification input and one for the Engineers to approve the Workflows and adjust necessary documentation. Each training package includes screenshots of the SC system and clearly illustrates the steps necessary to complete a Workflow using the EM revision technique. In addition, the training shows users where to locate Workflow forms that are still pending review or are complete. This training thoroughly covers all three steps of the document flow.

5.6.4. Testing the system

In order to test the functionality of SupportCentral Workflows, the team planned to send notifications within a small group of co-ops. The co-ops involved were the three team members and one other in the shop, known here as "co-op X". Each team member became an Engineer, subscribed to numerous different EMs, while co-op X acted as the main technical librarian. Using this system, the team sent Workflows within the group to test the idea of all Engineers being able to approve a form before it releases to the DC for Distribution. The purpose of co-op X was to understand the nature of the final Workflow screen without introducing it to the main librarian first. The test ran smoothly and, therefore, the established structure of SC Workflows seemed ready to pilot. A pilot scheduled for the week of September 15, 2008 did not occur as planned due to a few obstacles....

5.6.5. Effects of HTML

Along with the change to HTML EMs came pros and cons to using the new Workflows. First, the positives: before the project began, the team clashed with certain Quality members regarding the change in flow process. The idea of switching to entire EM sections over ATA sections posed as a huge culture change for Engineers and seemed to suggest a change to the DC "tollgate" system, which tracks all revisions that enter the shop. This switch to HTML forces the shop to release by entire EMs, since the individual ATA sections do not reside as separate files. In order to release a section of the manual, the DC must replace the entire EM on the server. Therefore, the HTML format supports the team's ideas and the shop must alter the current process of reviewing EM changes.

On the other hand, this system poses a problem to the current methods of Engineer approvals and routers at the shop. The release of entire EM sections instead of individual ATAs disrupts the system for router generation at Services-Cincinnati. Currently, the Quality team performs router generation in a system called SFE. This process begins once the Quality Leader, along with the pertinent Engineer(s), approves a paper copy of the individual ATA section. Once these parties approve the section, the Quality Leader enters the SFE system and generates a new router for the part(s) affected, using the revised EM sections. HTML affects this process because, if the entire EM holds up until all Engineers have approved the Workflow, the Quality Leader does not know when to create the router. Although router generation and SFE do not exist within the immediate scope of this project, the team must consider these challenges before moving forward with the document flow component of the MQP.

5.7. Measurable Results

In an effort to weigh the effectiveness of a digitization project, the team performed the aforementioned methodology to view measurable results. The results section solely discusses cost analysis, since these figures are the only true measurable results from the project at this point.

5.7.1. Cost analysis

When examining the cost savings from the project, the team explored the following areas of potential savings:

- Supplies used to maintain books on floor
- Operators walking to/from Satellite Libraries
- DC efforts to audit all books in shop quarterly
- DC distribution of EM sections to floor

The team developed a savings from supplies through reduction in paper, ink, binders, and tabs. They examined the books on the floor to determine a rough average of pages per EM section available and how often they are changed. In addition, the team used these figures from paper usage to determine how many ink cartridges the company uses per year for document control. Overall, the team found that the cost reduction in supplies from digitization is roughly ***$1,143 per year***. This is highlighted in Appendix E: Supply Savings.

To understand the cost savings from operators locating binders, the team performed a spaghetti chart study on the floor. This entailed asking operators how often they view their planning, how many operators may walk a given path to binders in each cell, and recording the time taken to walk to binders and back to the workstation. During the study, the team assumed that time to locate a binder from the shelf is comparable to time to locate planning on the computer. This assumption is a result of the recorded times to login vs. locate the desired binder, as found through the study on the floor. Every so often an operator needs to visit the Document Center when the section they are searching for cannot be found in the Satellite Documents. Talking with the Document Center, about two operators come in everyday requesting these certain sections. Taking the average distance from the shop floor to the Document Center, the average time from the shop floor to the Document Center was found. The average time to the Document Center and the two visits a day was used in calculating additional operator savings. The team also took into consideration how much time each operator spends waiting inline to voucher in and out of work each day. Adding additional computers will eliminate the currently limited vouchering stands accessible to operators. In addition, the team assumed five days per week to view work instructions and only 46 weeks per year, which accounts for vacation and sick time. After performing the spaghetti chart study in all cells at CPL, the astounding figure for savings indicated *$24,173.59 per year,* shown in Appendix 0.

Lastly, the team wanted to weigh the efforts of the DC and determine the reduction in work with the ideal digital system. Currently, the DC audits all books (400+) in the shop every three months. In addition, they are responsible for the maintenance of binders on the floor and replacing EM sections upon revisions. Initially, the team began mapping the spaghetti charts from the DC to each Satellite Library to gage the savings. However, after discussing the potential savings with the main technical librarian, the team found that one DC employee completes both of these main tasks. Therefore, the project assumes a savings from eliminating one head from the Document Center.

In order to counter these values, the team also considered the expenses of the following:

- New computers
- Server
- Additional hardware
- Power Drops

The analysis of hardware is located in Appendix 0.

After completing the layout for the entire floor, the team proposed 62 new computers, 1 laptop, and 3 additional monitors, resulting in a cost of *$33,228 per year*. The other leased equipment is the server, which IT quoted at $1827.86 per month, or *$21,934.32 per year*. This covers all hardware, storage, software, and networking for the server.

With all cost effects considered, the team derived a simple equation to determine the yearly savings from the digitization project:

(Supply savings + spaghetti chart savings + DC responsibilities) – (Computer costs + server cost)

During the first year, this figure will not exist, due to the one-time expenditures on hardware and power drops. Therefore, the savings for the first year are:

(Yearly savings) – (Cost of arms, stands, mobile carts, and power drops)

These figures and results reside below in Table 14.

Table 14: Total Cost Analysis

Total Cost Analysis/Year	
Total Savings	
$$	
Explanation	
Spaghetti chart	$26,086.10
Supplies	$1,143.03
DC responsibilities	$43,884.40
Rough salary of one employee	
Total yearly savings:	**$71,113.53**
Total Costs (yearly)	
Computers	$33,228
Server	$21,934
Total yearly cost:	**$55,162.32**
One-time Costs	
Network	0
Corporate cost	
Power (rough figure)	$15,000
	$10,703.84
All hardware (arms, stands)	$7,855
Total one-time costs:	**$33,558.84**
Total cost for first year:	**$17,607.63**
Total yearly savings after:	**$15,951.21**
Total time to see ROI (in years):	**1.1**

6. Conclusions

Accomplishing the primary goal of setting in motion the culture change toward a digital shop floor and sustainable, simplified technical document review process, the team was able to focus on long term implementation and the continued rollout of both components of the project. At the end of the project, each element and task of the project was rolled over to a GE individual at the discretion of the Quality Business Leader, for continued implementation.

Although the initiation of the culture change went smoothly, the team encountered certain roadblocks that hindered the full completion of all project objectives. However, this should not discredit the accomplished objectives and lasting effects on GE Aviation. The project helped to partially digitize both shops and uncover a potential problem for all engine service shops, as the company stares into a digital future. This section discusses this recent obstacle and the recommendations for Services-Cincinnati as a result.

6.1. Shop Floor Digitization

6.1.1. Obstacles with proposed solutions

The new direction of tech pubs called for a switch in EM format from the use of PDF documents to HTML files. In initial discussions with this group, the team understood that HTML files would cooperate with the GE Libraries set-up and load easily into the folder architecture laid out. Recently, a new revision of the GE-90 EM became available for JAL and, upon request; Services-Cincinnati received a duplicate copy in DVD format. To understand the new format, the team scheduled a meeting with a member of the Digital Data and Support Services team. Upon meeting with this expert, the new HTML files do not agree with the currently planned system. He helped to highlight the problems and propose initial solutions.

The problem exists due to images: with PDF files, images are contained directly within the different ATA sections and the entire section may be loaded as a file on GE Libraries. In the HTML sections, the images exist as separate documents with randomly generated naming conventions. Instead of viewing an image in the ATA section, a link exists to direct the user to another location, where the necessary image is available for review. This problem illustrates one downfall of GE Libraries: there is no ability to link between files in the system. Therefore, a new document housing system was required to hold all EMs at the repair facility.

After reviewing the plans of the company and possible solutions to this problem, the team concluded that the best feasible outcome would be to invest in a server for accessing EMs. The system known as eManuals, which facilities at Strother, KS and Wales, UK are already using, requires a server and Services-Cincinnati currently does not possess the hardware for this change. In fact, the current server at the repair shop is an old computer, which allows for a maximum occupancy of 10 users to view the EMs at any given time. Buying a new server would allow hundreds of simultaneous users and create an easier method to access EMs, also eliminating the need for a login to view the files. As a result, the team began to explore the option of a new server for the job.

Although this obstacle altered the project drastically and served as a detour, the team was still able to utilize GE Libraries as an effective tool. Since EMs are public information, it is acceptable to place them on a server for all employees to access without using a secure login. On the other hand, planning documents and Repair Documents (RDs) are GE-specific documents, which include special practices that separate GE as the top aircraft engine manufacturer. Using paper copies, these documents were vulnerable to espionage, creating one need for this project. As a result, the team decided to maintain these documents on GE Libraries, eliminating the Engine Manuals branch from each directory and adding an RD section. The new layout of GE Libraries is present in Figure 15: Final GE Libraries folder architecture:

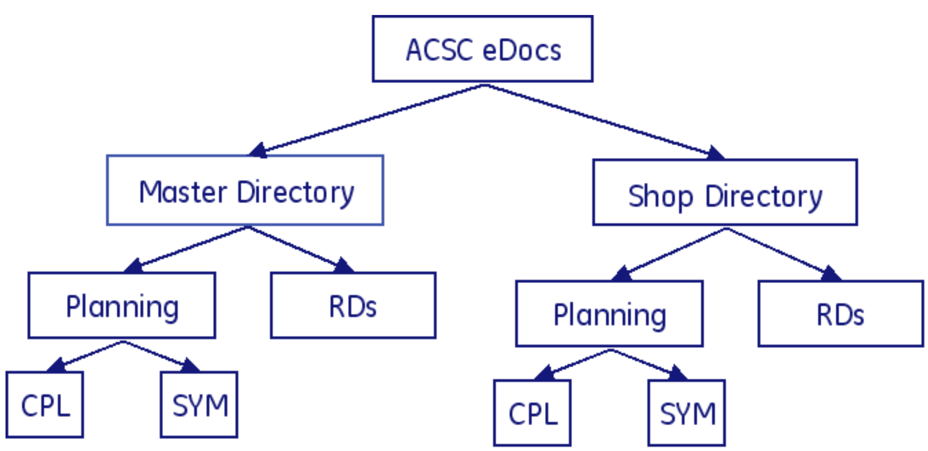


Figure 15: Final GE Libraries folder architecture

In order to access this information, the user must provide his/her SSO login and password, which GE IT protects. This level of protection assures the security of proprietary information for the use of GE employees only.

6.1.2. Server vs. Library

Unlike GE Libraries, a server will include monthly charges for maintenance, hardware, software, storage, and networking. The prices and memory usage need to be controlled by Infra Management to ensure the right equipment is purchased and maintained.

Both the server and GE Libraries will be backed up frequently ensuring that no documents are destroyed or lost. Because the team is trying to digitize and centralize documents, it is also important to have correct system backups. If either system goes down, the Document Center will have master copies to distribute so there is no productivity loss during such an event.

6.2. Document Flow

6.2.1. Culture Change

Similar to the digitization component of the project, the team began changing the shop culture through initiating a document control project. Previously, the Document Center and Engineers felt comfortable using legacy systems with no IT support. After introducing the idea of SC Workflows and displaying the concept of loading all documentation online upon review, the team convinced Services-Cincinnati staff of the importance of the change. Mainly, this alteration entails a switch from Engineers receiving individual ATA sections for review to the distribution of entire EMs. Although this may seem like more work, the Engineers simply identify the same changes to specific sections within a larger document. This flow lessens the DC workload and helps to stay compliant with future systems such as eManuals. As a result, the team avoided resistance from Engineers using a potential new system and prepared the shop for culture change with the use of various systems.

6.2.2. Format Change and Recommendations

Upon encountering the HTML problem, the team started meeting with corporate officials about the nature of the change and what it means for shops globally. Quality groups at all engine service shops have taken initiatives to digitize work instructions, change flow systems and use legacy systems, similar to that of Services-Cincinnati. Because of the HTML formatting, these shops would experience serious issues without a warning of the upcoming change. The team met with the General Manager of Global Operations – Quality and her team to discuss the switch and the effects on GE Aviation. This group informed the rest of Aviation about the HTML and effects on document flow for a digital floor.

In addition, the project team met with Services-Cincinnati business leaders and the entire Quality team to discuss the problems and potential solutions for the shop. The following recommendations arose from these meetings:

- Talk to IT team about adjusting the router generation system to hold revisions without releasing them until a desired date
- Weigh the pros and cons of Quality review multiple times before a router releases vs. converting each individual HTML file to a PDF; determine which would save more time and be more feasible
- Create a standard router format for CPL and Symmes, based off the current Symmes format (planning is built into the router)
- Determine how future systems such as eManuals and SAP will work with router generation: will they parallel existing systems or handle routers directly?

After examining these different options, the team especially recommends the examination of eManuals and SAP, since they are systems on the horizon for the entire company. Since these document control systems will supposedly encompass all documentation, they should have accommodations for router generation and release. In addition, different shops claim that eManuals possesses a document flow tool within the software, which could be useful for Services-Cincinnati. The team maintains that eManuals appears to be the most efficient tool for document control, based on demonstrations from Wales IT (already using it) and research by the IT team in Cincinnati. However, it seems that the Quality team will perform further research and structure the SupportCentral template for use within the business, as the initiative leaves room for improvement with further systems.

6.3. Recommendations for Measurable Effects

After viewing the benefits from the project components, the team discovered a great opportunity for monetary savings and regulatory advancements. These improvements suggest the advantages to an electronic shop floor. The evidence of improvements from cost savings, audit findings, and compliance validate this project as a success and priority for the company.

6.3.1. Cost Savings

The savings highlighted in the Results section show how beneficial the project is for GE Aviation. Although some derived figures cannot represent exact cost savings, the team developed a cost analysis to cover the low end of potential savings. Therefore, the figures used represent the minimum time used to locate work instructions and supply savings. Through this conservative analysis, the team ensures feasible savings and leaves room in the project for even more of a monetary benefit. Using these highly conservative values, following an estimated return on investment of 1.1 years, the company will save a minimum of $15,900 per year. *It is important to note the potential for increased productivity throughput/output is not factored into this analysis, and has the potential to greatly increase the value.*

6.3.2. Audit Findings

The effect on audit findings will require scrutiny upon completion of the digital implementation and solutions for document flow, since the changes depend on project completion. In order to monitor these changes, the team informed the Quality group about the possible improvements and asked that they watch the effects of digitization on audit findings. One internal GE system, controlled by Quality, helps to track all audit findings for Services-Cincinnati. This tool provides evidence of previous findings and will help to capture the improvements from digitization. The team recommends the use of this system to track any changes in audit findings and to react to any findings because of the new systems.

Although developed well, there is no guarantee that the proposed document control systems are flawless and, therefore, Quality should flag any issues found through audits.

6.3.3. Compliance

As GE Aviation pushes to work from digital manuals, Services-Cincinnati complied by undertaking a strong digitization project. This project team began shifting the work instructions from the floor to computers, changing the face of the shop and altering regular practices on legacy systems. This project helped to comply with GE Aviation on two main fronts: culture change for digitization and the discovery of problems with EM formats changing internally. These main facets are crucial to the company, considering the desired direction of all documentation.

The main goal of this project, from the standpoint of GE Aviation, was to develop electronic systems to place all documentation online and introduce the shop floor to computer usage. Because of the project, both CPL and Symmes started using GE Libraries for work instructions and claim to enjoy the switch. In a shop where some resistors posed a threat to this implementation project, the team started a major culture change to carve the way for future systems, such as eManuals. Since the company plans to embrace different systems in the future, the introduction of this digital era proved necessary for the shop floor. As a result, the team suggests that Services-Cincinnati shares this experience with other engine service shops so that all locations prepare well for eManuals. In addition, the facility should introduce eManuals as a slight deviation from the systems used currently due to the ease of transferring from a server and GE Libraries to new systems.

In addition, the team uncovered one main issue with technical publication flow, as the format change will affect all shops. The ability to identify this problem and present it to headquarters illustrates the level of compliance with GE Aviation. Because of this project, other shops are examining their current document control systems and considering changes, which will convert the company to using modernized practices. Without affirmative action from the project team, this issue may have flown under the radar until distribution of the first HTML EM to all shops. The team and officials at GE Aviation consider the project a success due to the depth of research for all proposed solutions and ability to educate the rest of the company about the challenges that "going digital" may pose to any facility.

7. Works Cited

Aharoni, Y., & Nachum, L. (2000). *Globalization of Services: Some Implications for Theory and Practice* (7th edition ed.). New York: Routledge.

Appleton, E. L. (1997). How to survive ERP. *Datamation* , *43* (3), 50-53.

Bernstein, A. (2000). How can cooperative work tools support dynamic group processes? Bridging the specificity frontier.". *Proceedsing of the Conference on Computer Supported Cooperative Work* .

Blumenthal, R. L. (1998). *Supporting Unstructured Activities with a Meta-Contextual Protocol in Situation-Based Workflow.* Department of Computer Science. Boulder, CO: University of Colorado.

Bradley, J. (2008). Management based critical success factors in the implementation of Enterprise Resource Planning systems. *International Journal of Accounting Information Systems* , *9*, 174-200.

Brandt, S. (2004). BACK Aviation Solutions. *Annual Gorham Conference on Commercial Aviation Gas Turbine Maintenance, Repair, and Overhaul, 8th edition.*

Code of Federal Regulations. (2008, July 10). Retrieved August 12, 2008, from Airworthiness Directives - Sec 39.11 - Title 14: http://rgl.faa.gov/Regulatory_and_Guidance_Library/rgAD.nsf/MainFrame?OpenFrameSet

Das, S. R., & Warketin, M. E. (1991). Integrating the content and process of strategic MIS planning with competitive strategy. *Decision Sciences* , *22* (3), 953-984.

Davis, F. D. (1989). Percieved usefulness, percieved ease of use, and user acceptance of information technology. *MIS Quarterly* , *13* (3), 319-339.

Dourish, P., Holmes, J., MacLean, A., Marqvardsen, P., & Zbyslaw, A. (1996). *Freeflow: Mediating between representation and action in workflow systems".* CSCW, Boston, MA.

el Ansari, W., Russel, J., Spence, W., Ryder, E., & Chambers, C. (2003). New skills for a new age: leading the introduction of public health concepts in healthcare curricula. *Public Health* , *117* (2), 77-87.

Elsner, M. (2004). IT for the Paperless MRO Environment. *Aircraft Technology Engineering and Maintenance.*

Federal Aviation Regulations. (2008). Federal Aviation Administration - Jeppeson.

Furumo, K., & Melcher, A. (2006). The Importance of Social Structure in Implementing ERP Systems: A Case Study Using Adaptive Structuration Theory. *Journal of Inormation Technology Cases and Applications* , *8* (2), Article 3.

Grudin, J. (1994). Computer-Supported Cooperative Work: Its History and Participation. *Computer* , *27* (5), 19-26.

Halliday, M. (2008, June 10). Workflow Systems of Wales. (M. Babb, C. McGrath, K. Schebel, & P. Trimby, Interviewers)

Keen, P. G., & Morton, M. S. (1978). *Decision support systems: an organizational perspective.* Reading, MA: Addison-Wesley Publications.

Laughlin, S. P. (1999). An ERP Game Plan. *Journal of Business Strategy* , *20* (1), 32-37.

Maciarello, J. A., & Kirby, C. J. (1994). *Management Control Systems: Using Adaptive Systems to Attain Control.* Upper Saddle River, NJ: Prentice Hall.

Nicolaou, A. (2004). Firm Performance Effects in Relation to the Implementation and Use of Enterprise Resource Planning Systems. *Journal of Information Systems* , *16* (3), 79-105.

ONEstone. (1998). *ProZessware for Lotus Domino/Notes.* Paderborn, Germany: ONEstone Information Technologies GmbH.

Oreg, S. (2003). Resistance to change: developing an individual differences measure. *Journal of Applied Psychology* , *88* (4), 680-93.

Quality. (2008). *Overview of Services Cincinnati.* Cincinnati: GE Aviation.

Special Airworthiness Information Bulletins (SAIB). (2007, July 16). Retrieved 07 22, 2008, from Federal Aviation Administration - Aircraft Safety: http://www.faa.gov/aircraft/safety/alerts/SAIB/

Taylor, S., & Todd, P. (1995). Assessing IT Usage: The Role of Prior Experience. *MIS Quarterly* , *19* (4), 561-571.

Tegtmeier, L. A. (2008). Planaud Talks Engines and Support. *Overhaul and Maintenance* .

The Price of Oil. (2008). *Washington Times* , *16*.

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS Quarterly* , *27* (3), 425-478.

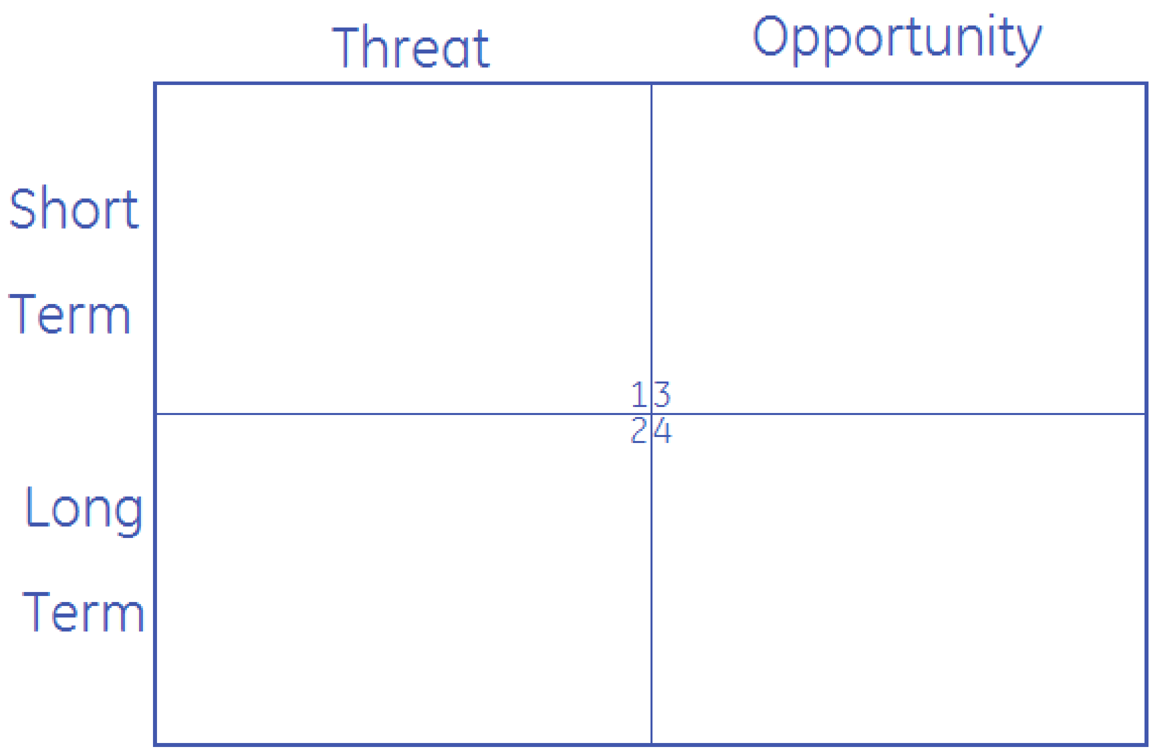
Willcocks, L. P., & Sykes, R. (2000). The role of the CIO and IT function in ERP. *Communication of the ACM* , *43* (4), 32-38.

Ye, C., & Nov, O. (2008). Users' personality and perceivedease of use of digital libraries: The case for resistance to change. *Journal of the American Society for Information Science and Technology* , *59* (5), 845-851.

8. *Appendices*

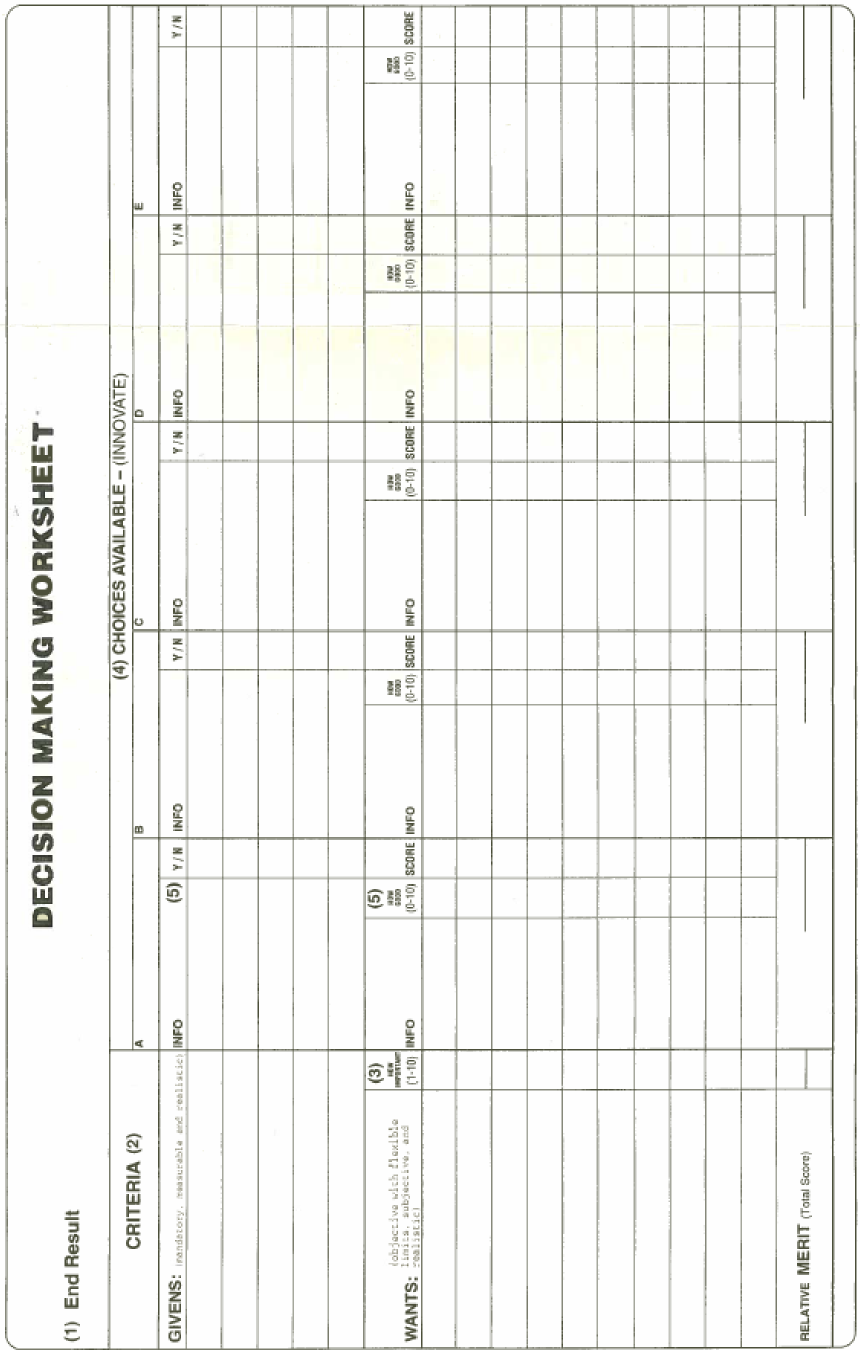
Appendix A: Threats & Opportunities

Template used during group discussions to realize perceived threats and opportunities, as well as their respect forecast of impact. Tool proved essential in understanding user-perception of the change.



Appendix B: Decision Making Matrix

Template used during project research to determine best plan of action. By clearly noting all possible decisions and then comparing all choices by a uniform set of values, and then applying a numeric rank to each, a "best choice" may be resolved.


DECISION MAKING WORKSHEET

(1) End Result

CRITERIA (2)

(4) CHOICES AVAILABLE – (INNOVATE)

A B C D E

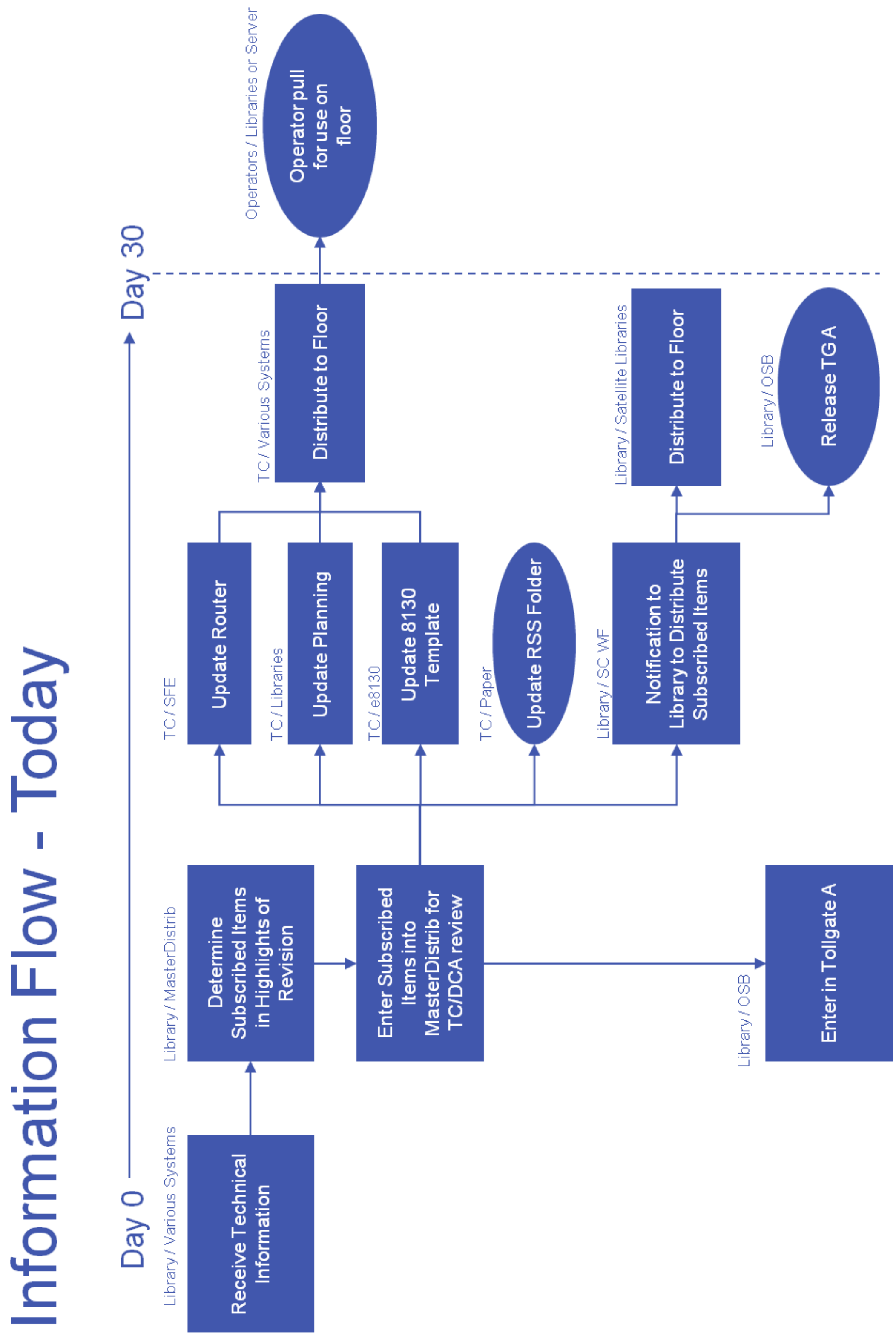
GIVENS: (mandatory, measurable and realistic) INFO (5) Y/N INFO Y/N INFO Y/N INFO Y/N INFO Y/N

WANTS: (objective with flexible limits, subjective, and realistic) (3) (1-10) INFO (5) (0-10) SCORE INFO (0-10) SCORE INFO (0-10) SCORE INFO (0-10) SCORE INFO (0-10) SCORE

RELATIVE MERIT (Total Score)

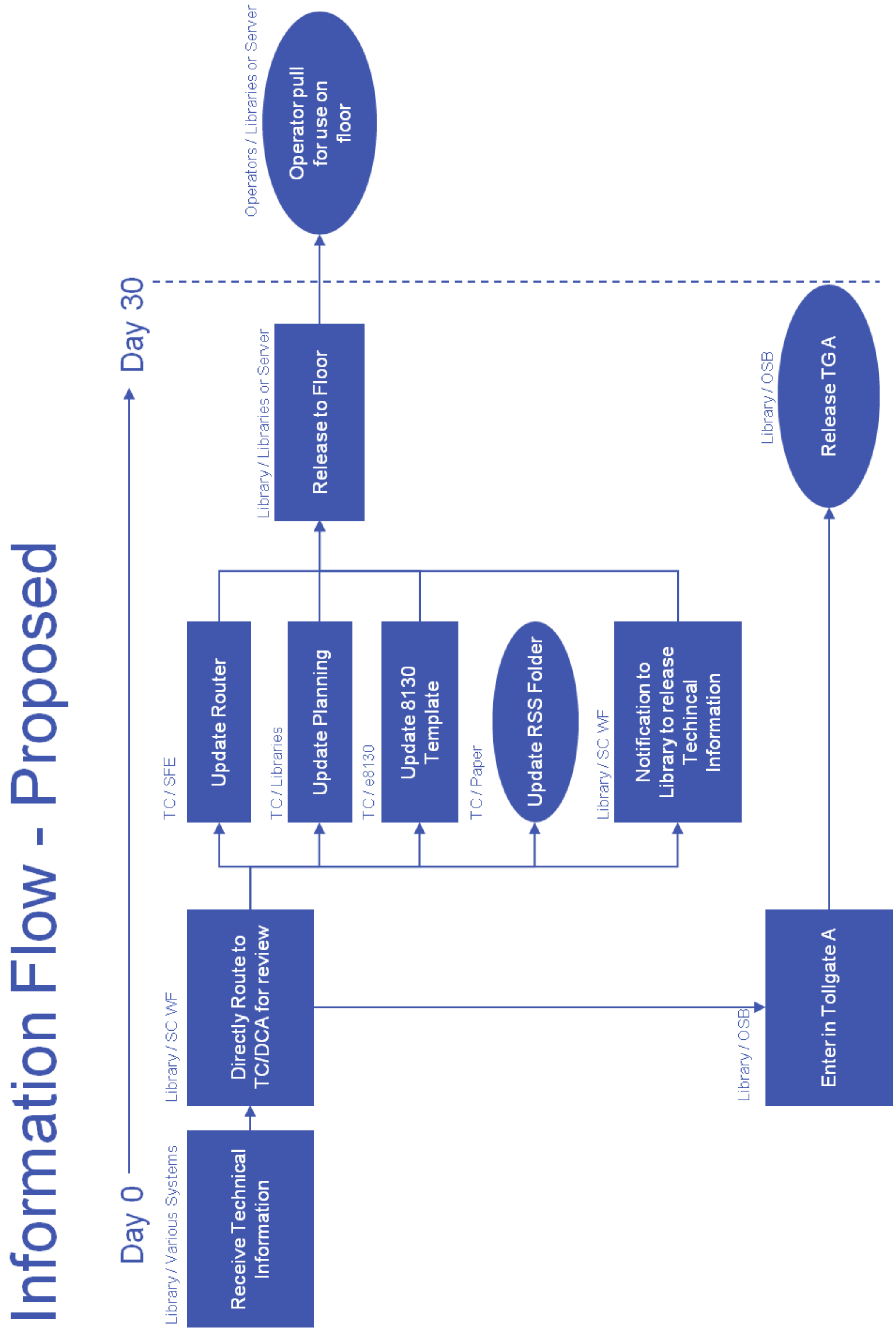
Appendix C: Current Tech Pub Workflow

A simplified, visual representation of the currently used Tech Pub Workflow.



Appendix D: Proposed Tech Pub Workflow

A simplified, visual representation of the proposed Tech Pub Workflow



Appendix E: Supply Savings

Savings predicted by eliminating paper copies of EMs and SOPs from the floor. Costs derived from typical supplier and other values obtained from Document Center.

PAPER

"Copies on floor"	"Pages per section"	"Updates/ yr"	"Pgs printed/yr"
4631	7	2	64834

13	"Boxes of paper a year"
$27.31	"Cost per box"
$355.03	"Cost of paper per year"

TONER

20000	"Pages per ink cart"
$120.00	"Cost per ink cart"
$396.00	"Cost of ink per year"

SUPPLIES

"Binders on floor"	"Changes per year"	"Tabs/binder"
217	1	20

$1.50	"Cost Per Binder"
$325.50	"Yearly Binder Cost"
$1.33	"Cost Per 8 tabs"
$66.50	"Yearly Cost Tabs"
Sum	$1,143.03

***Assuming 20 new binders x 20 new tabs per bind per year

Appendix F: Spaghetti Charting, Predicted Savings

After creating Spaghetti Charts for all operator-positions on the floor at CPL, a highly conservative estimate of savings from reduced walking was created; the reduced head count is also included within this figure, as one job function is focused solely on updating and audits of controlled papers. This does not include possible Indirect Manufacturing Expense, such as an individual stopping to chat en route to a Document Center.

SAVINGS

Operators to Satellite Libraries

Cell:	Position	# of persons	# of times check planning	Average seconds to planning	Seconds saved from vouchering	Total seconds saved/day	Total seconds saved/year	Total hours saved/year	$ saved/year
Sumps and Seals	Operators	9	4	24.4	100	1778.4	470386.8	130.66	$3,542.93
	Cell Leader	1	8	20	100	260	68770	19.10	$517.97
Hot Section	Operators	6	4	47.33	100	1735.92	459150.84	127.54	$3,458.30
GE-90	Operators	3	2	49.8	100	598.8	158382.6	44.00	$1,192.93
	Operators	1	2	79.8	100	259.6	68664.2	19.07	$517.17
	Operators	1	1	19.8	100	119.8	31687.1	8.80	$238.67
	Operators	2	1	180	100	560	148120	41.14	$1,115.63
	Operators	1	1	180	100	280	74060	20.57	$557.82
Tubes and Ducts	Operators	1	1	240	100	340	89930	24.98	$677.35
	Operators	1	1	300	100	400	105800	29.39	$796.88
	Operators	3	2	49.8	100	598.8	158382.6	44.00	$1,192.93
	Operators	2	3	90	100	740	195730	54.37	$1,474.23
	Operators	3	4	55.2	100	962.4	254554.8	70.71	$1,917.29
GE-90 Combustion	Operators	2	1	300	100	800	211600	58.78	$1,593.76
Cases and Frames	Operators	3	1	60	100	480	126960	35.27	$956.26
	Operators	4	1	30	100	520	137540	38.21	$1,035.94
Rotating	Operators	2	1	34.8	100	269.6	71309.2	19.81	$537.10
	Operators	1	1	31.8	100	131.8	34861.1	9.68	$262.57
NDT	Operators	5	1	19.8	100	599	158435.5	44.01	$1,193.33
EB Weld	Operator	1	1	600	100	700	185150	51.43	$1,394.54
								Sum	$24,173.59

Operators to Document Center

	Position	# of visits/day	Average seconds to DC	Total seconds saved/day	Total seconds saved/year	Total hours saved/year	$ saved/year
Entire shop floor	Operator	2	480	960	253920	70.533333	$1,912.51

Document Center to Satellite Libraries (SL)

# Librarians	# of visits/day	Average seconds to SL	Total seconds saved/day	Total seconds saved/year	Total hours saved/year	$ saved/year
1	7	360	2520	666540	185.15	$5,554.50
1	1	360	360	95220	26.45	$793.50
					Sum	$6,348.00

Total Savings $32,434.10

Constants:	
Average operator pay/hour	$27.12
Average # of working days/year	264.5
Librarian pay/hour	$30

Appendix G: Hardware Cost Analysis

After creating floor layouts with locations of each individual terminal, a tally was made of all required hardware. An analysis of this cost is shown below.

Computer accessories as an initial cost

Cell location	Single monitor arm	Double monitor arm	Stand	Network drop	Power drop	Mobile cart equipment	Total cell cost ($)
	CPL						
Sumps and Seals	6	1	1	0	0	0	1255
Hot section	0	0	1	3	2	1	485
GE 90	1	0	3	4	3	0	810
GE 90 combustors	1	0	2	5	3	2	1105
Tubes and ducts	1	0	0	3	2	0	135
Cases and frames	1	0	1	3	2	1	620
Rotating	0	0	0	1	1	0	0
EDM	0	0	1	1	1	0	225
Central services	1	0	2	3	1	0	585
Totals:	11	1	11	23	15	4	5220
	SYMMES						
Blades	5	0	4	8	3	0	1575
Energy Nozzles	0	0	1	1	1	0	225
HPT-AFR	1	0	1	3	0	0	360
HPT	2	0	3	4	4	0	945
LPT	2	0	2	5	2	0	720
Grit Blast	0	0	1	1	1	0	225
Vapor Blast	0	0	0	1	1	0	0
VPA	0	0	0	0	0	2	520
A-Bar	0	0	0	0	0	1	260
Totals:	10	0	12	23	12	3	4830

CONSTANTS

Component	Price ($)
Single monitor arm	135
Double monitor arm	220
Stand	225
Network drop	0
Power drop	0
Mobile cart equipment	260