AVIATION ORGANIZATION STRATEGY DEVELOPMENT IN NATIONAL AIRSPACE MODERNIZATION

By

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Abstract: The purpose of this qualitative study was to determine how small sub-directorates within larger organizations develop strategy to accomplish expansive legacy infrastructure re-engineering. There is significant, historical academic inquiry on Technological Transitions (TT)s with respect to infrastructure modernization; the conversion of the National Airspace System from ground-based to space-based navigation is an example of a TT. There are also studies on how to re-engineer legacy software systems to continue supporting organizational needs. This study is intended to explore a case of re-engineering the expansive legacy ground-based navigation system in the United States by efficiently reducing the size of the network and expanding then verifying signal coverage on over 4.5 million square miles. It is not a pure TT, nor a pure software re-engineering, but rather a large-scale re-engineering of a pre-existing hardware *and* software infrastructure. It constitutes a nationwide effort to re-design and expand the legacy ground-based navigation system developed over 70 years. The Federal Aviation Administration (FAA) advised the public in 2011 that it intended to re-engineer and reduce the Very High Frequency Omnidirectional Range (VOR) network from 896 stations down to 593 stations - to be defined as the Minimum Operational Network (MON). This reduction was based on the premise that two-thirds of the legacy VORs would be retained but their coverage expanded to cover twice the airspace within the US than the previous network. The FAA Flight Program Operations (FPO) is a small sub-directorate within the larger organization that is now responsible to validate signal coverage on several million square miles of additional airspace. Understanding how the FPO develops strategy and leverages technology to support this endeavor can provide a repeatable template for future, expansive, legacy infrastructure re-engineering efforts. This study discovered that the FPO developed and iteratively evolved strategy to accomplish the VOR MON using tribal knowledge, subject matter expertise and accepted business re-engineering practices. The template can be applied to other legacy infrastructure re-engineering efforts to support forthcoming TTs.

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CHAPTER I

INTRODUCTION

This dissertation was an endeavor to explore how small sub-organizations located within larger institutional frameworks develop processes to accomplish large multi-year legacy infrastructure modernization initiatives. Utilizing the Federal Aviation Administration (FAA) as a backdrop I looked at the FAA's initiative known as the Very High Frequency Omni Directional Range Minimum Operational Network (VOR MON) to explore strategy development and process re-engineering. Specifically, I looked at the conversion of a legacy infrastructure for continued usage.

The FAA has been modernizing the National Airspace System (NAS) by developing instrument flight procedures for use by aircraft equipped with performance-based navigation (PBN) systems since the mid-1990s. The PBN systems typically utilize space-based signals from the Global Navigation Satellite Systems (GNSS) allowing users to fly area navigation (RNAV) routes without input signals from legacy ground-based VORs. The FAA has since collaboratively developed and received budgeting authority to move forward with the VOR MON initiative which seeks to reduce the legacy ground-based navigational infrastructure (FAA, 2021b). This includes identifying VORs to be retained, expanding their service distance, and decommissioning the VORs considered redundant infrastructure no longer needed to support ground-based navigation procedures. The result of the effort will be safety back-up navigational system capable of supporting instrument flight during GNSS outages.

The FAA is the organization responsible for regulating the entire NAS. The NAS is the largest and most complex in the world and the FAA was budgeted at $17.5 billion for Fiscal Year (FY 2021) to oversee and modernize (FAA, 2021b). The resources required to manage the largest commercial airspace system in the world are commensurately significant in people and capital. The FAA employs 43,000 people that are considered experts in civil aviation management and safety (FAA, 2021b). The administration is responsible for modernizing the NAS thru a program known as NextGen that consists of 17 different aviation capital improvement programs and has a funding request of $1 billion for FY2022. The VOR MON program is forecasted for a budget of just under $6 million for FY22 (FAA, 2021b).

Capitalizing on the strengths of PBN capabilities and making for a more space-based navigable NAS was the cohesive force between the FAA and aviation stakeholders during the incipient phases of GNSS flight procedure development in the early 1990s. The result over the 25 years are thousands of published Area Navigation (RNAV) Instrument Flight Procedures (IFP)s (US Department of Transportation-Federal Aviation Administration [FAA], 2017). As aircraft are now able to utilize PBN procedures the NAS has technologically transitioned from a ground-based to predominately space-based navigational architecture free from the restrictions imposed by geographic location of the legacy NAVAIDs.

Technological transitions (TT) are defined as "…as major technological transformations in the way societal functions such as transportation, communication, housing, feeding, are fulfilled" (Geels, 2002, "Introduction"). Geels (2002) uses punch card technology conversion to small office digital computer transition during the period 1930 - 1960 as an example. The transition from record albums, reel to reel tapes, and compact disks is another example.

Developing the PBN NAS appears to fit Geels (2002) definition of TT for aviation navigation. Ground-based navigation was the basis of the NAS from the incipient years of aviation. Prior to the PBN NAS aircraft utilized ground-based navigation signals to fly along airways and approach airports during poor weather conditions. The ground-based VOR technology is considered legacy by today's PBN standards. The routings are limited to locations where ground based VORs are geographically positioned and are not always as direct as PBN point-to-point navigation. The limitations of geographic proximity and number mean they not as routing efficient as PBN. They are still considered reliable to make-up the safety navigation backup for PBN procedures during GNSS outages.

Much is said about how societies progress forward with technology, processes, and socialization of various affairs to modernize the way something is accomplished. Geels (2002); Roberts and Geels (2019) use the examples of the shipping industry's transition from sailing to steam during the middle 1800s, along with digital technology conversion, railway to roads (United Kingdom [UK]) and mixed farming to wheat [UK]. Steam to electricity in factory production from 1880-1930 is another example whereby modernization of an entire industry support structure occurred (Devine, 1983). Contemporary TTs examples include transition from hard wired telephone technology to cell phones and gasoline powered vehicles to electric (Attias & Mira-Bonnardel, 2017; Sovacool et al., 2018). Mohapatra (2013) devotes and entire dialogue on differences between process improvement and radical business process reengineering (BPR) to explain how companies modernize their production and cost management mechanisms. Table 1 presents examples of TT and relative timelines. The PBN NAS is a progression forward in the form of technological transition (TT)s and exemplifies the US modernizing the way air-navigation is accomplished.

Technology Transformation	**Mode**	**Industry**	**Time span**
Sailing to Steam	Shipping	Transportation	1860-1900
Steam to Electricity	Factory Production	Power	1880-1930
Hard wire to cell towers	Phones	Telecommunication	1982-Continuing
Railway to Roads (United Kingdom)	Trains/Automobiles	Transportation	1919-1970
Mixed Farming to Wheat (United Kingdom)	Food	Agriculture	1920-1970
Punch cards to digital computers	Office Technology	Information	1930-1960
Petroleum to Electricity	Vehicles	Transportation	2001-Continuing
Ground-Based to Satellite Navigation	Aircraft	Transportation	1995-Continuing

Table 1- Examples of Technological Transition (TT)s

There is also academic examination of how-to re-engineer ‘legacy systems’ in numerous research articles. Business theorists refer to mature systems as ‘legacy’ (Brooke & Ramage, 2001; Ramage & Bennett, 1998; Ransom et al., 1998). The defined terminology “legacy systems” are confined to software re-engineering and typically exemplified within the boundaries of business organizations. Brooke and Ramage (2001) say that “The study of legacy systems has tended to be biased towards a software engineering perspective and to concentrate on technical properties” (p. 365). Therefore, there is research on forward progressing technological transformation in society and re-engineering legacy computer software. The focus of this research is on how organizations transform large-scale legacy public infrastructure hardware and business processes to re-make a pre-existing infrastructure sustainable as a safety back-up on a national scale.

In December 2011, the Federal Aviation Administration (FAA) issued Notice of Proposed Rulemaking (NPRM 76 FR 77939) to the public explaining the VOR MON. The FAAs intent was a transformational reduction of National Airspace System NAS legacy ground-based radio NAVAIDs supporting published aircraft enroute and terminal instrument procedures.

The proposal outlined an architectural schema to continue maintenance of ground-based NAVAIDs throughout the conterminous US. This is accomplished by simultaneously reducing the number of VOR NAVAIDs while extending the standard service volumes (coverage) of retained VORs to ensure seamless conventional navigation across the US for users in the event of lost (GNSS) signal (Provision of navigation services for the next generation air transportation system [NextGen] transition to performance-based navigation [PBN] [plan for establishing a VOR minimum operational network], 2016). The overarching purpose of the effort was to continue transitioning the NAS from predominantly ground-based NAVAID (specifically VOR) make-up to PBN. The VORs selected for retention and consequential service volume expansion would form an optimized conventional back-up network. The FAA explains RNAV equipment supporting the PBN NAS as typically receiving navigational sourcing from either Global Positioning System (GPS)/Global Navigation Satellite System (GNSS), Distance Measuring Equipment (DME)s and Inertial Reference Unit (IRU) (FAA, 2015a; Helfrick, 2015).

The VOR ground-based navigation network has been in existence for 70 years (FAA, 2021e). FAA Flight Program Operations (FPO) is the directorate responsible for validating the US instrument navigation infrastructure network (FAA, 2020d). This dissertation inquiry explored how FAA FPO systematically develops an organizational strategy for validating the VOR MON service volume expansion initiative in the NAS. The VOR MON is an FAA nationwide initiative to re-engineer the legacy ground-based NAS.

This study paired up the organization FAA FPO with the VOR MON enterprise, as a case, to understand how a small sub-organization located within the FAA institutional framework develops processes to accomplish this large multi-year legacy infrastructure transformation. The FAA FPO directorate has a critical role in the NAS modernization initiative reducing ground-based Navigation Aid (NAVAID) infrastructure while expanding and maintaining commensurate service volumes of retained VORs. The FPO will need to accomplish this while continuing their support maintaining safe expansion of Performance-Based Navigation (PBN) navigation access as the primary means of instrument navigation in the NAS.

The VOR MON initiative is like a complete re-development of the ground-based navigation portion of the NAS. It is as a reduction of instrument support infrastructure. It also includes expanding the signal coverage of the VORs identified for retention. Expanding the signal service volume on the VORs identified for retention will require considerable resourcing. The retained VORs will need verification of signal reception at the expanded distances. The new signal propagation distances are nearly twice as far as the legacy circles and include an area three times the previous service volume. The signal reception throughout the proposed service volume expansion will require verification. The VORs identified for decommission will not be simply turned off. The airways and terminal IFPs supported by the VORs identified for decommissioning will need to be re-developed, verified for flyability, and published.

A purposeful exploration of VOR MON assessment practice, data retrieval and presentation provide a case on how small sub-directorates within larger organizations can develop strategies, use information, and implement modernization on legacy infrastructure. The legacy infrastructure case is the VORs located across the continental US. An examination of the process to implement and the tools to support can also assist with visualizing efficiency improvements completing this large-scale organizational endeavor. The research could be used in framing future legacy navigation modernization initiatives. FAA FPO is a central player within the greater organization to accomplish the effort to convert the legacy ground-based instrument architecture to a safety back-up to the (PBN) based instrument NAS.

Background

The FAA initiated an ambitious plan in late 2011 that contained proposed details on transitioning the NAS to Performance Based Navigation (PBN) for departure, enroute, and approach operations in the continental US (Proposed provision of navigation services for the next generation air transportation system (nextgen) transition to performance-based navigation (PBN), 2011, Supp Information). The Notice of Proposed Rulemaking (NPRM) explains that Area Navigation (RNAV) enroute technology using GNSS satellites has matured to the point of seamless navigation capability across the US. Additionally, the Wide Area Augmentation System (WAAS) had been operationally available since 2003 and was the fulfilment of terminal approaches with vertical guidance to supported runways. The intent was that by 2016 the FAA would have implemented WAAS-based terminal instrument procedure at every airport in the continental United States or Alaska with a supportable runway.

The airport design criteria to qualify for WAAS approach with vertical approach guidance is the same as for the comparable legacy ground-based Instrument Landing System (ILS) radio navigation based terminal navigation transmitters. Supportable runways are explained in FAA Advisory Circular 150/5300-13 and generally include completion of vertically guided approach obstacle survey, minimum runway dimensions, and suitable instrument markings (FAA, 2014). There are currently over 5,100 WAAS procedures active in the NAS (FAA, 2018c). The deployment of the WAAS-capable terminal procedures allowed for stabilized vertical final approach guidance similar to ILS and put PBN on a level of near parity with that of the legacy ground-based systems (FAA, 2021a; US Department of Transportation-Federal Aviation Administration [FAA], 2017). This meant that an aircraft could takeoff from an airport, fly enroute, and land at an arrival airport using PBN down to altitudes as low as 200 feet above the runway. A reasonable next step was to manage the legacy ground-based navigation network more efficiently to right size the infrastructure.

The FAA refers to the navigation transition initiative as VOR MON (FAA, 2018d). The intent of the program is to reduce legacy ground-based navigational infrastructure. The savings realization is commensurate with a system based on more accurate, modern, and sustainable PBN navigation technology. The FAA will retain a robust system of legacy VORs allowing users to continue utilizing the conventional instrument NAS as a safety back-up during periods of (GNSS) outage. Proponents with the FAA expect that removing 311 VORs from the inventory of 896 at the start of the program will result in cost savings equating to $1 billion (FAA, 2018d; Proposed provision of navigation services for the next generation air transportation system (nextgen) transition to performance-based navigation (PBN), 2011).

This undertaking is crucial because it helps the FAA fulfill it's four strategic initiatives:

- make aviation safer and smarter
- deliver benefits through technology and infrastructure
- enhance global leadership
- empower and innovate with the FAA's people (FAA, n.d.-b)

The FAA has built an industry around not only the NAVAIDs themselves but also the instrument architecture the stations enable. The proliferation of NAVAIDs and supported departure, enroute, and terminal published procedures is equally commensurate with the growth of the aircraft travel and cargo industry (FAA, 2017a). The VOR MON initiative drastically affects the entire legacy instrument-based NAS schema in existence since the late 1940s. Technical operations maintains the hardware, Aeronautical Information Services (AIS) publishes the supported instrument flight procedures (IFP)s, and Flight Program Operations (FPO) reviews, validates, approves, and periodically inspects usability typically on-site (FAA, 2018b).

The business case to convert the NAS from predominately ground-based to space-based is forthright. The inception of the GPS satellite constellation founded in the early 1990s bolstered the technological capability. The maturation of the published navigational procedures along with the equally important avionics (capable of receiving signals then formulating course and distance information with respect to known geographical coordinates) was groundbreaking. PBN accuracy is better and operates in tandem with other FAA NextGen initiatives.

Computer hardware and software developers have revolutionized the way most industries accomplish business during the time-period since the CAA completed installation of the first operational VOR. VOR technology has served as the primary instrument support node of our modern NAS, and it is on the backside of the lifecycle maturity curve. Computer technology appears to be just getting started as we may soon automate countless tasks using modelling and activity simulations previously accomplished by humans. The FAA is making use of cutting edge computer modeling and testing of NextGen systems for future incorporation into the NAS (FAA, 2019b).

The FAAs flight inspection function has a history that dates to the beginning of airway development when the Post Office Department (POD) had responsibility for the nascent system. The FAA FPO has a long-standing culture of safety assurance. Their responsibilities appear to be on a significant upward trajectory as the FAA seeks to reduce yet improve the transmission and reception capabilities of retained VORs while commensurately implementing and maintaining PBN procedures. The FPO is leveraging emergent technology to manage their responsibilities with respect to signal verification on legacy VORs.

The transition period connecting the legacy instrument NAS with the PBN architecture is a significant opportunity to understand modernization strategy development in large organizations. The endeavor includes not only FPO verification of expanded signal radiating distance around the retained VORs but also re-designing thousands of published ground-based navigable instrument flight procedures (IFP)s. This will be to remove VORs that likewise are to be decommissioned. This is a significant re-design of the entire legacy NAS developed over the previous 70 years.

Statement of the Problem

The central question examined in this dissertation was how small sub-directorates within the framework of larger organizations can develop strategies, use information, and implement modernization on legacy infrastructure. This dissertation explored processes of transitioning to the VOR MON to better understand legacy infrastructure conversion strategy on a national scale. The case examined the FPO as a small directorate within the larger FAA.

FAA Flight Program Operations (FPO) is at a critical juncture in the road of NAS transformation. The NAS ground-based infrastructure, in the form of VORs and ILSs, provided the foundation for legacy aviation navigation. The modern PBN NAS exists predominately on space-based GNSS navigation. The FAA is moving forward with a national-scale transitional modernization of legacy infrastructure. The intent is to significantly expand and validate the ground-based signal on two-thirds of existing VORs throughout the US while removing the other one-third from thousands of instrument flight publications for eventual decommission. The resulting network will form a safety back-up during periods of GNSS outage.

The FAA conducts alignment orbits to inspect VORs supporting instrument flight procedures (IFP)s every 540 days (FAA, 2015b). The FPO inspects VORs not supporting IFPs every 1080 days (FAA, 2015b). FPO accomplishes these periodic inspections on

VORs in addition to their other day-to-day safety assessments throughout the NAS with a fleet of 32 aircraft and 188 personnel (FAA, 2012a).

The VOR MON initiative significantly reduces the number of ground-based NAVAIDs supporting the NAS. At the outset the FAA began in 2016 with 896 VORs and intent to remove 311 while retaining 585 by 2025 (FAA, 2018d). This is significant in that it equates to approximately one-third (34%) of the inventory with proportionate savings on maintenance and infrastructure cost. Commensurate with the reduction is a simultaneous service volume expansion of the retained VORs from 40 NMs to 70 NMs radii (FAA, 2017d). This triples the surface footprint of the former service area (40 NM) from 5,026 NM^2 to 15,393 NM^2 (70 NM) per retained VOR. The total surface area for the retained VORs (585) is 9,005,375 NM^2 compared with that of the pre-MON (896) 4,503,787 NM^2. This, essentially, appears to increase the magnitude of VOR service assessment 100% in terms of surface area. Refer to Figures 5 thru 8 (Chapter II) for a comparative depiction between the two service volumes. This presumably applies not only to the MON initiative initially increasing the service area to 70 NMs but also to the continued periodic inspections at the 540/1080-day intervals thereafter.

In order to further understand the impact of information on strategy development and program execution, I utilized Sanders (1999) stance on the use of information base to identify challenges and make organizational decisions. Sanders (1999) notes that to understand and solve perceived challenges, organizations should view information as either chaotic or ordered. Specifically, Sanders uses the term “interrogation” of the information base to describe how organizational decisionmakers search for constructs to organize chaotic into ordered information (Sanders, 1999, p. 37).

The information base is a collection of "…facts, events, concepts, and behavior…"that decisionmakers use to develop technology, procedures, and processes for accomplishing organizational objectives (Sanders, 1999, p. 47). Sander's refers to the previous four components collectively as data and explains one cannot escape the need to organize it without having a set of working rules to make decisions (1999). Sanders refers to management information systems (MIS) as storage and retrieval mechanisms for information. Specifically, Sanders describes MIS as part of the challenge identification process that organizational users utilize to gather important information

Using Sander's discussion of interrogating MIS in mind, then, how does Flight Program Operations (FPO) leverage computer technology and automation to support accomplishment of a large initiative VOR MON? In what ways might they revise or update current computer automation processes to improve efficiency in MON implementation? The research questions examined in this study were:

Research Questions:

RQ1: How does FAA Flight Program Operations (FPO) systematically develop an organizational strategy for accomplishing VOR MON service volume expansion and verification in the NAS?

RQ2: How does FPO leverage computer automation to develop a VOR MON "information base" and inform organization decision-makers

RQ3: What new automation might FPO propose to gain efficiencies in balancing their normal instrument procedure validation workload with expanding retained VOR service volumes?

Professional Significance of Study

This research examined the VOR MON as a case study construct for developing organizational strategy to accomplish large scale legacy infrastructure modernization initiatives. There is significant research on how society progresses forward with new technology to modernize functions, processes and equipment related to infrastructure systems. An example of this transformative progress is the telephone. During its first 110 years it was a voice communication platform tethered by wiring, cables, and telephone poles. In the past 20 years it has evolved so that the hard wiring was replaced by signal towers. Smart phones today are the realization of data transmission that allow users to transfer voluminous information speedily thru computer applications. Cell phone towers and data networks are reasonably well understood mechanisms on our landscape to support the smart phone.

The infrastructure that previously supported the communications network platform is no longer suitable for today's smart phones. The legacy telephone infrastructure has since been caught in a market 'drift' since the mid-1990s with no apparent overarching initiative to modernize it in totality as a back-up architecture for cell phones (Sovacool et al., 2018). Sovacool et al. (2018) define 'Drift' as '…incumbents holding on to the status quo despite major shifts in contextual relevance" (p. 1078).

There is also research that addresses the concept of re-engineering legacy technological mechanisms. However, most of the research discussion in terms of legacy infrastructure references how to modernize computer server and software enterprises that support companies in the accomplishment of business functions.

More research is needed on re-purposing large scale legacy infrastructure enterprises for long-term retention. Managing large scale legacy infrastructure enterprises is a budgeting and resource challenge for organizations often with significant constraints. What is the end state of the large-scale legacy infrastructure enterprise? How long does the organization need to support it? How does the organization allocate resources to convert and maintain it? How does the organization allocate funds and processes? How does the organization resource the legacy infrastructure enterprise maintenance to balance future modernization initiatives? The FAA is constantly evolving the NAS to incorporate new technologies and users. The PBN NAS has been in development since the 1990s and the FAA advises that the NAS is now predominately PBN supported (US Department of Transportation-Federal Aviation Administration [FAA], 2017). The legacy VORs that were utilized for instrument navigation since the 1950s are numerous and geographically spread across the US. The FAA advises that the VORs will reduced (FAA, 2021b). To repurpose the VORs for long-term retention as back-up system for GNSS outages the FAA shall flight inspect VORs identified for retention and verify use to 70 NMs. The FAA also indicates that expected completion to validate service volume expansion and re-develop instrument flight procedures (IFP)s supported by VORs identified for retention is FY 2030 (FAA, 2021b).

Overview of Methodology

The study inquiry questions were designed and refined using the DELPHI theory (Linstone & Turoff, 1975). DELPHI is an iterative process for arriving at combined responses from a panel of individuals. The group of individuals are selected based on a research purpose. They are usually perceived as experts in the particular area of knowledge based on their postion within an organization or experience consulting in a field. An inquiry is proposed to the panel of respondents and re-proposed after iterative refinements thru the respondents. The panelists utilize written responses and typically do not meet. The quantitative and qualitative surveys in Appendices D and E were the product of iterative process using respondents with expertise in survey development and familiarity with flight inspection procedures (Figure 1). The resulting quantitative survey was designed to identify Very High Frequency Omni-directional Range Minimum Operational Network (VOR MON) experts within the Flight Program Operations (FPO) organization by using quantitative inquiry corroborating knowledge and years of expertise developing technology and processess to accomplish work. The same iterative process was utilized to develop the qualitative survey.

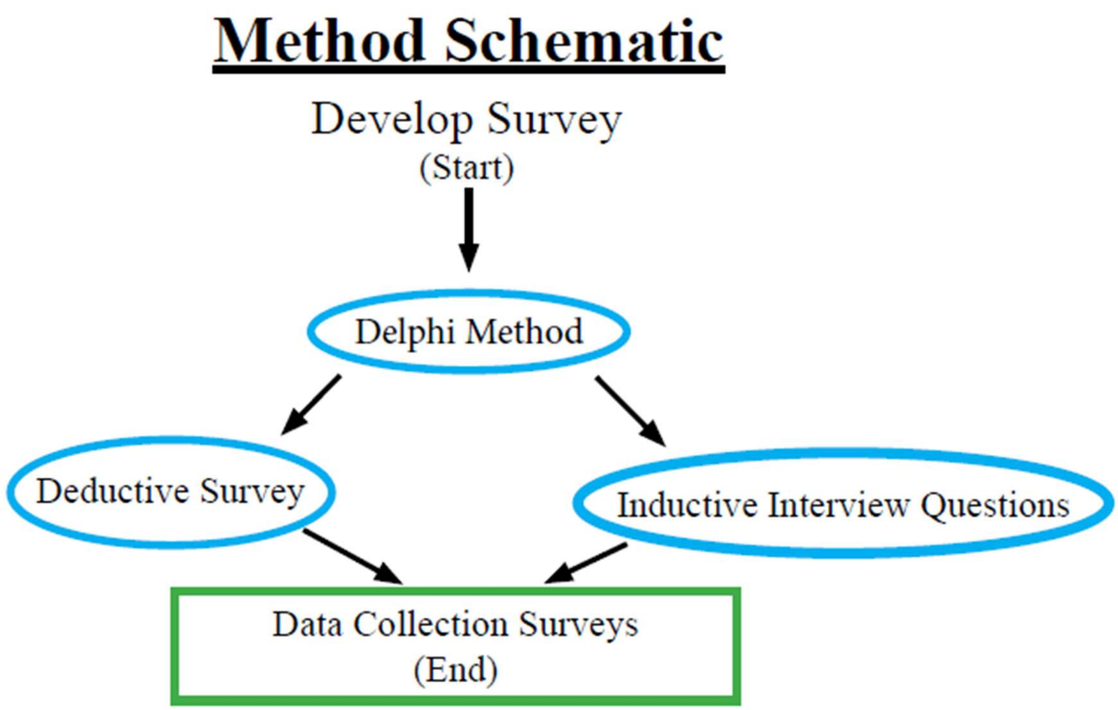


Figure 1-Survey Development

An FPO liaison assisted with ensuring the initial survey invitiation was sent to over 100 people in the organization. The intent of the quantitative survey was to identify candidates that were conversant on the FPO technology, procedures and processes for accomplishing the VOR MON. During this initial invitation process the FPO liaison advised that the VOR MON technology, procedure and process development experienced people were well-known and constituted a small group within the organization I received 9 FPO participants indicating they had significant experience developing technology, procedures and processes associated with the VOR MON initiative. The VOR MON conversant candidates were invited for qualitative interviews (Linstone & Turoff, 1975).

I was also advised that coordinating a collaborative group process by assembling all in the same time and space would be very difficult due to their professional responsibilities within the organization and the restrictions on group meetings due to the pandemic posture. The policy and procedures to conduct FPO VOR MON assessments had evolved over a period of the eight previous years by way of collaborative FAA working groups. Delbecq (1975) states that the purpose of collaborative meetings is to problem solve by tapping individual knowledge and combining because the way forward cannot be determined by one person. The organizational working groups were thus already formed within the FAA to outline paths forward on the VOR MON. The research methodology shifted focus to individual qualitative interviews rather than working groups.

Individual qualitative interviews in a case study format were use to gain an in-depth understanding of the practical context pertainining to large-scale infrastructure re-engineering within the FPO. The VOR MON initiative is a bounded system and offers an information rich opportunity to reveal practical examples of strategy development and information ordering. Case studies are hinged on a real life system that can offer practical example(s) within a contemporary context (Creswell, 2013). The case was the VOR MON and the context was Flight Program Operations.

The researcher utilized semi-structured interviews, FAA public documents, emergent interview opportunities, and member checking as a way to gain a deeper understanding of how the FPO utilizes the information base to develop policy and strategy to accomplish the VOR MON initiative. The opportunity to qualitatively interview participants from other FAA directorates beyond the the FPO was an emergent prossess (Creswell, 2012, p. 130). Creswell (2012) and Patton (2015) describe the emergent process as following the direction set by the study candidates. In this case, the FPO candidates advised contacting several people from other FAA directorates that were conversant in the FPO role accomplishing the VOR MON initiative.

Qualitative interviews were most suitable to conduct this research as the purposeful sampling accomplished during the quantitative portion of the inquiry revealed the relative maturity of the VOR MON program. The FPO and non-FPO participants were well known to have experience in developing technology, procedures and processes for the program. This type of purposeful sampling is refered to as combination or mixed and allowed the research to proceed based on a small group of participants most familiar with the program development (Creswell, 2013, Table 7.2).

The FPO is responsible for the service validation of navigational infrastructure constituting the NAS. FPO is likewise a critical player in validating VORs supporting the MON effort. Identifying the FPO role of technology development providing information bases to organizational decisionmakers supports the context of strategy for the VOR

MON. As the reseacher, I was an instrument for collecting data as a way to understand the the data (Merriam, 1998). I utilized interviews in the ‘field’ to gather information. Merriam (1998) explains that purposeful sampling “…is based on the assumption that the investigator wants to discover, understand, and gain insight and therefore must select a sample from which the most can be learned” (p. 61). The knowledgeable participants were not utilized to get an “average opinion” thoughout the entire FPO but rather to focus on the most in-depth knowledge (Merriam, 1998, p. 61). I implemented the use of purposeful interview allowing participants to share their understanding(s) of their individual and collective role as it related to the VOR MON iniative.

Limitations

Generalizations regarding this study are cautioned. Due to the nature of the flight inspection and the small number of personnel in this role, larger assumptions cannot be made. However, the findings of this research do allow for other organizations to consider how the process of strategy development and information ordering occurs in smaller sub-organizations as part of large-scale legacy infrastructure re-engineering efforts. In addition, the degree that organizational or unit operating rules, culture, or philosophies affected the study are not known. The degree that external pressures facing the FPO and other FAA offices engaged in the VOR MON initiative impacted the study are not known.

It is unknown if any biases or withholding impacted the responses of this study since participants are active members of a government agency. Recognizing this, I assume the following:

1. The participants are involved in the process and are considered well qualified in their field
2. Participants and researcher share a common understanding of aviation processes. Therefore, both can explain and understand aviation experiences and knowledge

Definition of Terms

Recognizing that this study addresses the complexities of the FAA, VOR MON initiative, and instrument navigation it is imperative to establish a shared understanding of common terms and abbreviations used in this dissertation.

This dissertation includes the following terminologies throughout:

- Aeronautical Information Services (AIS) - authoritative FAA source for collecting, validating, storing, maintaining, and disseminating aeronautical data for the U. S. and its territories. Develops and maintains all public instrument flight procedures and airways. Serves as the FAA's aeronautical charting authority for the development, publication, and dissemination of aeronautical charts and products to support aviation and to meet demand for increased capacity, efficiency, and predictability in the airspace, routes, and airports of the (NAS) (FAA, 2018a, "Aeronautical Information Services").
- Aeronautical Data - Information relating to infrastructure elements in the National Airspace System (NAS). An example might be a geographic fix whereby five-letter fix name is associated with geographic latitude and longitude. The responsible organization manages and stores data as ‘source’ or ‘authoritative’. It is the pieces that IFP developers, inspectors, and charting agents utilize to build diagrams,

sketches, maps etc. that depict locations of points or fixes and courses along with presentation of surrounding terrain and infrastructure (FAA, 2019a).

- Airway - An instrument flight area established within controlled airspace in the form of a corridor, the centerline of which is defined by radio navigational aids (FAA, 2021a, PCG A-9)
- Area Navigation (RNAV) - Navigation allowing aircraft operation on any desired flight path within the coverage of ground- or space-based navigation aids or the capability of self-contained aids, or combination thereof (FAA, 2021a, PCG A-12)
- Digital Data Format or Presentation - Refers to the process the FAA uses to display data in digital format or on forms. The organization originates the information for users (FAA, 2018a).
- FAA Flight Program Operations (FPO) - A FAA organization that recently re-aligned to optimize all flying operations. One of their primary missions is to ensure the integrity of instrument approaches and airway procedures that constitute our National Airspace System (NAS) infrastructure and the Federal Aviation Administration's (FAA) international commitments. FPO accomplishes this responsibility through the airborne inspection of all space and ground-based instrument flight procedures and the validation of electronic signals in space transmitted from ground navigation systems. (FAA, 2017b, "Flight Inspection Services")
- FIX - A geographical position determined by visual reference to the surface, by reference to one or more radio NAVAIDs, by celestial plotting, or by another navigational device (FAA, 2021a).

- Global Navigation Satellite System (GNSS) - GNSS refers collectively to the worldwide positioning, navigation, and timing determination capability available from one or more satellite constellations. A GNSS constellation may be augmented by ground stations and/or geostationary satellites to improve integrity and position accuracy. GPS is interchangeable with GNSS however, it refers only to the US maintained portion of the network. (FAA, 2021a).
- Instrument Flight Procedure (IFP) - A series of predetermined maneuvers for orderly transfer of an aircraft under instrument flight rules from an initial approach point to a landing or location where continued flight to the airport of intended landing is visually possible. IFPs are developed, approved and published by Aeronautical Information Services (AIS) (FAA, 2021a, PCG 1-3)
- National Airspace System (NAS) - The common network of U.S. airspace; air navigation facilities, equipment and services, airports or landing areas; aeronautical charts, information, and services; rules, regulations and procedures, technical information, labor, and material. Included are system components shared jointly with the military (FAA, 2021a, PCG N-1)
- National Flight Data Center (NFDC) - Responsible for the collection, validation and quality control of aeronautical information that is disseminated to support the (NAS) operations detailing the physical description, geographical position, and operational characteristics and status of all components of the NAS. (FAA, 2019a, "About the Aeronuatical Data Team")

- Navigational Aid (NAVAID) - Any visual or electronic device airborne or on the surface which provides point-to-point guidance information or position data to aircraft in flight (FAA, 2021a, PCG N-1).
- Nautical Miles (NM) - 6,076 feet.
- NextGen -Next Generation Air Transportation System is the FAA - led modernization of America's air transportation system to make flying even safer, more efficient, and more predictable. Consists of multiple interlinked programs (FAA, 2021d, "Next Generation Air Transportation System (NextGen)")
- Performance-based navigation (PBN) - Area navigation based on performance requirements for aircraft operating along air traffic service routes, IFPs, or designated airspace. The specified RNAV accuracy must be met 95 percent of the flight time. RNAV 1, for example, requires a total system error of not more than 1 nautical mile (NM) for 95 percent of the total flight time (FAA, 2015a, Para 4.b; 2021a, PCG P-1).
- Q-Route - Airways available for use by RNAV equipped aircraft between 18,000 feet MSL and FL 450 inclusive. Q-routes are depicted on Enroute High Altitude Charts (FAA, 2021a, 5-3-4.3(1)).
- Standard Service Volume (SSV) - The reception limits of unrestricted NAVAIDs usable for random/unpublished route navigation. Expressed in NM radius, ft. for altitude (FAA, 2021a, Sect. 1-1-8).
- T-Route - Airways available for use by GPS or GPS/WAAS equipped aircraft from 1,200 feet above the surface (or in some instances higher) up to but not including 18,000 feet MSL. T-routes are depicted on Enroute Low Altitude Charts (FAA, 2021a, 5-3-4.3(2)).

- Very High Frequency Omnidirectional Radio Navigation Aid (VOR) - A ground-based electronic navigation aid transmitting radio navigation signals 360º in azimuth, oriented to a pre-defined magnetic north. Used for navigation throughout the NAS (FAA, 2021a, PCG V-4).

Organization of the Dissertation

This dissertation is composed of five chapters. The introduction chapter is an overview of the study, its relevance and contribution to research and practice. Chapter I is also an overarching scope of the research completed. Next, chapter 2 is a review of the literature is important. It serves to ground the need for this study. The methods, chapter 3, provides detailed information on the processes to collect and analyze data. In the results, chapter 4, I provide further understanding of what was found during my analysis. Finally, discussion and recommendations for future research are addressed in the findings chapter 5. Appendices and references are found immediately following the findings.

CHAPTER II

REVIEW OF LITERATURE

This literature review begins with an explanation of the Very High Frequency Omnidirectional Range Minimum Operational Network (VOR MON). It then flows into a historical review of the Federal role in navigation development, legacy infrastructure modernization, knowledge objects, modernization cases and research questions.

This literature review is to provide:

a) understanding of the FPOs role in validating NAS navigation systems
b) A comparison of Geels (2002) Technological Transition with legacy infrastructure modernization
c) Cases of legacy infrastructure modernization
d) Lastly there is a discussion of data in the form of knowledge objects and how they can be managed to provide visualizations that help provide better understanding for organizational decisionmakers. Displaying it requires processing that makes it easy for users to understand and integrate across internal organizational boundaries. New processes may allow for scaling back legacy processes in favor of more efficient mechanisms to arrive at the same result while continuing the same high-quality work.

The VOR system architecture in existence at the outset of the MON initiative to reduce and transition is the result of 70+ years of installation, procedure development, and validation. Flight Program Operations (FPO) flight inspection is the primary office responsible for navigation signal and supported IFP validation. The hardware, software, and processes for maintaining the VOR system architecture can reasonably be considered legacy in that it has been superseded by Performance Based Navigation (PBN) design and procedures. PBN is modern point-to-point navigation based on area navigation (RNAV) made possible by more precise aircraft positioning, using multiple navigation sources, and allowing any desired flight path.

The FAA has purposed the VOR MON initiative to strategically reduce and streamline the ground-based navigation supported National Airspace System (NAS) resulting in large-scale re-engineering of the legacy system. This re-engineering of architecture will allow the improved system to continue supporting ground-based NAS navigation as a safety back-up during periods of Global Navigation Satellite System (GNSS) outage (Proposed provision of navigation services for the next generation air transportation system (nextgen) transition to performance-based navigation (PBN), 2011).

This re-engineering effort is based on retained VOR service volume expansion to support the removal of approximately one-third of the FAA maintained NAVAIDs in the NAS. This not only requires FPO validation on the retained VORs, but also the consequential redevelopment and redistribution of ground-based airways and instrument flight procedures (IFP)s in the NAS. Re-engineering legacy infrastructure is a process to increase service life on existing technology. When viewed at the strategic architectural level this is a proposed benefit of the VOR streamlining strategy.

Ralph Sanders (1999) indicates that leaders and executives must grapple with information when faced with organizational challenges. It is the information base consisting of "…facts, events, concepts, and behavior…"that decisionmakers use to develop technology, procedures, and processes for accomplishing organizational objectives (Sanders, 1999, p. 47). Organizational decisionmakers use the 'information base' to identify and solve challenges (Sanders, 1999). The information comes in two forms that Sanders identifies as either ordered or chaotic (Sanders, 1999). The ordered pertains to information that is already organized according to the standards adopted by the organization (Sanders, 1999). Examples of ordered information include, organizational reports that are routinely accomplished at periodic intervals and in standardized formats (Sanders, 1999).

Sanders (1999) notes that chaotic information is typically disorganized and un-refined. The information may be available in databases. but not stratified in a manner that allows for easy translation into trends or may place undue burden on the user to interpret. Sanders (1999) refers to this as the inability to use the information to easily make connections and use for problem solving analysis. One might presume that without the organization of data pieces, decisionmakers are unable to make accurate decisions to improve the institution.

The current VOR service volumes and navigational signal restrictions are published in the FAA chart supplement and based on a premise of periodic review and maintenance through flight validation (FAA, 2015b, 2019a). This information appears to be ordered by

Sanders (1999) definition as it is periodically published for users. Expanding the service volume on nearly 600 VORs requires time and resources to validate areas then process and document appropriate findings, prior to publication. The information needed to support the validation will need to be gathered, processed, and published. This process seemingly fits into Sander's definition of chaotic and not yet fully refined.

a) Federal role - Commercial Aviation Navigation Development

The Wright Brothers introduced the US to powered flight at Kitty Hawk North Carolina in 1903. The result of their achievement was transformational not only from physics, mechanical and practical perspective but also for the events and doctrine that it precipitated. The brothers innovative design prompted powered aircraft acceptance that included military, exploration, commercial passenger travel, mail and sport usage (Bilstein, 2001). The order of acceptance, however, was shaped by groups of potential users that had specific needs.

Military Use of Aircraft

Military use of the aircraft arose from a budget large enough to leverage further research and development. The US Army (USA) negotiated contract for one airplane at a cost of $25,000 in 1908 (Bilstein, 2001). The presumption was that that the USA would advantage it as a scout and reconnaissance vehicle. Still, Bilstein (2001), highlights that the period of flight prior to World War I was circus-like. Barnum and Bailey's interest in flying stunts to entertain crowds of onlookers punctuated the public's pervasive lack of vision concerning long-term practical use. The price for purchase of the craft was daunting ($5000 - $7500) and did not include any type of infrastructure for support such as maintenance or operational standards based on comprehensive flying lessons (Bilstein, 2001, p. 29). The desperation of military commanders to edge battlefield enemies out during the stalemated trench warfare of WWI gave the airplane a significant boost in acceptance as a more serious platform for wartime endeavors. The specific role-usage at the beginning of the conflict, although limited to intelligence and battlefield awareness missions, helped give aircraft an anchor-point from which to evolve. Refinements in airframe and power plant technology came commensurate with doctrinal thinking and forward minded individuals such as General Mitchell who foresaw strategic offensive utilization as a serious option for future combat (Anderson, 2002).

The end of WWI marked a potential stopping point in the evolution and practical use of airplanes. A future of reduced funding allocations for post wartime budget meant there would be a surplus of airplanes and pilots that did not fit into any proportionate commercial enterprise effort to continue advancing development. Airplane ventures after the war would be deviled by a dearth of airport and navigation infrastructure that made profit-making endeavors extremely challenging (Davies, 1982).

Post Office Department (POD)

The US Government temporarily leveraged a subset of the surplus airplanes and pilots at the close of the war by charging the Post Office Department (POD) with institutionalization of a new airmail service for America. Investment is a critical ingredient to enliven any potentially lucrative enterprise and the government appropriated $100,000 in late 1917 for the acquisition of air-mail aircraft (Davies, 1982). The beginnings were unbecoming in that the funds, intended for the procurement of new aircraft in a still immature civil industry, were too late for the proposed May 1918 service implementation date. The interim solution, surplus Army aircraft, provided a very primitive start to the fledgling non-military aircraft enterprise.

Between May 15 and August 12 Army aviators equipped with Army aircraft-initiated airmail along a route connecting New York to Washington using Philadelphia as a stopover in both directions. The success rate during this time was about 75% of the mileage flown (David, 1934). Most would likely consider the completion rate to be substandard and attributable to inexperience, opposing weather conditions and lack of supporting airport infrastructure to allow for sustained safe service.

The POD progressed forward on the edge of ambitious expansion coupled with overbearing risk. The business model was to begin a transcontinental airmail route that would eventually include New York to San Francisco by way of Chicago. The POD set about to conquer the first portion from New York to Chicago as early as late 1918. Success was elusive and regular service delayed until July 1919.

Problems were many and began with the aircraft. The surplus military aircraft were simply not built or designed for heavy commercial use (David, 1934). Combat design included lightweight and minimal hauling with a focus on speed. Austere weather conditions and lack of prepared airfields along the route spelled doom for the DeHavilland aircraft initially utilized to initiate the service. Postponements and delays centered around rebuilding engines and airplane structure for better performance in the opposing environmental conditions (David, 1934). Lastly, the aircraft needed more capacity for mail. Revenue generation was critical and there was a dearth of storage space hampering the primary goal of postage movement.

Weather and terrain were formidable foes that accentuated a lack of emergency landing sites. This limited service success to mostly daylight hours in temperate weather conditions. Naturally, the summer months made up for the more dark and stormy seasons. David (1934) makes a considerable point that the land mass in between New York and Chicago included the Allegheny Mountains where bad weather not only prevailed but the terrain would not even support the possibility of an “uncontrolled” emergency airfield. This meant that pilots forging forward only had the option of a crash landing in the case of engine trouble. Daytime visual meteorological conditions were the only real option.

Early Navigation

To reconcile these difficulties, the POD developed ground-based navigation systems to accommodate night and all weather flying. The systems were initially primitive. Bonfires were a nascent attempt at making landing sites navigable at night (Bilstein, 2001; Davies, 1982; Kraus, 2008). As the POD progressed in the expansion of the intended transcontinental airmail route between New York and San Francisco there was a commensurate evolvement in technology to allow for night and all-weather capability. The bonfires gave way to lighted airway towers that utilized electrical power when feasible and gas when not (Komons, 1978)

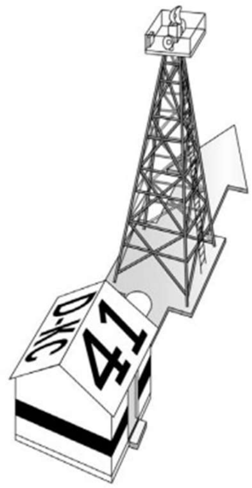
The government passed the Kelly Bill in 1925 to transition the airmail service to contracted carriers. There was presumably never an intent for the government to manage the enterprise in perpetuity and the effort to commercialize the situation was underway (Air Mail Pioneers, 1962). The Air Commerce Act of 1926 followed the Kelly Bill and delineated responsibility for the incipient air navigation system to the administrator of the newly formed Department of Commerce Aeronautics Branch (David, 1934; Shrader, 1953).

National Airspace System Instrument Navigation

The US government retained responsibility for the oversight and development of the navigation system initially over the concern that corporate entities should have the opportunity to make the air-mail service competitive and efficient (Komons, 1978). The overlying assumption was that flying mail was a profitable endeavor. Responsibility for developing and modernizing the architecture of the national airspace system was a different matter altogether.

By 1926, it was becoming apparent that modern innovation would underpin significant roles in the continued development of the airways. The government did not expect that potential contracted air-mail carriers of the early 1920s could reasonably shoulder the financial investment burden of developing navigable airways that would cross the entire US (David, 1934). Leveraging existing governmental departments to provide physical support in the form of beacons, lighthouses (Bureau of Lighthouses), large directional concrete arrows, and air navigation charts (Coast and Geodetic Survey) was critical in addressing navigational needs (Whitnah, 1967). Figure 2 is a cartographic depiction of how the arrow and lighthouse concept appeared to pilots.

The Air Commerce Act gave way to other legislative refinements over the 80 years following that evolved government oversight of the national airspace system (NAS). Congress passed the Civil Aeronautics Act in 1938 and amended in 1940 to balance the responsibility between the government's function to promote commercial air



A standard airway beacon tower. Image: Courtesy Federal Aviation Administration

Figure 2-Adapted from Giant concrete arrows across the US, by Gaudinski, J. 2016 (http://www.mobileranger.com/blog/giant-concrete-arrows-across-the-united-states/). In the public domain

carrier safety while giving the Civil Aeronautics Administration (CAA) continued overarching responsibility for airways and navigation (United States, 1938; Woolley, 1929). Included was not only the responsibility to develop the infrastructure of the airways but also the charting for use by the public (United States, 1938). This comprised development of "…visual, mechanical, electrical, radio or other like aids…" (United States, 1938, Sec 302a and 302b).

Development of a futuristic and navigable airspace system was a significant endeavor. Airways and instrument flight access to communities meant large and pervasive investment to not only initially implement systems but also to maintain. The POD's estimates to annually maintain 100 miles of airway in 1926 was nearly $10,000 (Joint Committee on Civil Aviation of the U. S. Department of Commerce & The American Engineering Co, 1926). This number is foundational to understanding multiplicative cost based on the proliferation of lighted airways, as it was additional to the front-end investment to initiate the lines. The first 1,886 miles between New York City and Rock Springs, Wyoming cost over $500,000 in 1924 (Smith, 1942). The initial transcontinental airway completed coast to coast in the early 1920s was over 2,600 miles in length (Whitnah, 1967). The airway maintenance per year was over a third of what it cost to implement. The Department of Commerce Aeronautics branch began implementation of primitive Low Frequency (LF) radio navigation airways in the late 1920s to technologically improve the capabilities of the system (FAA, 1980). Low-Frequency (LF) airways paved a pathway to Very High Frequency Omnidirectional Range (VOR) navigation stations (Figure 3) during the years following World War II (WWII) (Thompson, 2002).

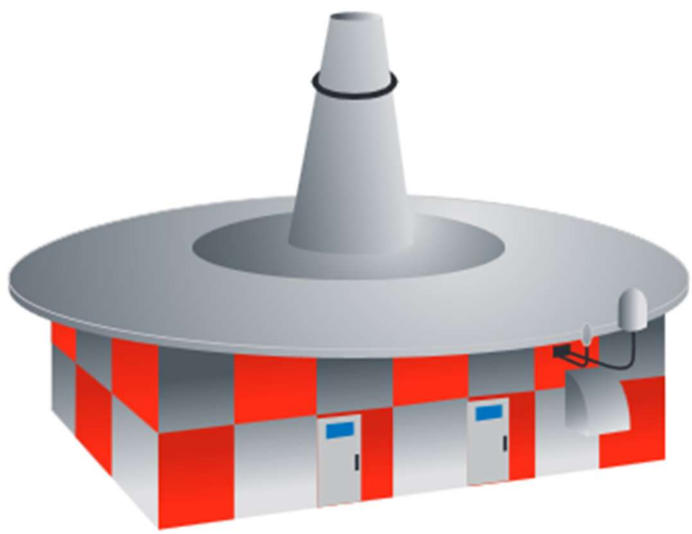


Figure 3-Cartographical Depiction of VOR facility. Adapted from Instrument flying handbook (FAA-H-8083-15B), FAA, 2012b, Washington, DC: US GPO. (https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/media/FAA-H-8083-15B.pdf). In the public domain

Very High Frequency Omni-Directional Range (VOR)

The CAA implemented the first VOR anchored navigation airway in 1951 and the system dependability along with commensurate affordability made it the foundational choice for the US National Airspace System (NAS) (Thompson, 2002). Instrument Landing System (ILS)s were likewise principal to the navigable NAS and the CAA began a program to institute terminal

instrument flight procedures (IFP)s at airports around the nation also following WWII (FAA, 1980). Lt. Doolittle first demonstrated the possibility to utilize (ILS) for landing at airfields during periods of low ceilings in 1929 (Smith, 1942). The system did not reach technological or implementation maturity until the late 1940s but was a significant catalyst to increased weather access at larger airports throughout the US. The concept allowed for aircraft "stacking" by phasing aircraft procedural clearances (Smith, 1942, p. 365). By 1964 both systems (VORs and ILSs) accounted for 1,684 radio navigation aids making up charted airways and IFPs (FAA, 1980).

Flight Inspection

The maintenance and inspection function of the government with respect to airways was incipient during the early 1920s when the POD managed airmail service. A major component of this function known collectively as flight inspection was instituted during the mid-1920s when POD inspectors utilized DeHavilland DH-4B aircraft to assess and verify the first light beacons used on the transcontinental route (Thompson, 2002). Execution of the plan to disperse radio navigation aids throughout the US in the late 1920s brought more need for periodic inspections to ensure proper station signal propagation. The flight inspection organization was very regionalized and each pilot typically inspected between 3,000 and 3,500 miles of Federal airways (Thompson, 2002, p. 26). The Department of Commerce Aeronautics branch appropriated a variety of aircraft beginning in the late 1920s so that by 1940 the organization utilized 8 different airframes for inspections (Thompson, 2002).

By the summer of 1952 over 45,000 miles of airway required periodic patrol to ensure adequate performance (Thompson, 2002). The responsibility and time commitment to manage the architecture was significant. The price of overhauling the entire system in 1956 was $450 million [~ $4.37 Billion in 2021 dollars] (Thompson, 2002). It became evident that a larger and more comprehensive re-structuring of the overarching organizational administration would likewise be necessary. Thus, the FAA emerged following passage of the Federal Aviation Act of 1958 (Kraus, 2008). The legislation followed concern over two significant accidents in 1957 and 1958 involving civil and military aircraft along designed airways that were poorly managed reference frequency and speed of aircraft (Davies, 1982).

Flight inspection responsibility continued to grow with an expanding transportation system. Significant events in the 1960s included continued rapid proliferation of NAVAIDs, centralization of the flight inspection NAS responsibility in Oklahoma City, fleet modernization, and a major FAA re-organization (Thompson, 2002). The airway responsibilities grew significantly with the advent of jet airliners in the late 1950s. The altitudes mandated more vertical service volume for VORs to cover the expanse of higher altitudes traversed by the modern jets. The FAA flight inspection mission likewise required aircraft that could not only fly faster but were equipped with improved radio signal testing technology (Kraus, 2008; Thompson, 2002). Additionally, the FAA assumed responsibility for flight inspecting stations and airfields supporting the military services.

VORs and ILSs remained the backbone of the air navigation infrastructure overseen by the FAA until NPRM 76 FR 77939 in 2011. Notwithstanding, the transition from ground-based NAVAIDs to a more space-based structure was in motion several years prior. The Department of Defense (DOD) completed the phase emplacement of the Global Positioning System (GPS) satellite constellation in 1992 (FAA, 2012b). The array allows suitably equipped users to assess location and time, distance, courses to specified latitude longitude coordinates with much greater flexibility, reliability, and accuracy than legacy ground-based NAVAIDs. The functionality was groundbreaking but only an early step to a space-based or PBN airways and IFPs. There was still much work to develop, test, implement and publish new area navigation (RNAV) airways and terminal procedures.

Performance Based Navigation (PBN)

The FAA launched Operation Evolutionary Plan (OEP) in June 2001 to advise NAS users of a collaborative plan with commercial industry for improving airspace capacity (FAA, 2009). One of the top priorities was significant expansion of RNAV procedures available throughout the NAS. This included dramatically deliberate efforts to prepare enroute and airport infrastructure for the forthcoming wave of space-based PBN procedures. It called for a phased implementation of airspace re-designs. The FAA referred to this focused effort as optimization of airspace procedures in the metroplex (OAPM) and sought to leverage economies of scale by closely managing multiple traffic priorities of airports within close geographic proximity to one-another (FAA, 2017c).

This structured approach to metroplex development has significantly increased the number of instrument procedures (to include those utilizing ground-based NAVAIDs) over the years since inception of the GPS satellite constellation. The FAA indicates in Table 2 there are currently over 11,996 RNAV, and ground-based terminal procedures published throughout the NAS. Obtain this number by adding the total RNAV (6,941) with the total ground-based (5,055). FPO responsibility in the NAS has doubled since implementing OEP in 2001 to increase RNAV approach access. Each of the “lines” (of the 11,996) is at least one instrument final approach located at an aerodrome. An example of a line of approach minima would be a Localizer performance with Vertical guidance (LPV) displayed in Figure 4 (FAA, 2020f).

The flight inspection manual (FAAO 8200.1D) periodic review timetable shown in Figure 11 (Chapter IV) is 540 days for an IFP final approach safety assessment (FAA, 2015b). The number of IFPs from Table 2 (excluding the circling procedures) is approximately 12,000. Every duty week there are over 100 periodic reviews conducted just on the final approach segments. This is a major FPO commitment in support of NAS assessment. This does not consider orbital alignment for each VOR (540 or 1080 days) (FAA, 2015b) Travel time to and from the inspection sites is another item not detailed.

NAS Maintenance

The FAA IFP Gateway indicates that there are nearly 2,000 new procedures and amendments lined up for calendar year 2022 (FAA, 2020e). FPO is responsible to inspect new or amended procedures in addition to managing the review periodicity of the minimums in the left column plus Standard Instrument Departures (SID)s, Standard Terminal Arrivals (STAR)s and AIRWAYs. The varying complexity and geographic scale of the NAS make the responsibility to develop, validate, and periodically assess ostensibly appear monumental.

Federal Aviation Administration

Instrument Flight Procedures (IFP (Instrument Flight Procedures)) Inventory Summary

For Publication Cycle: **10/07/2021**

RNAV	Charts	DP / ODP / STAR	
GPS (Stand - Alone)	81	Conventional DP	865
RNAV (GPS)	6,442	RNAV DP	1,293
RNAV (RNP)	418	Conventional ODP	89
TOTAL	**6,941**	RNAV ODP	103
		Conventional STAR	863
IAP	**Charts**	RNAV STAR [1]	1,085
ILS	1,291	**TOTAL (Includes Military)**	**4,298**
ILS (CAT II)	31		
ILS (CAT II-III)	132	**AIRWAY**	**Count**
ILS (CAT III)	0	Alaska Colored Airway (A, B, G, R)	45
ILS PRM	38	Jet (J)	250
ILS SA (CAT I)	119	Jet RNAV (Alaska)	2
ILS SA (CAT I-II)	57	Q-Route [1]	175
ILS SA (CAT II)	15	T-Route [1]	154
ILS/DME	1	TK-Route [1]	2
LDA	22	Victor (V)	605
LDA PRM	0	**TOTAL**	**1,233**
LDA/DME	9		
LOC	1,346		
LOC BC	46		
LOC/DME	75		
LOC/DME BC	15		
LOC/NDB	2		
NDB	227		
NDB/DME	7		
SDF	1		
TACAN	128		
VISUAL	52		
VOR	994		
VOR/DME	366		
VOR/DME RNAV	0		
TOTAL (FAA ONLY)	**5,055**		
IAP	**CHARTS**		
CIRCLING (All Types)	828		

Page last modified: October 01, 2021 11:57:56 AM EDT

This page was originally published at: https://www.faa.gov/air_traffic/flight_info/aeronav/procedures/ifp_inventory_summary/

Table 2-Instrument flight procedures (IFP) inventory summary, an indicator of FPO day-to-day workload. FPO flies every procedure on a on a 540 day interval directed in FAA Order 8200.1D Table 4-1. FPO also concurrently flies new and amendmed procedures annually. Adapted from "Production Data", FAA, 2018c (https://www.faa.gov/air_traffic/flight_info/aeronav/procedures/ifp_inventory_summary/) In the public domain

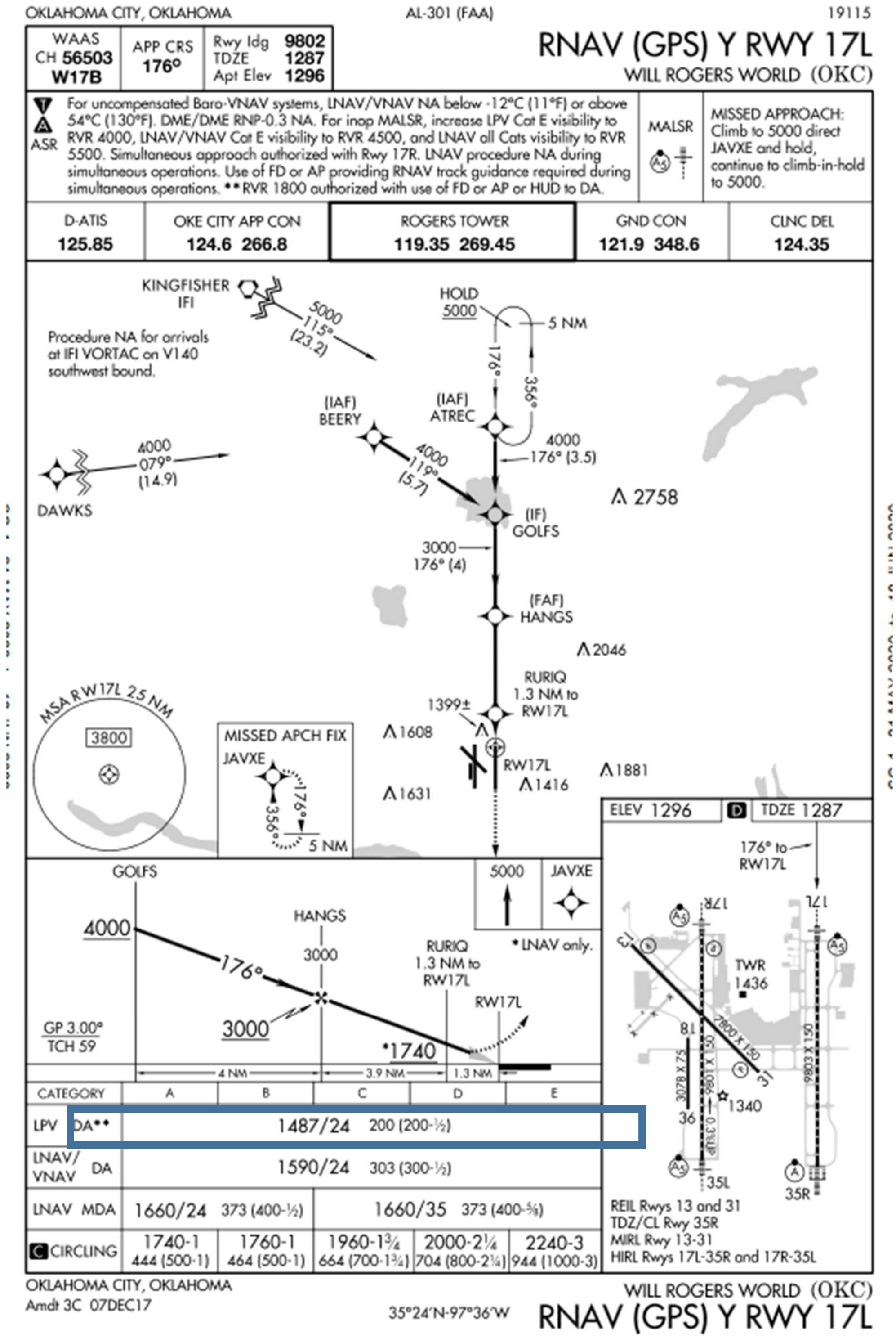


Figure 4-Published IFP with LPV (Localizer Performance with Vertical guidance) line of minima boxed in blue rectangle. Adapted from KOKC RNAV (GPS) Y RWY 17L amdt 3C, FAA, 2020f, (https://aeronav.faa.gov/d-tpp/2006/00301ry17l.pdf#nameddest=(OKC)). In the public domain

The FAAs commitment to supporting the ground-based infrastructure is likely far from over. The FAA advises users thru Federal Rulemaking document 76 FR 77939 that the intention of the initiative is to convert the NAS over to predominately PBN-based navigation. This includes a clause retaining a minimum operational network (MON) of VORs and commensurate distance measuring equipment (DME)s (Proposed provision of navigation services for the next generation air transportation system (nextgen) transition to performance-based navigation (PBN), 2011).

The FAA will maintain the legacy ground-based systems for back-up instrument NAS capability in a GPS outage scenario. There is also an inherent duality noted in the initiative conceding that many NAS users are not suitably equipped to fly instruments in a solely space-based PBN NAS.

DME's are significant in that, although a 'legacy' ground-based NAVAID, also support a PBN navigation concept that uses DME/DME/Inertial Reference Unit (D/D/I). (FAA, 2011). Advisory Circular 90-108 explains that the D/D/I RNAV concept of location and course is similar to GNSS navigation solutions except that the sourcing utilizes position determination by triangulating DMEs rather than GPS satellites. The FAA announced (76 FR 77939) an enhancement program to improve DMEs throughout the country to support D/D/I operations in and around CORE 30 airports. This potentially an additional FPO responsibility in the form of ground-based equipment service volume to assess and periodically evaluate.

Legacy VOR NAVAID infrastructure supports several hundred thousand miles of air routing (FAA, 2020g). If one conservatively considers the average length of an airway crossing the conterminous US or Alaska as averaging 400 NMs and over 2,500

Instrument approach plates similarly equvalent to 25 miles each the figure is extensive. In the near term the Agency's maintenance function has significantly expanded in that there now exists a published PBN infrastructure comparable (if not more extensive) than the legacy ground-based structure. Added to that is the inclusivenes of enhanced DMEs for use on PBN procedures that support D/D/I.

The FAA responsibly develops, maintains, and controls the air traffic that use instrument airways and flight procedures throughout the US including Alaska, Hawaii, and territories. This includes over 1,200 published airway routes, 956 of which the Agency defines by ground-based navigation aids and fixes. It also includes the terminal instrument flight procedures (IFP)s serving public and select private airports. Published Instrument approach and departure procedures number over 16,000 (FAA, 2018c). This includes the Standard Terminal Arrivals (STAR)s, Obstacle Departure Procedures (ODP)s, Standard Instrument Departures (SID)s, Area Navigation Procedures (RNP and RNAV)s and all the ILS, LOC, VOR, SDF, LDA, and NDB procedures-based on ground navigation emitters.

Aeronautical Information Services directorate (AJV-A) and Flight Program Operations (FPO) develop and inspect the procedures based on Terminal Procedures Development Criteria (TERP)s regulatory guidance written by Flight Standards Service (AFS) (FAA, 2018b). AJV-A designs and amends the published procedures, posts them to the instrument flight procedure (IFP) coordination site on the FAA internet and charts them in the IFP digital volumes. The publishing cycles are every 56 days.

FPO assesses each VOR in the NAS by way of on-site inspection every 36 months to ensure proper signal alignment (FAA, 2015b). Inspectors reduce the interval to 18 months for VORs supporting IFPs. Their organization consists of pilots, technicians, schedulers, maintenance personnel and a fleet of approximately 32 aircraft equipped to electronically assess navigation aid NAVAID signal reception and potential safety surface penetrations by man-made obstacles and terrain/vegetation (FAA, 2015b).

The amount of maintenance work for the NAS in the form of periodic procedure reviews (PR)s alone is extremely significant. The workload for FPO is approximately 30 procedures every workday. To assess, FPO must schedule a crew and aircraft for appraisal at varying geographical locations where weather and daylight play into the overall schema. It is time intensive and equates to aircraft hours, fuel, and mechanical maintenance.

These periodic review numbers for FPO constitute only NAS maintenance and exclusive of the amended IFPs scheduled for publication every 56-days. AJV-A developed 4,459 procedures in FY 2019 and approximately one-half to two-third of that number requires flight inspection assessments for publication (FAA, 2018c). The development of new or amended procedures can be due to any number of factors including airport improvement through construction to incorporation of restrictions or improving access following airspace safety reviews.

The VOR MON is a national initiative to help transition the NAS to performance-based navigation (PBN) and reduce the reliance and maintenance of legacy navigation equipment (FAA, 2018d). Reducing the number of VORs in the NAS is a matter of intricacy due to the overlapping nature of procedures. Removal of a VOR is like removing and replacing a pillar in a building or a stanchion on a bridge. A contingency plan to redesign surrounding NAS infrastructure must be in place and ready at the time of the switch. This again puts a significant level of workload upon FPO to review the procedure design and fly the redeveloped segments to validate safety on a phased project timed schedule.

Data and information make-up the IFP and airway designs. Geographic location of fixes is a very critical attribute. Moving fixes to accommodate air traffic in the interest of efficiency and safety creates cascading affects across all the instrument procedures that utilize the named geographical coordinates. In some cases, there may be a need to request legal docket action to increase controlled airspace supporting the actual procedure. Other associated pieces of critical data include the navigation information between route segments, magnetic course change due to fix re-locations and altitude updates due to obstacles, airspace or air-traffic requested altitudes.

The maintenance workload coupled with the modernization efforts to develop, re-develop, and publish Performance-Based Navigation (PBN) procedures weigh on the procedure development and validation resources of the FAA. The periodic maintenance is a safety commitment that uses FPO resources and affects the implementation timeline of other initiatives. Periodic fluctuations in resources such as mandatory periodic aircraft inspections create temporary reductions in capability that slow the pipeline and force re-stratifications in the chart-date publication process for IFPs during annual cycles.

b) Legacy Infrastructure Modernization

Organizations that are intent on modernizing infrastructure have pre-investment decisions to consider that will impact funding, implementation, and execution of modernization initiatives. Whether the entity provides a product, service or both there are typically opportunities to make use of emerging technologies to improve the end-state.

Emerging technology implies a completely new system architecture that will be modern yet resource-development intensive (Ransom et al., 1998). The development of the PBN NAS using GNSS for navigation is an example of modern technology that was emergent in the early 1990s. It is now a technological transition TT that includes the way society functions in terms of transportation infrastructure (Geels, 2002).

Organizations can also utilize existing infrastructure to bridge gaps between current circumstances and the envisioned end state by re-engineering systems (Ransom et al., 1998). Re-engineering systems is typically an endeavor that is inclusive of preserving some part or all a design that is already mature to conserve organizational resources and simultaneously maintaining some type of process (Mohapatra, 2013).

There is significant theory pertaining to systems in large organizations. Institutions are faced with many considerations that pertain to business transformation all typically centered around economic costs, feasibility of actions and subsequent opportunities to progress forward. The mechanisms large organizations utilize to transform their business processes in terms of computerized support is heavily discussed in much of the information system academic literature during the 1990s. Business infrastructure theorists refer to mature systems as legacy (Brooke & Ramage, 2001; Ramage & Bennett, 1998; Ransom et al., 1998).

Previous studies on system re-engineering in organizations were typically focused only on software (Brooke & Ramage, 2001; Ramage & Bennett, 1998; Ransom et al., 1998). This type of software modernization is referred to as legacy system re-engineering (2001; 1998; 1998). Determination of the quantitative business value and cost to the organization was based intrinsically on the legacy software re-engineering expense assessment (2001; 1998; 1998). Software re-engineering assessment also included associated organizational factors such as processes as inclusive within the quantitative cost. Software, together with organizational factors to support is referred to as a 'system' (Ransom et al., 1998).

Software evolution theorists consider organization factors to be the business processes that precipitated the development of the software under consideration for replacement (Ramage & Bennett, 1998; Ransom et al., 1998). Therefore, the software technology and the business processes they automated exist together. Legacy systems under consideration for either re-engineering, or replacement, are nested business processes that are automated differently in terms of software. This implies that what organizations are grappling with in modernization is an option to either re-engineer or replace legacy systems. Re-engineering is retention of legacy business software, processes, and automation. Part of the consideration in re-engineering is how the modernized components will work with the other parts of the system that are retained in their current state (Sneed, 1995). Replacement of a system is a start from scratch systemic development of new processes and automation (1995).

Re-purposing or re-engineering legacy systems is frequently viewed as a long-term quality improvement to reduce waste (Couto et al., 2017). The overall cost of the effort is a significant consideration. Large systems under consideration for modernization re-engineering have numerous supporting processes and automation activities also connected to the enterprise.

Preserving VOR infrastructure and re-developing the support process is a comprehensive effort. Bititci and Muir (1997) define process as 'structured activities' and ‘collected task’ with a purpose to produce a resultant output (p. 2). The output or result of the ‘process’ is arguably contingent on many sub-processes all having mini-support infrastructures of their own.

The VOR MON is an example of an expansive streamlining effort that constitutes a seemingly paradoxical plan of removing one-third of VOR hardware while simultaneously increasing the commensurate geographic spatial coverage of legacy system VORs identified for retention. The FAA is divesting the American public of one-third of the VOR NAVAID infrastructure while re-investing in the makeover of the remaining legacy ground-based navigable NAS. There is considerable complexity as it will constitute a re-engineering of the entire ground-based navigable NAS along with processes to manage the legacy infrastructure. Commensurate with the MON initiative there is consequential necessity to re-develop airways and terminal procedures previously supported by VORs soon designated for decommission in support of the MON infrastructure. The re-development of published instrument flight procedure infrastructure is a resource-intensive endeavor for the FAA FPO in addition to the service volume expansion.

The VOR MON is a case of legacy system modernization thru optimization. Determining which VORs would be retained were based on the following criteria:

- Retain VORs to perform Instrument Landing System (ILS), Localizer (LOC), or VOR approaches supporting MON airports at suitable destinations within 100 NMs of any location within the CONUS. Selected approaches would not require Automatic Direction Finder (ADF), Distance Measuring Equipment (DME), Radar, or GPS.
- Retain VORs to support international oceanic arrival routes.

- Retain VORs to provide coverage at and above 5,000 ft AGL.
- Retain most VORs in the Western U.S. Mountainous Area (WUSMA), specifically those anchoring Victor airways through high elevation terrain. Retain VORs required for military use.
- VORs outside of the CONUS were not considered for discontinuance under the VOR MON Implementation Program (Provision of navigation services for the next generation air transportation system [NextGen] transition to performance-based navigation [PBN] [plan for establishing a VOR minimum operational network], 2016, "Criteria for Assessing VOR Discontinuance").

FPO was then assigned the responsibility to verify expanded service volume around the remaining VORs. Their constraints revolve around:

- Budget
- Timeline
- Impact of intervening terrain on expanded signal
- Terrain and infrastructure growth in the immediate vicinity of retained VORs
- Flight validating the resulting thousands of airways plus IFPs re-designed to accommodate the 300+ removed VORs

System complexity is a perspective-based terminology describing the NAS VOR infrastructure A single VOR can be defined as a system in that it is a physical building that encapsulates electronic components that transmit signals usable for navigation. If one zooms out farther pulling more VORs into the view, then the definition of system transitions from one VOR to multiple VORs that support one or more airways along with terminal instrument approach procedures comprising a regional segment of the NAS. One may define both examples (and levels in-between) as a system. Incorporating data, visualization, software automation and business processes help us create a more robust definition of the system. Together, these components describe a system architecture (Mohapatra, 2013). The legacy system architecture includes the VOR hardware and software infrastructure along with processes to manage the system. The VOR system architecture extends across the entire US.

In 2016, the FAA published the PBN NAS Navigation Strategy to advise the greater aviation community and flying public of near, mid, and long-term efforts in transitioning the NAS to an infrastructure based on area navigation (RNAV) technology and reduction of legacy radio navigation aids. Specifically, the primary goals were "Leverage evolving aircraft capabilities; enable new operations;…[and] reduce dependence on legacy navigational infrastructure" (US Department of Transportation-Federal Aviation Administration [FAA], 2017, p. 1). The strategy underscores the FAA's focus on improvement and implementation of processes to extract efficiency of operations for users wherever possible. Force multipliers include employable systems the FAA refers to as "decision support tools" and "automation" that leverage data retrieval and display technology made available by computers.

A critical theme of the strategy is to gain efficiencies throughout the NAS. Removing nearly one-third of the pre-existing 890+ VORs appears simple and clever. The expected savings of the VOR reduction is $1 billion (Proposed provision of navigation services for the next generation air transportation system (nextgen) transition to performance-based navigation (PBN), 2011). The required expansion of the SSV on the retained VORs is challenging in that the FAA will need to make more with less, thus expanding to downsize. In the 30-year time scheme, the FAA will realize meaningful savings (US Department of Transportation-Federal Aviation Administration [FAA], 2017). In the 10 years spanning the 2020s, the SSV expansion will likely yield opportunities to improve techniques and processes used to inspect and assure safe utilization of ground-based navigational infrastructure providing a secure back-up system for PBN outage.

Re-purposing or re-engineering are terms used to describe the process organizations utilize to modernize pre-existing system architecture. System architecture includes not only the software and processes but also the hard infrastructure in the form of VORs. The FPO, as a sub-organization within the FAA had similar decisions to make with reference to their own business hardware, software, and processes. The decision was to either re-engineer or replace. Understanding how the FPO interrogates Sanders (1999) information base and formulates a strategy to modernize FAA VOR legacy infrastructure is a case of legacy system modernization.

FPO modernization

The FAA Flight Program Operations (FPO) Operations Group is responsible for the "…integrity of instrument approaches and airway procedures that constitute our National Airspace System infrastructure and the FAA's international commitments" (FAA, 2012a, Flight Inspection). The ground-based NAS navigation infrastructure is extensive and complex. The FAA has a plan to reduce the foundational hardware footprint supporting the NAS that includes extending service volume on VOR NAVAIDs scheduled for retention as part of the MON. The FAA's transformational VOR MON initiative underscores the criticality of FPO's role in safety oversight of the airspace architecture.

The VOR Minimum Operational Network is an undertaking that extends across the continental US. FAA FPO is the directorate responsible for ensuring the integrity of the radio navigation signals to reduce VORs targeted for removal while simultaneously improving coverage on those stations retained. FPO operates from five locations throughout the US, employs a workforce of approximately 188 employees, and maintains an inventory 32 aircraft. The VOR MON is a transformational opportunity to further their institutional role in oversight of the design, flyability and NAS evolution to PBN complete with commensurate fortuity to capitalize on emerging technological developments in data and automation.

The expenditure in the retained ground-navigation VOR infrastructure appears to be a very work, resource, and time-intensive effort based on the programmed completion in 2030. While doing so the FAA continues ahead with cementing complete PBN navigation (new technology) access throughout the NAS. The FPO's role in the VOR MON is an example of how a directorate deep within the FAA can leverage new inspection techniques, computers (automation), adapt business processes, and manage employees through a seemingly paradoxical situation. How does FPO smoothly increase inspection footprint to validate new service volume and maintain a reduced yet significantly enhanced VOR infrastructure?

National Airspace System (NAS) Modernization

Government organizations have a distinct interest in gathering, managing, and presenting information particularly with respect to infrastructure it regulates. Specifically, the Federal Aviation Administration (FAA) is responsible for maintaining millions of pieces of information with respect to the National Airspace System (NAS). The FAA

National Flight Data Center (NFDC) web-site indicates that their office is responsible for "the collection, validation and quality control of aeronautical information that is disseminated to support the National Airspace System (NAS) operations detailing the physical description, geographical position, and operational characteristics and status of all components of the NAS" (FAA, 2019a, "About NFDC").

The FAA has completely re-developed and transitioned of the legacy NAS with PBN architecture. The organization has been diligently working to create space-based access to NAS users in the form of airport standard instrument departures (SID)s, enroute navigation, Standard Terminal Arrivals (STAR)s, and terminal IFPs with vertical final approach guidance. The IFP inventory and Minimum Enroute IFR Altitudes over Particular Routes and Intersections (Part 95) visibly display Q and T-Route infrastructure traversing multiple hundreds of thousands of miles of US airspace (FAA, 2020g). Similarly, the numbers of PBN SIDs, STARs and IFPs is now comparable to the commensurate legacy ground-based procedures (FAA, 2018c, 2020g).

The proliferation of modern PBN procedures has monumentally changed the instrument NAS. The FAA's decision to retain the VOR MON is a safety endeavor aimed at maintaining a viable back-up ground-based system for users in the event of GNSS outage. It serves as a primary system for users not RNAV equipped (Proposed provision of navigation services for the next generation air transportation system (nextgen) transition to performance-based navigation (PBN), 2011). The duality of the infrastructure likely creates some inherently challenging issues with respect to maintenance of the system in its entirety.

For a visual on what this means, refer to the following figures. Figure 5 displays Standard service volume (SSV) on both High “H” and Low “L” altitude designated VOR NAVAIDs. The FAA defines “low” altitude structure from 1000ft above station (or ground) level (AGL) to 18,000ft AGL (FAA, 2018b). The navigation signal nominally emanates to a straight-line distance of 40 NMs within that altitude structure (FAA, 2012b). The distance on “H” designated VORs extends beyond 40 NMs to 100 NMs within the 14,500 - 18,000ft altitude range. Before VOR MON, extending signal reception beyond the SSV nominally required submission of an extended service volume (ESV) request. The request, based on an operational need to support navigation procedures beyond 40 NMs, was processed thru the FAA Frequency Management Office (FMO) and then to FPO to determine whether or not the facility can operationally support the procedure (FAA, 2018b). FPO could sometimes make this determination based on supporting data from within the previous 5 years. If not they would conduct an on-site inspection of the VOR to determine feasibility (FAA, 2018b). Flight inspectors would adjudicate or deny ESVs based on the NAVAID performance. If approved, the extension would be documented as part of the NAVAID record and considered an extension of signal service as operational service volume (FAA, 2018b). This process typically takes place only in certain very limited segments of airspace that the FAA needs to support specific location. Usually, it is a point longitude and latitude defined as a ‘FIX’ in space. An example is along defined airway that extends beyond 40 NMs from the supporting VOR.

The FAA proposes in the MON to extend service on retained VORs above 5,000ft site elevation to 70 NMs lateral distance displayed in Figure 6

Original Standard Service Volumes

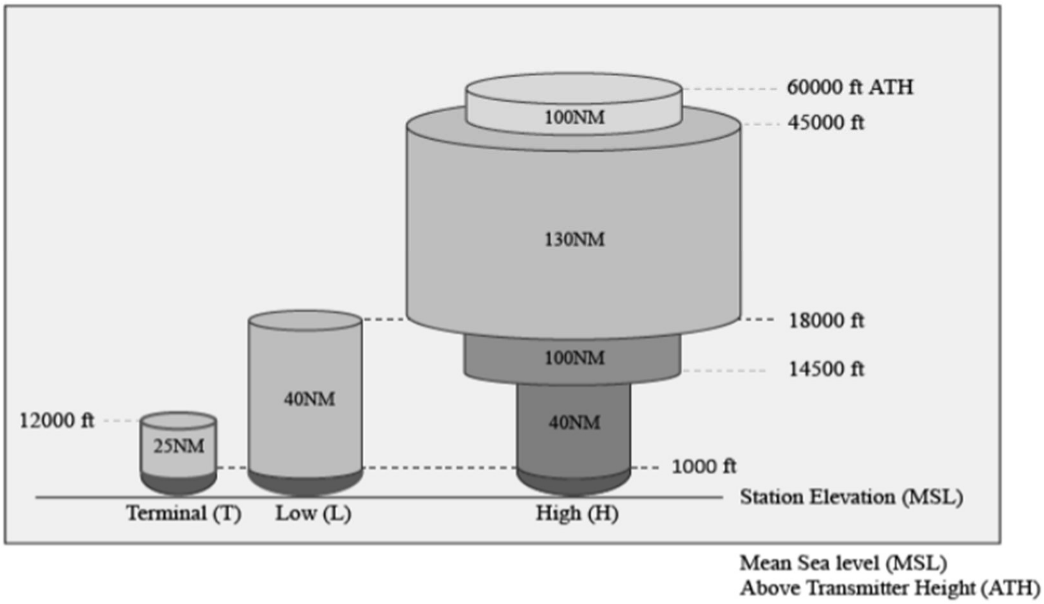


Figure 5-VOR Standard Service Volume Depiction. Adapted from Aeronautical information manual official guide to basic flight information and ATC procedures, FAA, 2021a. (https://www.faa.gov/air_traffic/publications/media/aim_basic_6_17_21.pdf). In the public domain

New VOR Service Volumes

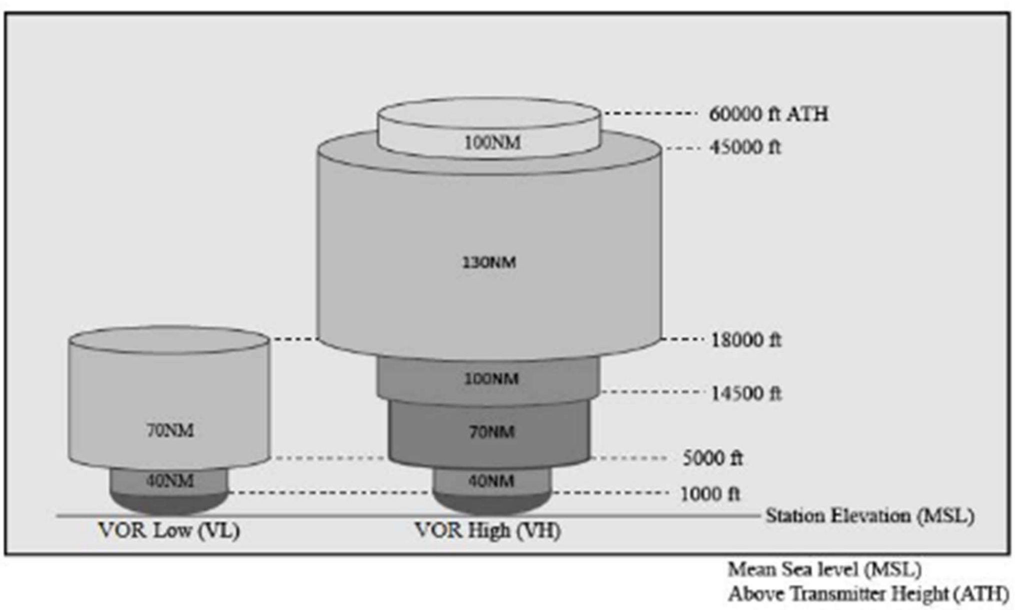


Figure 6-New VOR Service Volumes. Adapted from Aeronautical information manual official guide to basic flight information and ATC procedures, FAA, 2021a. (https://www.faa.gov/air_traffic/publications/media/aim_basic_6_17_21.pdf). In the public domain.

(FAA, 2012c, 2017d; 2021a, pp. 1-1-8). Further the FAA will retain enough ILS or VOR terminal IFPs to ensure NAS users can navigate between "MON" airports no more than 100 MN transit distance without using GNSS (FAA, 2012c). Certain airports in the NAS are designated as MON airports and retain terminal IFPs that can be flown solely using a retained ground-based NAVAID in case of GNSS outage. The consequences of extending the retained VOR's normal service volume are a multi-stage endeavor.

First order of significance is the responsibility of FPO inspecting the remaining 585 retained facilities for service volume extension. The additional lateral circular area between 40 and 70 NMs is 10,367 NM^2 per NAVAID. This figure excludes the additional vertical area when considering the vertical cylindrical structure from 5,000ft and 14,000ft (18,000ft if the retained NAVAID was previously classified as "L") surrounding the station.

Second order of significance is the phased re-development of the IFPs within the NAS to remove 300+ VORs from the cartographically depicted terminal procedure flight publications (FAA, 2018d). The FAA plans to accomplish this in thru FY 2030. The process will include identification of supported instrument procedures, followed by re-design to accommodate VOR removal from usage, then flight inspection, and finally publication. Each VOR can support from one to as many as 20 or 30 IFPs including airways. Publication chart cycles occur every 56 days and therefore equate to 6 or 7 every fiscal year (FAA, 2020a).

These two supporting endeavors constitute a complete makeover of the legacy NAS that has existed since the early 1950s. The proposal to achieve this was originally intended for completion in 2025. In mid-2020 the program was extended to 2030. With the extension to 2030 the re-make of the legacy NAS based on VORs is 20 years. This timeframe (2011 - 2030) is approximately one-third of the time the legacy VOR-based NAS existed.

The FPO airborne inspection of NAVAIDs is a two-part process that includes evaluating the 'signal-in-space' (radiation patterns) and certifying the IFPs designed to utilize the airport in adverse weather conditions (FAA, 2012a). According to FAA regulation 8260.19I FPO has two options to certify extensions when assessing NAVAID signal performance beyond the SSV. First, presumably least resource intensive, is to review the facility files and supporting data not more than 5 years old (FAA, 2018b). Second, is to assess the NAVAID on-site in an FPO aircraft (FAA, 2020c).

The FAA VOR MON program office has developed a visual depiction to help quantify the geographic expanse of the expansion initiative. Figures 7 and 8 visually depict conterminous coverage of the US prior-to and after VOR MON implementation (FAA, 2018d). The preparation requires extension of service volume such that the previous SSV (40 NMs in the "L" airspace) will increase to 70 NMs (FAA, 2017d). The increased area exceeds 10,000 NM^2 per VOR (Figure 9). We assume then also that the surety of the program would guarantee use of air-routes (as currently displayed in 2020). NPRM 76 FR 77939 states "The MON would enable aircraft anywhere in the CONUS to proceed safely to a destination with a GPS-independent approach within 100 (NM)" (FAA, 2018d, Transition to PBN for En Route, Terminal and Approach Operations in CONUS). The implication is that a scheduled or unscheduled GNSS outages would not effect a GPS navigation equipped aircraft flying direct between waypoints from proceeding to a MON airport that could be as much as 100 NMs from their location at the

Initial 2016 FAA VOR Network

40 NM Service Volume at 5,000' AGL

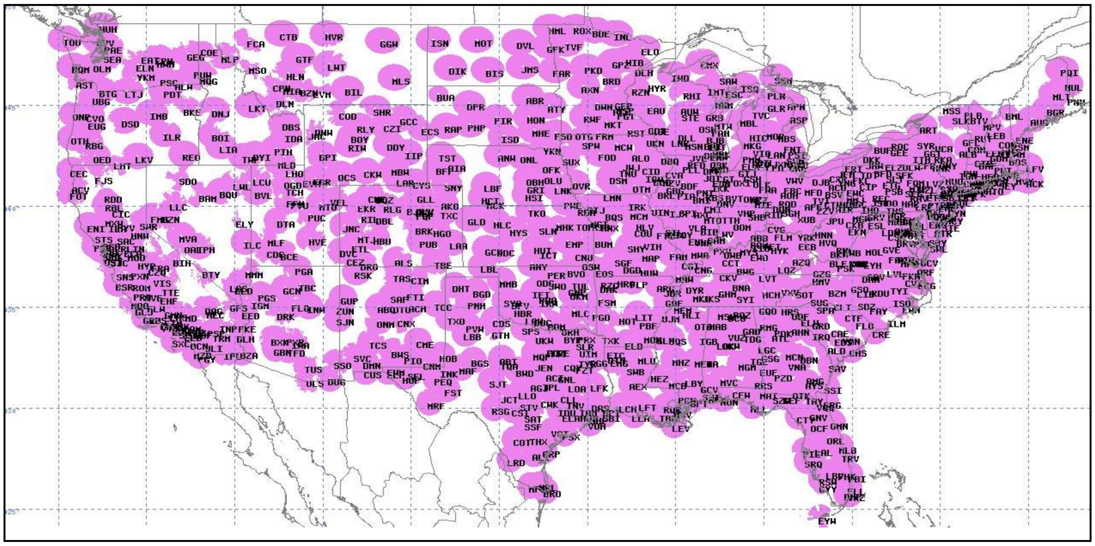


Figure 7-Prior to VOR MON implementation - More VORs with commensurate signal coverage. Adapted from *VOR minimum operational network (MON) implementation,* FAA, 2012c. (https://www.faa.gov/air_traffic/flight_info/aeronav/acf/media/Presentations/12-02-Discon_of_VOR_Srvcs_presentation.pdf). In the public domain

Notional VOR MON at 5000 ft. AGL

70 NM Service Volume/En-Route Coverage

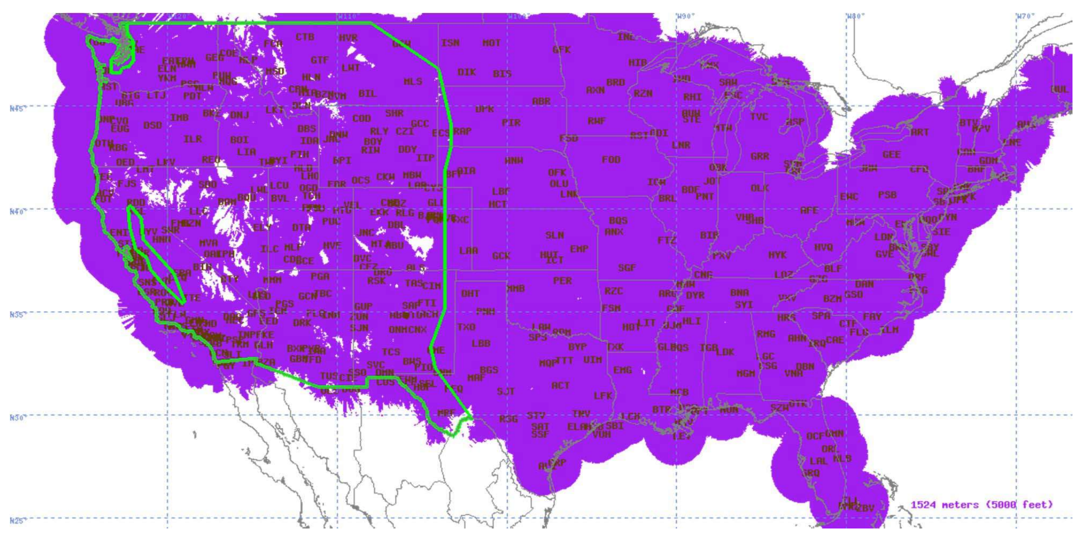


Figure 8-Post VOR MON showing retained NAVAIDs with increased signal coverage. Adapted from *VOR minimum operational network (MON) implementation*, FAA, 2012c. (https://www.faa.gov/air_traffic/flight_info/aeronav/acf/media/Presentations/12-02-Discon_of_VOR_Srvcs_presentation.pdf). In the public domain

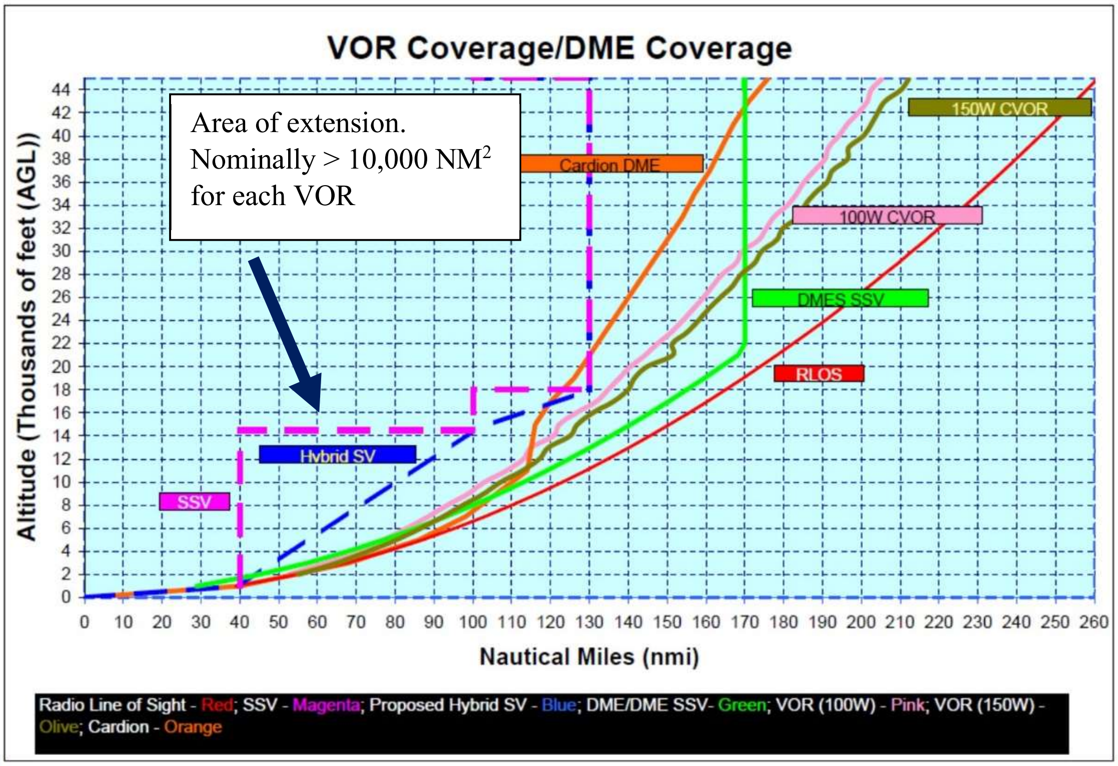


Figure 9-VOR MON area of extension horizontal view. Adapted from *VOR Minimum Operational Network (MON) implementation*, FAA, 2012c (https://www.faa.gov/air_traffic/flight_info/aeronav/acf/media/Presentations/12-02-Discon_of_VOR_Srvcs_presentation.pdf). In the public domain

time of service interuption. We should also take into account (worst case) that a VOR (part of the MON) may also be simultaneously off the air for maintenance or other service interuption. The FAA indicates that service volume at 5,000ft MSL extending to 70 NMs on retained VORs adequately compensates for simultaneous disruption of the GNSS network allowing users to naviagate to a MON designated airport and fly a non-GPS dependant (ground-based NAVAID) approach (FAA, 2017d).

A clear understanding of data requirements along with software automation requirements has the potential to yield significant benefits. FAA FPO is a critical node in the FAAs effort to modernize the instrument NAS while retaining dependable back-up capability in the form of down-sized infrastructure. Are there available force multipliers to verify and validate the signal extension of the legacy VORs? What synergistic enhancements are possible in the form of computer automation to assist over such a geographical expanse?

Maintenance is a normal day-to-day commitment as FAA FPO is required to review VORs for periodicity every 1,080 days (FAA, 2015b). The United States Standard Flight Inspection Manual (USSFIM 8200.11D) specifies not only that alignement orbits are required within this time-frame but also that the interval is reduced to 540 days for VORs supporting a Standard Instrument Approach Procedure (SIAP) (FAA, 2015b). The 540-day periodic interval is likely the case with most of the 585 VORs identified for retention. The FAA's final policy (FP 81 FR 48694) specifies that the NAVAIDs would support a SIAP (either ILS or VOR) within 100 NMs of any location in the CONUS (Provision of navigation services for the next generation air transportation system [NextGen] transition to performance-based navigation [PBN] [plan for establishing a VOR minimum operational network], 2016).

Data visualization software and automation design could play a significant role in the FAA FPOs solution on managing the ground-based NAS insfrastructure. FPO is uniquely positioned to likewise implement groundbreaking processes and technology in their remaking of the entire foundational infrastructure for reduced footprint yet improved efficiency. Research is necessary to understand what alternative resources FPO can reasonably leverage to multiply successes that speed delivery of NAS transformation while progressing their legacy of flight integrity and validation of published IFPs.

c) Example Infrastructure Modernization Cases

IRS

Long-standing organizations with histories of process modernization have provided examples of successful technology and process adaptation. In the mid-1990s, the Internal Revenue Service (IRS) transitioned their employee compensation and benefits program to a more streamlined experience serving the organization's 800,000 employees. (Khosrow-Pour, 2006). The organization formed a team utilizing three consultants along with three subject matter experts (SME)s from differing lines-of-business. Their team had 12 weeks to "…investigate, innovate, and implement" a transformation process in the employee benefit delivery architecture (Khosrow-Pour, 2006, p. 52).

The previous program of employee benefits consisted of 13 benefit and 6 compensation plans spread out among field offices located throughout the US. Information was spread throughout the government agency using physical information packages during open enrollment periods. The complex structure of organization governance created a significant amount of overlap with considerable differences among enrollment processes. The variation among the segmented programs being combined with the day-to-day operations tempo for the team SMEs in their primary duties made for significant challenges that could have easily jeopardized the programmatic timeline (Khosrow-Pour, 2006)

Fully understanding the multi-faceted dimensions of the current programming by the team members was perceived as not possible in the 12 week delivery time-frame (Khosrow-Pour, 2006). There were also doubtful perceptions as to the goal of their endeavor as the organization had recently orchestrated itself through an employee reduction-in-force (RIF). The challenging environmental conditions coupled with the double-duty job rationing for the 3 SMEs was a headwind for progress on such a complex endeavor (Khosrow-Pour, 2006).

The team persevered through the conditions and multiple iterations of professional differences in opinions. The resulting collaborative re-design of the compensation and benefits included a call center that eventually grew into a central communication hub for inquiries supported by self-help software. Khosrow-Pour (2006) rate this business technology and process re-engineering endeavor a success based on innovative development of a workable small-scale model. The model was adaptable to larger scale over time and became the national call center for IRS employee benefits and compensation. The author notes that the project management team was divided yet eventually coalesced although, there were significant mis-giving between several of the members (2006). There is also little said about how it was received by the gaining workforce. Another success of the call center may well be in its consolidation and reduction of overlapping programs. Therefore, it may have provided an equally good service for customers yet with reduction in overlapping layers of oversite.

The IRS case and the ongoing VOR MON initiative share similar constraints

- Fixed budget (programmed spending environment)
- Complex organizational structure (large government agencies with sub-agencies)
- Employees from multiple lines-of-business called on to develop program

Dissimilarities include:

- Budgets were fixed but VOR MON is recurring over program length in years
- Completion timeline (weeks vs years)

- Infrastructure complexity (Software vs. Hardware/Software)

Geodata

Another technology and business process endeavor was the transformation of three Danish Geodata mapping agencies into one centralized geodetic administration. This re-engineering effort spanned 10-years from 1985 - 1995 (Khosrow-Pour, 2006). The legacy agencies included the National Land Registry, Geodetic Institute, and Nautical Archives. All three institutions had organizational roots dating back more than 100 years each along with correspondingly unique organizational cultures. A common attribute of the three organizations was the technological precision of their product (Khosrow-Pour, 2006). The merged organization evolved into the National Survey and Cadastre.

The goal of the business transformation was not immediate evidentiary savings but reduced expenditure outlay growth over the longer run. Without organizational consolidation the Danish Minister of Agriculture explained that 25% of the country's future investment outlay to digitize maps would be miss spent on overlapping administrative business functions and parallel map development (Khosrow-Pour, 2006). One of the significant charter issues of the merger committee was to report on financing the activities of the new agency thru user payments economically to better align the balance between demand and supply of cartographical depictions (2006).

Another theme for the merger was the follow-on ability of the agency to produce a variety of new products by leveraging other national mapping system resources (Khosrow-Pour, 2006). The software enterprise would be named Geodata Information System (GIS) and would support the complete conversion of all geodata from analog to digital. The information would then be shared among not just the three converted agencies but throughout a database sharing system connected to multiple Danish government agencies (Khosrow-Pour, 2006).

The case author concluded that the modernization merger of the three organizations was a success. Compared to the IRS employee compensation and benefits modernization endeavor, the transformation of Danish cartographical organizations into a more centralized entity with re-engineered functions was significantly longer term and had more managerial involvement. Another significant difference was the plan evolution. With the Danish merger case, it was very difficult to foresee that processes could not be regimentally developed and adhered to but rather needed to evolve while retaining the final goal in the cross hairs (Khosrow-Pour, 2006).Researchers Khosrow-Pour (2006) say that projects of this magnitude are difficult to plan because they are "…highly complex activities often on the edge of what humans can comprehend" (Khosrow-Pour, 2006, p. 333).

Similarities between the transformation of the Danish Geodata Sector and the VOR MON include:

- Timeline (years)
- Upper Management Involvement
- Intent (optimization of pre-existing infrastructure)

Dissimilarities between the Danish-Geodata Sector and the VOR MON include:

- Purpose (new products vs. similar products)
- Systems (new vs. legacy)

The previous cases do not fully adhere to the legacy process re-engineering guidelines described by Jacobson et al. (1995). The Object Oriented model of process re-engineering is very structured and mandates standardization with pre-application diagraming of objects linked by inputs, associations, and outputs (1995). Jacobson et al. (1995) admit early on in their process guide for mapping objects that, for re-engineering processes and automation, well over 50% of organizations will fail in their modernization endeavors. The researchers are persistent that the success rate can be significantly improved by strict adherence to concrete planning mechanisms (1995).

A research snapshot of a small directorate organizing to transform legacy infrastructure into a more optimized, back-up navigation network on a national level can provide value in understanding how organizations manage long-term legacy infrastructure transformation and achieve successful outcomes. FPO is part of an integrated effort to complete the implementation of the VOR MON by 2030. The FAA conceived the initiative in 2011 and intends to complete the conventional (ground-based) NAS re-design in 19 years. The FAA FPO was a sub-organization consequentially affected long-term and had decisions to make with reference to their own hardware, software, and processes compared to the larger VOR MON. That is to either re-engineer or replace.

This dissertation is a foundation for how a legacy infrastructure modernization activity might be planned. The VOR MON is an examination of a large-scale case that goes beyond a software enterprise and spans many years. The program is specifically a government endeavor. There are significant opportunities ahead to consider the disposition planning for legacy infrastructure following possible forthcoming TTs. Some may be predominantly government endeavors with significant input from the public. Others may be private enterprise transitions.

Examples of Forthcoming Technological Transitions

Highway Infrastructure.

- Highway agencies transitioning roadway and highway infrastructure in the wake of automated vehicle technology. Saeed et al. (2021) posit the transition time for this will be 30 years. Their research also advises that the current road infrastructure design aspects will not support connected and automated vehicles. They warn that the changeover from human driven vehicles (HDV)s to automated will be phased. This means there will be a continuing need to modernize everything from bridges to road signs and pavement markings. Allocating funding rescources to modernize legacy while implementing automated vehicles support infrastructure will be a delicate balance of resources and funding.

- **Fossil Fuel Production and Refinement.**

- Legacy fossil fuel logistics and refinement facilities in the wake of electric vehicles (EV)s. Fenton (2016) advises that there are more forthcoming oil gluts that will create turbulence in the oil industry. His assessment is by 2040 the amount of EVs in the world will offset approximately 15% of the oil supply. How might the infrastructure and processes utilized to obtain and refine oil require modernization?

- **Non-Renewable Energy.**

- Transition from non-renewable to renewable electric energy. Borenstein (2012) indicates that coal and natural gas make up over 65% of North America's electrical generation source. This too will change over time with polical pressure to and technological advances. How might the legacy supply and generation infrastructure be managed for modernization?

d) Data, Information and Sensemaking

Data accumulation and presentation has become an increasingly challenging affair for companies and governmental agencies to manage. Ever increasing advances in computer equipment storage capabilities combined with user needs to retrieve the data and meld it into a format that is useable to the consumer has created a virtual and potentially endless supply-demand relationship between providers and users. Yoon (2010) indicates, for example, with respect to research studies that there are in excess of 24 million scientific abstracts among three different databases (p. 378). Yoon further states that there is a significant problem in the retrieval of information for practical purpose (Yoon, 2010).

Huber (2016) uses the terminology "…awash in data…" to describe staggering magnitude (p. 13). The author suggests that data overloads us and restricts our ability to benefit fully from interpretation. Deadlines and other discriminators unique to the environment have the tendency to reduce the potential efficacy of information. This is due to the time constraints on the would-be benefactors to come up with a work-able way forward on implementation of the design, initiative or whatever plan based on the data.

Information overload is a common term to describe data overwhelming a person, or group of persons, so that they are unable to effectively implement action. It's not only the mass of the data but processing of multiple sources and multiple formats that are roadblocks to 'sensemaking' (Buchler et al., 2016).

According to Sanders, sensemaking is using data to form constructs for decision-making (Sanders, 1999). Lebiere et al. (2013) state that it is "…an active process to construct meaningful and functional representation of some aspects of the world" (p. 1). Authoritative source information that users can piece together for logical sensemaking purposes consists of data located in databases. Effectively piecing the data together in a manner that makes sense leads to greater demand for information that would entail such matters as improved storage hardware, processes, and mechanisms along with presentation of the material to the user.

The proliferation of computer and internet access in the world has created an increased demand for information. Internet speed allows users to consume visually presented data at exceedingly faster speeds in a manner that compares to the revolutionary invention of the printing press. The printing press was a catalyst for increasing frequency in assimilation and transportation of information. The associated follow-on problems resulting from the printing press included some start up issues including literacy rate of would-be consumers. Additionally, format and presentation became issues to both the creator and user. Charles Knight (1856) describes the invention of the printing press by Guttenberger and Fust as an artistic as well as practical endeavor.

Research on data retrieval, assimilation mechanisms and presentation are reasonably robust. There is still opportunity to develop the story even better. Segel and Heer (2010) indicate that sophisticated data retrieval tools focus on "…exploration and analysis…" with little assistance on analysis results and story building (p. 1139). In the same vein, Buchler, discusses information networks as having had their share of research from social scientists with not enough focus on individual ability to make order out of the information (2016).

The FAA is working thru NextGen advisory committees to implement systems with "…high-benefit, high-readiness capabilities…" (FAA, 2021d, NextGen priorities). User programmed networked computers that automate functions are an example of a system.

The automation is arguably pricey in terms of front-end investment. The US government mandates the FAA to work within a federally budget framework to modernize the NAS not only thru NextGen but also thru the consequential sub-initiatives that include the PBN-based NAS supported by the VOR MON. The US government, among interested parties, monitors the cost figures of transition and implementation. Reasonable estimates in funding, time and other resources are critical to provide a supportable plan.

Critics of the FAA's stream of monitored-modernization-initiatives contend that the Agency has not advantaged itself of the information technology revolution that has transformed Fortune 500 companies (Shantz & Hampton, 2005). Specifically, Shantz and Hampton (2005) assert that the FAA modernizes to curtail future costs but not expenditures per measure-of-service. An example might be that the FAA is transitioning the NAS to PBN navigation to avoid future life-cycle costs of the legacy VORs (Proposed provision of navigation services for the next generation air transportation system (nextgen) transition to performance-based navigation (PBN), 2011; Shantz & Hampton, 2005).

Organizing Knowledge Objects

Companies and governmental agencies experience many difficulties organizing and stratifying data. Database hardware and software developers make easy work to store un-imaginable amounts of data on servers that allow for immediate access and retrieval. The preponderance of data and accessibility creates a supply-demand relationship between hardware maintainers, software developers, and users that need to format it and utilize for business processes.

Researchers Padova and Scarso (2012) use the phrase 'knowledge objectification' to describe the embedding of corporate knowledge into "…documents, artifacts and procedures…" in a manner that make the data independent of the holder (p. 287). The researchers further use term knowledge management (KM) as the mechanism organizations utilize to oversee the processes of knowledge objectification. The purpose of KM is to capitalize, transport, manipulate, re-use, and create common cognitive centers for the knowledge (Padova & Scarso, 2012). Simple examples of stored knowledge might be all information relating to ground-based navigation aids throughout an entire state within the U.S. Users then have access to the unique information that describes that piece of equipment such as latitude/longitude location, frequency, aligned magnetic variation and other defining characteristics. A contemporary knowledge object could be an aviation chart developed using the stored database information. The KM of the chart is how its publication is managed. How often it is published and how progressive changes are incorporated into the visual depictions are examples of KM.

Padova and Scarso (2012, p. 288) define the human/organizational side of knowledge objects as "…inseparable from the mind of individuals and the result of social processes". This includes not only the shared knowledge objects but also the KM. Organizational knowledge providers and users can utilize various forms of working groups as mechanisms for KM that includes process formation. This would enable the cognitive information to benefit the organization more fully (Padova & Scarso, 2012).

Volume of Data

A significant obstacle that can hinder organization of knowledge objects is the concept of volume. The terminology 'big data' has recently emerged with respect to the amount and complexity of unstructured knowledge objects. Gandomi and Haider (2015) state that there is not a fully developed definition what comprises ‘big data’ but that the component objects are voluminous and complicated. They additionally state the volume and complexity of the knowledge objects create significant challenges for the organizers and users. Size is the component of the data definition based on the terminology volume. Size can also be interchangeable with magnitude (Gandomi & Haider, 2015) Other knowledge object characteristics are descriptively useful when discussing data or knowledge object repositories.

Identification and performance characteristics of VORs are located within publicly accessible FAA-maintained aeronautical databases and can be accessed and displayed utilizing interactive, internet browsers. There may be multiple user inputs and outputs to that database. Input providers might be organizations responsible for data maintenance of the VOR identification and performance characteristics based on some form of validation. Examples of output users are organizations that chart it on digital IFP plates or enroute publications. The data may be the same, but the users may have different needs and responsibilities. Padova and Scarso (2012) refer to this as the technically cognitive vs. the organizational side of knowledge objects and it is particularly noticeable in large organizations that maintain significant amount of source or authoritative data. One group tends to be responsive for maintaining the technical source data that embodies the database. Other user groups will likely have differing needs with respect to the information contained therein and require objectification framing.

Variety and Velocity of Data

Variety and velocity are two additional components that likewise describe the characteristics of big data (Gandomi & Haider, 2015). The researchers explain that variety refers to the relative heterogeneity of the knowledge objects (2015). Variety of knowledge objects can be exemplified using our previous example of VOR identification and performance characteristics.

Input providers may have object repositories with the capability to store historical records on the VOR identification and performance characteristics. The ability to compare archived objects across a specified period allows users the ability to build a characteristic or performance timeline. The mass of historical objects may be unmanageably large and thus create volume challenge. Within the volume of knowledge objects there may also be unstructured information that is no longer in a format the user KM tool can easily translate into display. The knowledge object may rather align with a free form category and not into a pre-formatted homogenous label. Input administrator free-form remarks in within VOR historical records are an example. The free-form text is still readable for humans. Considering that VOR records contain numerous categories of data such as precise surveyed locations, magnetic variances, or facility navigation radials, supported navigational fixes, monitoring status, reception restrictions and other specified characteristics there could be thousands of information lines for each NAVAID. Some of the information can be in a free-form format and not machine-readable. The records may be catalogued by input dates and could go as far back as the nascent construction of the facility. With 900+ VORs at the outset of the MON program there could be thousands of historical records aligned with previous charting dates adding up to millions of database record lines. The categorized data alone is voluminous. The un-categorized free-form information is not only voluminous but also varied.

Proliferation in the variety of the data is therefore caused by multiple user inputs over time (Gandomi & Haider, 2015). As technology emerges for knowledge object storage formats users migrate their personal or business processes over to the new KM formats based on cost, effectiveness, and availability of new technology. There may be supported data object formats that have survived multiple evolutionary cycles, or varied formats within a similar timeframe, that result from un-aligned input sources. An example un-aligned-input-source is a knowledge object repository or database that has multiple groups inputting information but using different KM tools to interact with each other.

Knowledge object output users can struggle with variety as well. The data may be in an agreed upon location but require a manual search within the information storage to locate. If different users with unaligned data retrieval tools are searching the same objects with different display mechanisms, there could be problems. A presumption within a database retrieval program is the data format consistency allowing the software to search and retrieve the requested information. Pieces of historical information can add to the 'big data' definition by creating multiple heterogeneous and presumably disconnected files constituting highly varied objects.

Velocity (or speed) of data movement can be a restricting force on information propagation. Velocity refers to the rate of data generation and how quickly data display mechanism are able to transact with the data (Gandomi & Haider, 2015). Refreshing and replacing database information multiple times over a short time span is notional example. A practical example is how fast the FAA can translate expanded service volumes on retained VORs onto the user charts? Likewise, how fast can a VOR signal restrictions be displayed in the chart supplement following a periodic assessment?

Data Processing

Data processing tends to invoke ideas of a solitary and tedious work. It is very important. Multiple sub-groups typically utilize similar data within organizations. An example is the Digital Obstacle File (DOF) that the FAA maintains. The FAA and third parties utilize the DOF. The DOF contains all documented obstacles that could negatively affect aircraft departure or arrival. Airport managers, pilots, municipal officials, and engineers are critical users of the DOF and utilize the information to identify and mitigate hazards. The maintenance of the database is not necessarily solitary but perhaps definitively group oriented.

The FAA receives input form survey engineers to add obstacle information into the DOF. An example of a triggering event is an airport improvement grants to implement new IFPs at a location. The obstacles are approved for entry into the database and become source data on navigable airspace that the FAA maintains (FAA, 2018f). The FAA allows use of the database for users to proactively manage their airport environment. This gives the airport authorities ability to know what obstacles they might consider attempting to remove and give the IFP users improved access. Engineers can remove or lower obstacles and provide the information to the FAA Obstacle Team. This action will similarly remove or reduce restrictions that impede user access at the airport.

Organizational decisionmakers are motivated to obtain requisite information as evidence to support an idea or initiative. The idea or initiative then is tangibly supported by information and is subject to efforts to refine and clarify. Many refer to this as data-driven decision-making. Rubart et al. (2017) explain that business analytics is dependent on data-driven decisions. Providers need to understand knowledge object patterns and utilize them to plan the future. Users consider how well an organization analyzes and supports their analytical need and reward this priority by returning.

Rubart et al. (2017) describe the data development process as a multi-layered event. The data begins in a definitive location following an event designed to gather the knowledge objects. KM developers use analytic processing to clean and transform the data from an un-refined state to a format more manageable by the organization. Rubart et al. (2017) contend that data processing is an inherently collaborative event that crosses business function boundaries.

Many organizational employees conclude erroneously that because their job duties are not data or math-centric, they have a minimal role in the data processing. However, organizational employees who are involved in end-user-defined requirements relating to hardware and software are part of the framework for determining collaboration design. Organizations that fund design database development and retrieval automation for workers have tools and mechanisms to collaborate with others regarding data gathering, meaning and presentation. Corporate examples include digital dashboards with networking capabilities for access from many different geographical locations. An FAA example might be collaborative design on a new automation tool used to collect necessary information for the VOR service volume expansion.

KM as a Social Process

The digital dashboards facilitate meetings among workers that not only are geographically but also semantically separated. Semantics implies the differing meanings and interpretations among the user groups. Rubart et al. (2017) assert that improving digital boardrooms using equipment that allows users to manipulate the data for shared understanding is a collaborative process to overcome the semantics barriers among the providers and users. These researchers use the recent trend in multitouch surface technology that allows employees to transact information from mobile locations as an example of collaborative architecture for integrative processing.

KM activities as a social process can further be refined into knowledge systems supported by facilitated decision processes. Montibeller et al. (2006) define a knowledge system as comprised by three elements. Meeting participants may utilize some type of software to support group idea modelling for shared input. This first element of a knowledge system could be as simple as markers and flip-charts to much more sophisticated software that catalyzes and captures group information sharing for historical purposes and collectivizes it in digital fashion. An example of this is interpretive analysis software.

The second element, a facilitator is a person designated to help guiding meeting participants thru the process of sharing knowledge among the group (Montibeller et al., 2006). This individual assists with the task of turning divergent thoughts into convergent ideas and reframing the problem so all have that same information (2006). The last element is mode. The facilitator uses a manner to interact with the shared input model and group members to process thru idea generation. Examples of this may be small groups and even separation of groups into separated venues with time restrictions.

Design thinking is a contemporary terminology that describes KM as a social process that includes not only the knowledge objects and decisionmakers but also the design of the process used for collaboration. Tim Brown (2008) proclaims that design thinking should be foundational in product development, strategy and process development. He continues by explaining Thomas Edison is an early and recognizable example of 'design thinking' (2008). Many notably remember Edison for developing light bulbs but there was significantly more he taught with reference to collaborative and iterative information. Edison's research and development laboratory was really an example of an idea-hub whereby teams of inventors and developers were surrounded by each other in an open atmosphere of shareable information (2008). Montibeller et al. (2006) might describe this idea-hub as the facilitation of the social process.

Given that data development or KM is an inherently social process Montibeller et al. (2006), the question that remains is, then who ultimately owns the data? Data ownership can become unclear in any organization where it is proprietary. In many instances owners are organizationally diffuse and not necessarily centralized among a small group. The taxpaying public presumably owns the data in a government organization. In a publicly-traded company, it is the customers, workers, and stockholders. The case for maintaining data integrity and providing oversight for the data maintenance is important when considering due diligence to the owners. Data is the foundation for products, processes, and strategies and is therefore a valuable organizational resource.

In organizations with geographically separated knowledge object users KM evolves into standardization by way of regulatory guidance. The guidance may be a revisable regulation, periodically amended, explaining standards for design and maintenance of objects. In an aviation development organization, an IFP charting cartographical charting standard is an example. Regulatory guidance may also be in the form of an aircraft techorder specification that explains flight or maintenance operations for a complex aircraft with computerized maintenance data. Maintaining the integrity of the knowledge objects is part of the organizational KM standards. The KM standards should be such that they accommodate evolution and innovation needs for varying users (Padova & Scarso, 2012).

Researchers Keraron et al. (2009) studied the annotation of closely held technical order specifications on the French multi-role fighter aircraft, Rafale. The researchers assert that digital documents are objects but also that revisions and comments over significant time will notionally be part of the document itself. They assert that digital data documentation tools are more restrictive than their paper and pencil predecessors. The users of the paper and pencil were less restricted in making annotations that would later be captured in document revisions. They propose more research and development on digital tools that enhance KM annotations in the downstream object revisions. This allows better incorporation of annotations that percolate from cognitive KM social processes (Keraron et al., 2009).

Researchers Keraron et al. (2009) describe digital annotation as layers on top of pre-existing content. Since, knowledge object owners and users will somehow need to update and revise the content there needs to be an efficient process for incorporating the layers. Additionally, there also should be some retention of the source layers for easy reference and archival purposes. There also needs to be established KM that facilitates the incorporation in terms of revision timeline and user notification that something is changed.

Keraron et al. (2009) concluded that annotation technology on digital documents needs additional refinement to fully benefit from the social KM process. Their study to incorporate socially processed objects indicated that the digital tools to incorporate the layers of annotations were difficult to use in terms of time benefit trade-offs. The significant time required to make the amendments created a backlog of data that needed edits for incorporation into the documents. They noted the inflow of new information as overwhelming to such an extent that a separate staff of input people would be needed to keep pace with heavily utilized objects.

Data Visualization

Arrangement of the information becomes important when users are concerned with forming visual story with knowledge objects. The preceding paragraphs contain information about the building blocks of visualization. Data, KM, and processing are all part of the refinement process that leads us to the next step in how to display objects for viewing and interpretation. The consequences of failing to properly display is lack of understanding. Common understanding is important when decisions based on knowledge objects are in the balance.

Data visualization is a form of KM whereby object-users arrange data to create better understanding. The display of the data objects can serve as evidence arranged by the crafting display technician (Tufte, 2006). Simplifying large amounts of data by organizing it visually can make the output users more efficient in searching for information. Visualization examples range from common knowledge objects such as a bus schedule layout on a web page or paper tri-fold to much more information dense presentations. Tufte (2006) advises well-developed, complex, images that encompass geography, time, performance, or events arrayed in a visual format emphasizing relationships stratified between multiple variables creates ‘intense seeing’ (p. 9). An example could be picture presentations in an aerodynamic manual that display the forces acting on an aircraft during varying flight conditions.

Tufte (2006) indicates that there are ways and mechanisms to convey information to users that can simplify large sums of data. Tufte also warns that intense seeing does not necessarily convey intense understanding. Mis-display of data in a visualization such that the user easily becomes lost in detail is ineffective.

Isett and Hicks (2018) state that, “Information is cheap, meaning is expensive” (p. 479). Their research highlights the challenge in building intense meaning into visualizations by efficiently using smaller objects to build accurate pictures. The researchers also note that data presentation is an assessment between the visual developers and consumers (Isett & Hicks, 2018; Tufte, 2006). Isett and Hicks (2018) contend that there is a significant gap between scholars and public servants in particular over the issue of meaning and term the situation as ‘cognitive inaccessibility’ (p. 479).

The importance of developing useful visualizations of data for decisionmakers is significant in terms of time. Expert KM developers may invest significant resources gathering empirical data pieces to build a story for organizational decisionmakers. The organizational decisionmakers will usually have much less time to review the visualization than was used to develop. The decision makers in the research are public servants that they consider bombarded by information (Isett & Hicks, 2018). In some cases, 10 minutes or less is the extent of an organization decisionmaker’s cognitive availability to understand. This highlights the significance in the relationship between complex data arranging and the timeline organizational decision makers operate on (Isett & Hicks, 2018).

Dissemination Pathways

Dissemination is a terminology recently used to describe the connection between data arranging and visualization. Isett and Hicks (2018) explain that facilitative factors and pathways are terms utilized by previous researchers to explain the connection between data arranging and decision maker understanding (Isett & Hicks, 2018). The terminologies are all used to describe research avenues for improving the efficiency between the data arrangers and organizational decisionmakers. The premise of the research is that the pressure is on the data arrangers to construct better messaging but also that decision maker engagement is critical to visualization improvement.

Much of the research prior to 2010 into dissemination pathways between data arrangers and decisionmakers has been a scholarly centered endeavor (Head, 2016). However, more contemporary technology has created opportunities to study dissemination pathways outside of academia (Isett & Hicks, 2018). Other groups of data brokers such as online news agencies have been able to develop visualization practitioner models for engaging the general public using electronic media (Isett & Hicks, 2018). Social media has also had a considerable effect on the increased engagement between visualized data consumers and arrangers.

Static visualization that used charts and graphs prior to social media has evolved into a much more interactive relationship between arrangers and user groups through participatory online processes. These ‘processes’ allow the users to choose their dissemination thru interactive exploration based on areas of their own interest (Isett & Hicks, 2018). Engagement by way of interactivity allows users to express selection and choice as a mechanism that may strengthen the relationship between the communicator and the receiver (Isett & Hicks, 2018). Isset and Hicks believe that balancing interactivity is an area for further research.

Engagement and Bias

Hullman and Diakopoulos (2011) discuss the concept of rhetorical framing with respect to data visualization. The researchers define rhetorical framing as utilization of techniques to gain user acceptance of the message. Dr. Tufte advises that visual displays are a moral act of the creators and the integrity of quantitative information must always be maintained (Tufte, 2005, 2006). While doing so, however, the creator should also "...encourage the eye to compare different pieces of data" (Tufte, 2001, p. 13) Hullman and Diakopoulos (2011) refine rhetorical framing further stating that bias is always a potential problem with any display formulated by one individual. Therefore, visualization developers should distribute the cognition of development using shared mental models to remove partiality (Hullman & Diakopoulos, 2011).

Engagement can be a mechanism to assist with the alleviation of potentially biased data. Notionally, there should likely be design groups on the front end of any development effort to display information. Groups implies visualization development responsibility by more than one individual in a collaborative relationship between arrangers and users. This can be accomplished thru iterative review of steps in creating visualizations. Maximizing the interactivity process is a mechanism to improve the design so that it better reflects the objective members of the group rather than the more subjective views of one individual. The users ultimately would need to be interactively engaged to reduce the potential for an un-usable visualization product.

Qualitative Visualization

Information visualization is rooted in reasoning and analytics according to Dr. Tufte (2005). Empirical data collection, refinement and categorization was previously alluded to reference the examples pertaining to knowledge objects, data management, and visualization. Moere and Purchase (2011) state that the historical context of converting data into visualizations is rooted in scientific reasoning and execution to serve very utilitarian design constraints. Because of this, visualization development is perceived as inherently neutral due to 'scientific' focus on objectiveness and purity so as to help humans understand complex data objects (Moere & Purchase, 2011). They agree with Isett and Hicks that the solution for the gap between arrangers of information and users is more engagement. Moere and Purchase (2011) focus on the concepts of utility, soundness, and attractiveness to describe the functionality of information visualization. Their qualitative research highlights that visualizations can be both useful and attractive. They indicate that there is commensurate lacking on attractiveness within visualizations to promote engagement with users that have more qualitative perceptions.

Properly balancing utility with aesthetics is a pathway to ensure that the users are not overwhelmed with quantitative information. If the success to a visualizations' effectiveness is inherently interactive then it would also allow for minimum time for decisionmakers to form meaning (Moere & Purchase, 2011). Having the data and planning to display it is a quantitative endeavor. Reducing the time required for users to gain meaning is a qualitative function. Arrangers can load data objects into a very limited area. In doing so, they risk the user missing the meaning of the data due to the complexity created by too much on too little. Different users have different capacity to understand the data display based on their cognitive perception ability.

The right balance between the arrangers and users is an inherently artistic function at this time. Segel and Heer (2010) assert that the design continuum between the author and user exemplifies a potential gap of extreme magnitude. The design author drives the linear quantitative ordering, alignment, and messaging. If there is no interactivity to improve the aesthetic engagement they may miss the user target (2010). If the user is unconcerned with quantitative ordering, and prefers more aesthetic interactivity on their own timeline they may miss the meaning also (2010). The artistry is somewhere in between, and the researchers concede there is no right answer for every situation but rather candidate visualizations that are better or worse depending on the audience.

Qualitatively communicating meaning is a very subjective term. Segal and Heer's (2010) article contains examples of visual structures, interactive slideshows and drill-down data stories as avenues for artistic design and assert that intended audience is critical in determining the balance of interactivity as aesthetic design. Moere and Purchase (2011) Explain that aesthetics of visualization designs should not be compartmentalized or developed by a small group of presumed experts using pre-formatted templates. Doing so results in highly standardized technical looking visualizations with no room for innovation. Moere and Purchase (2011) also refer to aesthetics of information visualization as the 'fuzzy' aspect and believe that investigation through these avenues is lacking. The two introduce the term 'information aesthetics' and propose it be defined by design quality, data focus and user interaction. This field of expertise should be made up of human computer interaction specialists (Moere & Purchase, 2011).

Sheelagh Carpendale (2008) identifies Human Computer Interaction (HCI), perceptual psychologists, and cognitive reasoning specialists as three types of possible dissemination career fields bridging the gap between the empirical and the aesthetic . HCIs utilize both quantitative and qualitative research methodology to develop understanding of the relationship between information display and understanding while exemplifying the growing sense that there is a great need for varied investigative research techniques (2008). Carpendale proposes more use of adaptive and exploratory research that can leverage the limited number of available domain experts with study that is independent of any specific prefabricated software suite (2008).

Domain experts are the individuals Carpendale equates with empirical data. These professionals are the notional data experts but not necessarily authorities on display matters. Working groups have proven effective mechanisms to assist with software development support in organizations that are in the process of employing very specific digital presentation techniques. When proponents correctly form and manage the working group the result is a design solution as a process. This not only involves the domain experts but also non-expert users from differing areas of the organization. Carpendale re-emphasizes the benefits of quantitative and qualitative investigatory avenues and states that quantitative methodology is rooted in centuries of formalized and accepted methods (2008). Qualitative methodology is more rich and considers the interplay of factors in a much more encompassing manner (2008).

Visualization integrity

Soundness describes how well a visualization maintains it's integrity over time. Iterative visualization using the same structure or multiple variants with significant similarities indicate the data arrangement was likely solid the first time it was developed (Moere & Purchase, 2011). Other integrity indicators are how adaptable the design is to variations in the input data. The visualization software should be able to process the data inputs that may be increasingly complex (2011). As the depth and width of the input information expands then the visual clarity should remain intact (2011). An example might be how well does a VOR performance plot indicate capture very discreet changes in NAVAID performance.

Applying Visualization to FAA and VOR MON

The purpose of converting data to visualization is reduce information seeking costs (Fu & Gray, 2006). Fu and Gray (2006) conducted research to determine the optimal relationship between information seekers and environmental costs or knowledge structures. This is inherently economic and presumes that users have limited time to accomplish a tasking. The decision then is how much time to focus on information interpretation before one should accomplish the tasking. The overall task time includes the information-seeking endeavor with the execution of the effort and can be minimized (maximum efficiency) with the correct combination.

As Fu and Gray (2006) explain, a person potentially stuck on an interstate has options. The individual could elect to invest time on the front end to avoid the vehicle slow-down areas by investigating best routes using their local traffic cell phone application. Front-end investment costs some execution time on the practical end. However, it also saves on the back end. There are many variables involved but the effort remains the same. The intent is to reduce the overall time it takes to accomplish the task.

Dr. Edward Tufte (2006) states that "Analytical presentations ultimately stand or fall depending on the quality, relevance, and integrity of their content" (p. 136). Tufte also defines information visualization as a 'content driven craft' that is only evaluated by how well it assists with thinking (p. 136). As for good presentation he comments that "…we are all in it together" (p. 137). This assertion is congruent with Isett and Hicks (2018) referencing the price of information being cheap compared to meaning.

Possible improvements in both the data objectification and KM functions to manage the signal information of retained VORs could be in the form of flight inspection collection automation to support the service volume expansion. The purpose of data visualization supporting the MON initiative could be improving user cognitive understanding of the retained VOR service volumes performance. The visualizations could improve the dissemination pathway between the data arrangers and FAA decision makers converting chaotic information to ordered and building a picture of the MONs health throughout the NAS. The visualizations could also be used by the flying public in VOR MON charting depictions.

This aligns with the FAAs mid-term focus from the PBN NAS strategy document:

KEY MID-TERM FOCUS

The focus of the mid-term timeframe will be to expedite the delivery use and subsequent maintenance of PBN services. Commitments include:

- Developing procedure-design tools and processes that accelerate the ability to move from criteria to implemented procedures. This is accomplished by syncing criteria, data, and design-automation software;
- Completing the transition to digital delivery of chart data. This continued modernization of how procedure information is delivered to operators will improve coordination and reduce the time required to introduce procedure changes to the NAS. Collaboration with DoD will ensure a chart delivery option that accommodates the capabilities of military aircraft operating in the NAS;
- Completing development of an automated tool for periodic review of procedures, which will reduce the resource requirements to maintain procedures…(US Department of Transportation-Federal Aviation Administration [FAA], 2017, p. 23)

Summary

The US government has been the maintainer and developer of the NAS for nearly 100 years. The VORs have been part of the instrument NAS infrastructure since the early 1950s. The transition from ground-based navigation sourcing to PBN has been a complete modernization of the legacy NAS that began in the mid-1990s. The VOR MON initiative to re-engineer the legacy ground-based architecture is a conversion initiative resulting from the dominance of PBN instrument procedures supporting the NAS by 2010. It was necessary to ensure a safety net for continued instrument flight in the event of GNSS outages as well as to serve users not RNAV capable.

The conversion of the NAS to pre-dominantly PBN is an example of a Technological Transition (TT). The VOR MON is an example of re-engineering a legacy architecture. The legacy VOR architecture is above and beyond the information system technology enterprises discussed in academic literature. This makes the VOR VON unique for modernization research study as it is the optimization of a large-scale legacy architecture that is much more than a computer system enterprise. It does entail significant amount of data collection, arrangement, and depiction as validation support. It is complex in that it will take many years to complete.

Executives and organizations must first understand organizational challenges before attempting to solve them (Sanders, 1999). If, as Sanders (1999) states, organizations and leaders should not rush to diagnose solution application before challenge identification, then the first step in this study of FPO is an assessment. A first step to understanding how to modernize legacy system infrastructure is to examine FPO's process to develop organizational strategy for accomplishing and implementing the VOR MON. Sanders discusses decisionmakers and data arrangers using knowns to find unknowns thus interrogating the organizational information base. This normally requires some type of process to execute the initiative. Legacy VOR MON service volume is known. The future service volume is also known. The FAA wants to achieve the increased coverage of the continental United States using one-third less VORs than they began with. How can the FPO expand the known service volume coverage of the continental United States to 70 NM for each retained VOR?

Data visualization has become increasingly complex due to the amount of information collected, made available and presentation options. Computers capable of storing enormous amounts of data and presentation software options create multitudes of possibilities for visualizing messages between developers and users. How does FPO develop and organize a VOR MON "information base" to advise organization decision-makers?

Are there possible improvements the FPO can incorporate in this legacy modernization initiative? What has been learned and how can it be utilized for future legacy modernization endeavors to support TTs in the future?

Research Questions/Hypothesis

RQ1: How does FAA Flight Program Operations (FPO) systematically develop an organizational strategy for accomplishing VOR MON service volume expansion and verification in the NAS?

RQ2: How does FPO leverage computer automation to develop a VOR MON "information base" and inform organization decision-makers

RQ3: What new automation might FPO propose to gain efficiencies in balancing their normal instrument procedure validation workload with expanding retained VOR service volumes?

Hypothesis: A small sub-directorate inside the FAA will manage a nation-wide, multi-year initiative with a combination of tribal knowledge, subject matter expertise and business re-engineering practices.

CHAPTER III

METHOD

This section describes the design, participants, collection instruments and analysis of the research dissertation.

Design

The design intent of this qualitative study was to interview FPO personnel that were personally engaged in conducting the FAA VOR MON initiative. A synchronous focus group was originally desired to gain information on how the development of FPO strategy to conduct the VOR MON evolved. The role of automation and visualization in conducting the VOR MON initiative was also critical. This would lead to an understanding of how automation and visualization were used to modernize the legacy VOR infrastructure.

To identify an FPO VOR MON focus group the process in Figure 10 (Develop Survey) was followed. First, both quantitative and qualitative questions were developed to determine whom in the FPO could be considered VOR MON-conversant and what would be discussed in the detailed interviews. The questions, deductive and inductive, were submitted to a panel of four experts to refine. Two of the panel participants were pilots. One was a former FPO pilot and the other was a former military evaluator pilot. The other two panelists were experienced academic researchers. Their assessment and

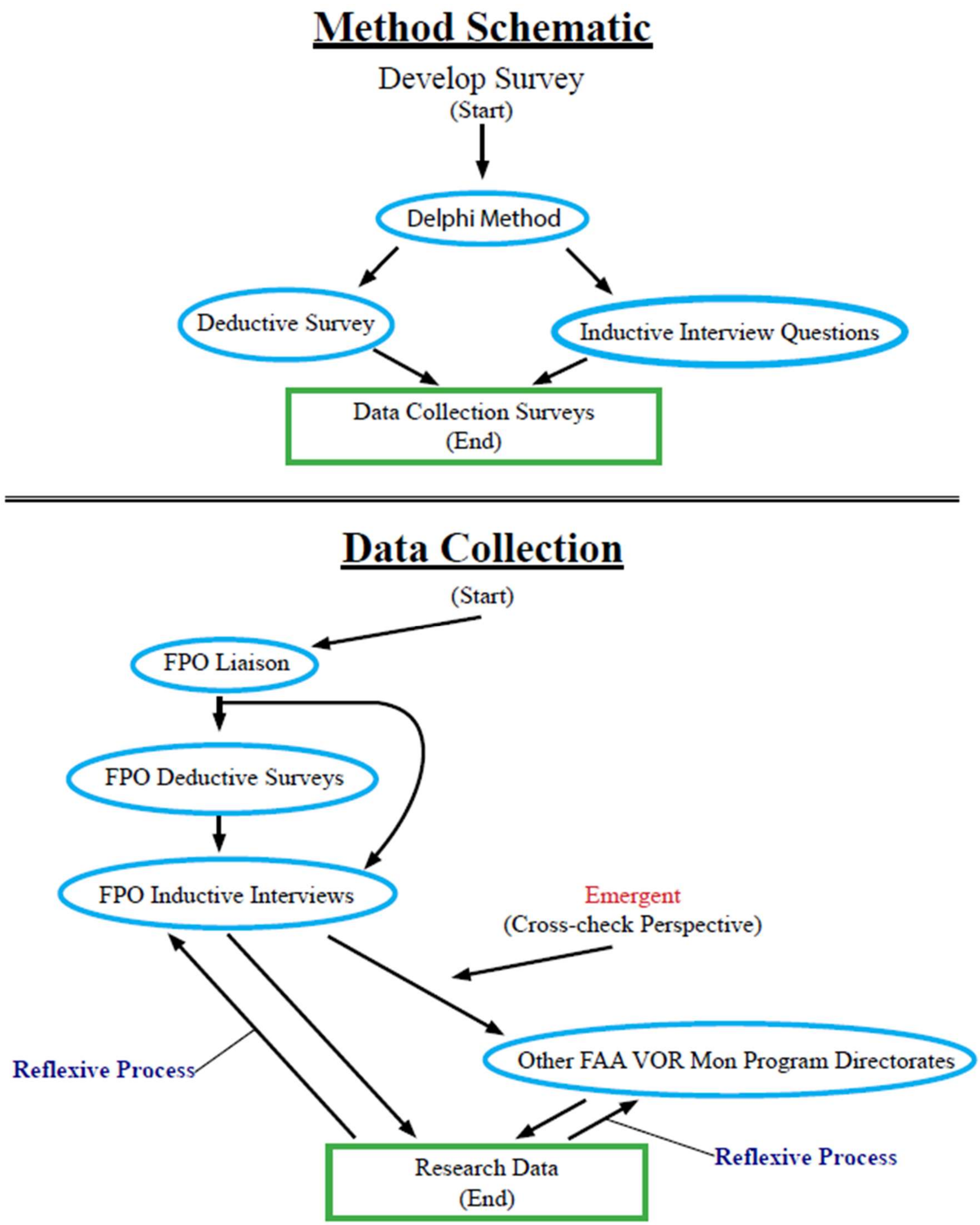


Figure 10-Survey Schematic

suggestions were a form of the iterative DELPHI process (Delbecq, 1975; Linstone & Turoff, 1975). This was similar to the Nominal Group Technique (NGT) in that panelists were utilized to screen facts for development of inquiries (Linstone & Turoff, 1975). The

DELPHI method does not require all panelists interact with each other in time and geographic proximity (Delbecq, 1975). This arrangement was suitable due to the professional obligations of the panelists used to develop the surveys. The quantitative survey and qualitative interview questions were updated to reflect the panel's inputs through two iterations and reviews. The resulting surveys interview questions are displayed in Appendices D thru E. This marked the completion of the develop survey phase.

The next phase was data collection (Figure 10 - Data Collection). An FPO supervisory liaison was necessary in order to gain access to candidate study participants. The liason electronically canvassed the FPO with over 100 participant study invitations and quantitative (deductive) surveys (Appendices B and D). The liaison additionnally advised that the VOR MON policy and technology experts within the FPO were already well-known and that the deductive surveys, although distributed throughout the FPO, were not necessary. The liaison thus facilitated direct contact with the VOR MON policy and tehnical experts inside the FPO organization. The liason also advised the conditions for interviewing candidates. The conditions included compliance with FAA policy on group gathering restrictions during the COVID pandemic and accommodating the participant's professional schedules. The restrictions precluded a synchronous focus group. The group of participants the FPO directorate liason identified as VOR MON experts totaled 9. These 9 study participants thus became the FPO inductive interview participants. Their qualifications were confirmed with the quantitative surveys. The number and high qualifications of the particiapants met the research objective for in depth interviews with VOR MON-experts within the FPO.

This FPO group had significant professional duties including flying and temporary duty locations throughtout the continental US. Delbecq (1975) indicates that researcher planning on decision-making processes will reflect real-world contraints and the working hours required along with proximity and timing. The quantitative surveys were used to develop demography of the FPO Study Participant (SP) experience and job knowledge reference the VOR MON program (Table 3 - VOR MON Participant Demographics).

The next research phase, FPO inductive interviews, was utilized in place of the intended synchronous focus group (Figure 10). The participants selected were interviewed utilizing digital videoconferencing thru the internet. Interview questions were intended to be a first iteration of discussion pertaining to strategy and information interrogation process development for the VOR MON initiative. Qualitative questions and format appear in Appendix E.

Additional inductive interviews were anticipated as emergent opportunities to validate information obtained from FPO interviews (Figure 10 - Other FAA VOR MON Program Directorates). The emergent opportunities to pursue cross-check interviews with other VOR MON program experts outside of the FPO directorate were pursued (Gay et al., 2009). The number of emergent candidates totaled 5. The emergent participant cross-check perspective candidate demographics appear in Table 3 (VOR MON Participant Demographics).

The interview schema included inviting all participants to discuss FAA FPO's use of process development for implementing expanded service volume in support of the VOR MON. Further inquiry pertained to automated data collection and presentation as it related to VOR service volume assessments. Exploration of plans for periodic maintenance and solicited solutions for better efficiency were also a focus. The interview format for each separate study participant was semi-structured and notionally planned for approximately 30-45 minutes to retain focus on data tools and processes specific to the VOR MON. The study participants were invited to speak for as long as they wished necessary to discuss the organizational strategy and technological support mechanisms to accomplish the VOR MON. The intent of the qualitative designs was were based on:

a. understanding the processes by which events and actions take place
b. developing contextual understanding
c. facilitating interactivity between researcher and participants
d. adopting an interpretive stance
e. and, maintaining design flexibility (Bloomberg & Volpe, 2008, p. 118)

The reflexive process indicated in Figure 10 between FPO Inductive interviews, Other FAA VOR MON Program Directorates and Research Data (End) is explained this chapter in subsection Instrument.

Perspective

The central question in this research methodology was how a small sub-directorate within the FAA FPO develops strategy to successfully accomplish a large multi-year aviation initiative. The additional research questions included how the FAA FPO leveraged the use of automation to accomplish and recommendations for automation and programming. The research question conclusions are addressed in chapter 5 'Results Summary and Discussion'.

The research approach was originally designed to utilize a synchronous focus group for data collection. Patton (2002) explains that pragmatism is to focus on the individuals and interview questions without allegiance to a particular methodology theory. Although the initial design was to utilize quantitative data collection to determine a focus group, the intention was to study the research issue with a small cadre of VOR MON experts. The interview questions were designed for the participants to discuss matters of contemporary practice and process within their organization. Utilization of contextual research that focuses on participant determined problem definition is the means to practical and workable solutions (Bloomberg & Volpe, 2008).

Recognizing the lived experiences and knowledge of others is critical for understanding how individuals make meaning of the world. The constructivist world view is grounded in the notion that reality and truth stem from participant assignment of meaning to lived experiences and the values assigned to those clips of time (Bloomberg & Volpe, 2008). Conditions are significantly less managed and variables, to include perceived truths, become presumably more numerous. Cause and effects are viewed thru the perceptions of the participants and may vary significantly between individuals. The study environment typically includes a more natural setting where the interactions occur and the depth of the research is not gained thru vast numbers of participants but rather broad exploration of descriptive thoughts where the participants define their truths and perceptions (Merriam, 1998).

Social constructivism was present in this study. The quantitative portion was intended to provide an objective understanding and confirm the pool of potential respondents within FPO. The directorate is composed of approximately 180 assigned personnel. It was plausible that most individuals assigned to the directorate had not participated in any working groups to develop a plan for VOR MON program execution. There was a pathway to locating VOR MON-conversant individuals using an instrument that accommodates transformation of objective inquiry pertaining to roles and experience within the directorate into a high-density smaller group of qualitative study participants. The planned parameters of the case-study for in-depth research were employees within the FAA FPO instrument flight procedure validation directorate possessing detailed experience in VOR MON. The interview group satisfied this purpose.

The problem statement was deliberately open-ended to allow the participants a role in defining their own high-impact strategy components. The components were collectively and iteratively presumed to exert leverage on the situational problem which included how a small sized directorate develops architecture to manage a large multi-year initiative. Linstone and Turoff (1975) propose that properly defining potential challenges affecting large programming strategy should begin with reduction into components that participants determine to have the most causality impact. These open-ended questions allowed assessment by participants to continually refine program challenges until the core issues were identified. Creative approaches to refinement are necessary due to the complexity of the central problem (Delbecq, 1975). These techniques or methodologies are particularly useful to ensure the problem statement(s) are clear and understood. The purpose was to leverage group expertise among technological experts and provide useful inroads to the complexity of the issue.

Dissertation Context

The research setting was 100% virtual following FAA mandates reference interpersonal contact during the COVID-19 pandemic. FPO operates five Flight Inspection Field Offices (FIFO)s geographically dispersed throughout the US (FAA, 2020b). Participants were initially contacted following their completion of the quantitative and engaged using internet videoconferencing.

The personnel that make-up the FPO directorate were anticipated to be skilled aviators and technicians. Their primary duties included aviation safety training, flight inspection, research, development test and evaluation support (RDT &E) and critical event response and transportation (FAA, 2020d). The professional working environment was respected knowing that interview time was a premium. Study participant workdays are typically heavily scheduled with events that could not easily be adjusted and action suspense that dictated participant availability. There was strong possibility of significant interruption during the interview scheduling process and activity that would lengthen the discussion session but also provided opportunity for robust response and inquiry into real-time activities.

The complete medium for connection to participants is displayed in Appendices B thru E. Information retrieval was initially by way of e-mail messaging that included both a recruitment invitation, informed consent, and a quantitative survey with response boxes. The FPO supervisory liaison assisted with dissemination and collection of the inquiry artifacts to ensure the VOR MON knowledgeable candidates were completely canvassed.

Interviews occurred over two months. Interview prep and conduct allowed approximately 1-2 interviews per week. The intent was to collect interview data thru videoconferencing, and when able, receive informational artifacts via electronic data transfer.

The uniqueness of the context for this study was intended to provide highly-concentrated information that would develop answers to the central research questions.

Emergent opportunities to pursue cross-check interviews with other VOR MON program experts outside of the FPO directorate were pursued (Gay et al., 2009). FPO personnel expertise in developing operating procedures and methodology for VOR MON initiatives were found to have coordinated significantly with other FAA directorates to ensure timing and scope of various program phasing. This exemplified a connectedness into a bigger scheme for program accomplishment. The emergent opportunity to research FPO connection with other FAA offices responsible for progressing the VOR MON program to final success was leveraged to provide the historical perspective, setting and social construct supporting data refinement creating a more robust assessment (Patton, 2002).

Cross-check sampling from other directorates was an avenue to triangulate using an additional collection strategy (Creswell, 2012; Gay et al., 2009; Patton, 2002). The opportunity to gather perspectives from FAA representatives representing other directorates collaborating with the FPO created a multi-lateral view of the circumstances surrounding the VOR MON implementation in terms of project timing and technical issues. The additional perspective offered the potential to support and enrich the FPO research, thus further refining the data collection.

Participants

The qualitative interview goal was 12-15 participants. The planned minimum experience level for participants was a minimum of 5-years within the FPO or commensurate instrument NAS procedural knowledge with other FAA VOR MON program offices. Ultimately, 9 FAA FPO personnel were identified as the FPO senior VOR MON policy and technical process specialists. In addition, the interview sample crossed over into two other VOR MON program offices. Understanding the coordination between directorates within the agency helped identify the strategy development as it related to interaction between differing offices. The qualitative research design was purposeful in order to gain unbiased views of participants (Creswell, 2012).

Creswell (2012) advises on the criticality in selecting participants that can aid us in developing a detailed understanding of the situation. The discussion study participant comprised a cross section of VOR MON program personnel. FAA FPO had multiple position descriptions assigned that included pilots and mission specialists. FPO experience within the context of VOR MON was deemed critical for the short interview time. Additional interviews were conducted in consideration of cross-check as a form of triangulation as the need to focus on additional experiences became evident. The researcher used information obtained in the initial interviews to re-clarify with participants as necessary. There were no other exclusion factors.

The intent of utilizing multiple VOR MON knowledge sets is what Gay et al. (2009) refers to as 'cross-section' (p. 377). There is a potential gap between the notions of empirical analytics and visual consumers as Carpendale (2008) previously explained. There were expected different informational understanding and needs among the various FAA VOR MON program implementors. The specialist positional cross-section resulted in responses that assisted with 'referential accuracy' received from the first interviews (2009). Follow-on clarification interviews and feedback from participants thru transcript review was also accomplished (Creswell, 2013).

The instrument referred to the participants numerically (P1, P2 etc.) to protect identity.

Participant Demography

The demographical data displayed in Table 3 was arranged using the information from the quantitative survey inquiry. The study included 14 total participants. Nine of the participants were assigned to the Flight Program Operations directorate. The other five included participants from the National Navigation Office, VOR MON Program office and FAA Navigation and Landing Branch. Five of the 14 Study Participants were managers with supervisory responsibilities. The FPO participants included crew positions Mission Specialist and Pilot. The non-FPO participants were all professional engineers including the Program Office participant. The average FPO experience level was well over 10 years' experience. The FPO participants were further detailed as working within sub-groups Technical Support (Policy) and Technical Branches.

VOR MON Participant Demographics

Participant Group	Organization	Participants (P)	Managers	FPO Years	VOR MON Experience Years
1	FPO	9	3	4 - 20+	2 - 10
2	NON - FPO	5	1	NA	4 - 10

Table 3-Participant (P) Organizational Demographics. Notes: FPO - Flight Program Operations

Data Collection

The qualitative interview candidates were invited for a digitally recorded meeting (videoconference). The interview questions in Appendix E were used as an inquiry mechanism to gather information concerning FPO strategy development for the VOR MON initiative. The interview duration ranged from 45 to 90 minutes. The interviews were semi-structured, and participants could speak as long as preferred. One of the interviews was an automation intensive discussion and demonstration. The data and automation demonstration included instructional artifacts and examples of digital visualization. The intent of the automation demonstration was a purposeful understanding of capabilities in-place for assessing and validating NAVAID service volume expansion.

Instrument

This dissertation was a qualitative inquiry. A panel of experts was utilized thru a DELPHI process to refine the surveys prior to canvassing SPs. The instrument for collecting data was the researcher. Providing accurate and useful clinical data was be a foremost concern to assure validity. Critical concepts with respect to instruments in qualitative study include reflexivity, trustworthiness, and credibility (Gay et al., 2009).

The instrument used the reflexive process as described by Guillemin and Gillam. Specifically, it " …means that the researcher should constantly take stock of their actions and their role in the research process and subject these to the same critical scrutiny as the rest of their 'data'" (2004, p. 15). Qualitative researchers are not simply to report 'facts' but also actively form interpretation (Guillemin & Gillam, 2004, p. 274) Gay (2009) add that trustworthiness and credibility means qualitative researchers have an obligation to ensure the research accounts for the "…complexities in the study and address problems that are not easily explained…" (p. 375). This means the researcher is managing the context and site description in a manner that allows the reader to place themselves into the setting and view the 'details'. (Gay et al., 2009, p. 375)

Gay (2009) posits that this is practically accomplished by:

a. Peer debriefing - test your insights by interacting with other professionals
b. Collecting 'slice of life' observations - collecting artifacts such as pictures, audio recordings, etc.
c. Establish structural corroboration and coherence

d. Member checks - share with participants before the final product is completed

e. Structural corroboration - account for conflicting material in a transparent manner

f. Referential adequacy - check for accuracy in interpretation of 'slice of life' observations (Table 14.2)

Data Analysis

Following the interviews, the results were transcribed utilizing third-party software. The researcher utilized MS Excel to code the transcripts into themes. Creswell (2012) describes this process as aggregating similar data into core elements (p. 248). The transcripts were reviewed multiple times to refine the themes and eliminate redundancy (2012). The study participants were re-contacted and provided spreadsheets containing themes from their respective interviews. The purpose of this was to debrief, establish coherence, member-check, resolve conflicts, and ensure accuracy with what was transcribed and collected artifacts (Gay et al., 2009). The themes are reported in chapter 4.

Summary

Digitally recorded subjective interviews were the mechanism for obtaining data for this dissertation. The interviews were conducted by way of video conferencing software that accommodated digital presentation. The duty location of the study participants was undisclosed FPO locations. Multiple criteria were used to triangulate information from the participant interviews. This included utilizing DELPI theory to develop the survey instruments, selecting FPO SPs that served in both policy and technical process development, cross-checking, and member checking. The cross-checking element was used to include emergent and purposeful interview opportunities (Gay et al., 2009). This resulted in opportunity to include other FAA VOR MON program specialists external to the FAA FPO. The interview transcripts were coded and condensed into themes. Member-checks were utilized to confirm the themes. The intent was to develop the findings as a case study format to determine how strategy formulation for accomplishing the VOR MON was developed within an FAA sub-directorate.

CHAPTER IV

EMERGENT THEMES

Introduction

The purpose of this dissertation was to examine how small sub-organizations located within larger institutional frameworks develop processes to accomplish large multi-year infrastructure modernization initiatives. The case utilized was the Federal Aviation Administration (FAA) Flight Program Operations (FPO) effort to convert the ground based navigation VOR stations in the NAS to a Minimum Operational Network (MON). Study participants from the FPO, VOR MON program office and the FAA New Jersey Technical Center were utilized for their expertise developing and executing the VOR MON program.

This chapter begins with a review of the qualitative interview questions. A discussion of the themes follows with a summary to wrap-up results.

Interview Question Review

There were five qualitative interview questions utilized to guide the inquiry discussions.

> Qualitative Interview Question 1)-Beyond what was asked of you in the quantitative survey, please offer anything else youwould like to discuss or describe concerning your position in FPO with respect to VOR-MON?

The first question in the qualitative inquiry was designed to ensure clarity of FPO demographical data and to allow for the non-FPO participants to explain their roles with respect to programming, engagement with FPO personnel, and length of time with the VOR MON initiative. This question also solidified study experience and expertise with respect to the VOR MON program initiative.

> Qualitative Interview Question 2)-Discuss your understanding of the VOR MON methodology to extend service volume on retained VORs in the NAS.

The second interview question was designed to obtain a baseline study participant explanation of what VOR MON initiative was intended to accomplish and how the FPO was proceeding with implementation. The study participants all uniformly stated that it is a backup to the GNSS based NAS to support safe IFR aircraft continuation thru GPS outage areas. Well over half (57%) of the Study Participants (SPs) additionally referred to the NextGen DME program that is intended to enhance the PBN network. The NextGen DME is a program to expand the distance measuring navaid network across the NAS to support D/D/I PBN operations also as a back-up for GNSS ourtages (FAA, 2018e). SP 7 stated that their office is analyzing DME radio frequency behavior in support of the NextGen DME program and that "…they are still two different programs, as far as I understand, they're two different programs with two different target users" (SP7, personal communication, Apr 22, 2021). It was unclear what the work consequences of the DME expanision might be for the FPO directorate. SP7 also noted the diss-similarities of the VOR MON program in that part of it is a NAVAID reduction program (discontinuance) as opposed to the NextGen DME which intends to expand navigation infrastructure.

Qualitative Interview Question 3)-How would you explain the automation processes used to support the flight test information and assessment of extending retained VOR service volume from 40NM to70NM above 5,000 ft Above Ground Level (AGL)?

Interview question three was intended to allow study participants to explain, demonstrate and provide artifacts that described automation use with respect to the VOR signal assessment. The study participants explained both automation evolvement and use of visualization to build a picture of retained VOR signal performance. This automation and visulization was also utilized to refine and even re-develop business processes to balance quality assessment with available resources.

Qualitative Interiew Question 4)-What (if any) VOR MON expanded service volume inspection solutions would you recommend for better efficiency (innovating to make aviation safer and smarter)? [refer to Airman's Information Manual Paragraph 1-1-8c.2. (12-31-2020)]

Interview question four was designed to gain understanding of participant recommendations for possible program improvement. Participants provided information that ranged from more robust electronic modeling to improving the location and access to the digital repository of VOR MON program guidance and procedures within the FPO.

Qualitative Interview Question 5)- What process/es should a medium sized directorate (~150-200 full-time, assigned personnel) within the FAA utilize to develop a resourceful, methodological strategy to manage accomplishment of a nationwide multi-year initiative?

The final interview question was used to provide any closing comments on FPO strategy development. It was anticipated that study participants would summarize a higher-level review from having answered the four previous questions. They would be able to re-emphasize the importance of anything they percieved as successful and others that might still be a program challenge.

The forthcoming data included over 700 minutes of discussion with 14 study participants. Following the interviews, the results were transcribed and organized into common information using MS Excel software. Creswell (2012) describes this process as aggregating similar data into core elements (p. 248). The core elements were then used to provide answers to the three research questions of this study (chapters I, II, and V). Spreadsheets containing core elements from each interview were sent back to each participant for member-checking, validity and confirmation (Gay et al., 2009). The transcripts were reviewed in this manner multiple times to refine the core elements and eliminate redundancy Creswell (2012). The emergent themes were based on the core elements and answered the three research questions. The emergent themes are reported in this chapter.

The study participant interview data transcription process yielded six emergent themes and 14 sub-themes pertaining to the FPO role in the VOR MON navigation initiative. The interviews were conducted over a two-month time length based on participant availablility. All of the interviewees were full-time employees engaged in multiple FAA navigational development and supprt activities. Refer to Table 3 (Chapter III) for demographic descriptions of the study participants. The following paragraphs identify and explain the 6 themes and 14 sub-themes.

Emergent Theme 1: FPO Realign

FPO directorate realignment was an emergent theme with sub-themes pre-consolidation and post-consolidation. The composition of FPO has evolved since the inception of the VOR MON program. This topic of Flight Inspection Services (FIS) re-alignment into the Flight Program Operations (FPO) directorate was discussed by 4 of the SPs. SPs 1 and 2 described the re-alignment as a “merger” of sorts whereby the Flight Inspection mission is now a part of the bigger FPO (SP1, personal communication, Apr 09, 2021; SP2, personal communication, Apr 09, 2021).

Realignment (2018)

The timeline of the re-alignment was 2018. FIS at the time had 29 aircraft assigned and was solely responsible for the navigational system integrity of all published IFPs in the NAS. The FIS directorate moved under the Air Traffic Organization (ATO) as an incorporation of 6 separate FAA flight programs responsible for “aviation safety training, flight inspection research, development, test and evaluation support, and critical event response/transportation” (FAA, 2020d"What We Do"). SP13 indicated that the intent was to benefit overall flight operations within the FAA by leveraging aircraft, personnel, maintenance, and oversight under one supervisory chain. SP13 exemplified the benefits of the re-alignment explaining:

> Okay, so when that reorganization happened and [Training Aviation Safety Instructors] TASI and Flight check were part of one…family, then it became very easy to say, "You two organizations are working together, what can you do to help each other?" And now we're able to, as we're all with one boss, able to share airplanes if we need to, very easily and able to even share some personnel if we need to. For instance, one of the gentlemen at Alliance is very experienced in C90

> [Beechcraft C90 King Air] and he's also a check airman. The check airmen at Alliance airport are referred to as Training Aviation Safety Inspectors (TASI)s. So, we've used them on occasion, even for some VOR MON programs because they are familiar with the aircraft and we've used them as check airman. (SP13, personal communication, June 06, 2021).

There had previously been an extended period of reduction in flying hours for what was then Flight Inspection Services (pre-realignment [2019]). SP4 described the flying hours reduction over the timeframe 2010 - 2020:

> …over the last 10 years even, we've been cutting our flight hours for flight inspection. I mean, at the height when I was starting, we were probably 20,000 hours a year. Now we're down to something like 12 [12,000]. So, VOR MON comes along, and it was a pretty significant impact on our available resources…they're trying to think outside the box. When we combine all the Aircraft Operations into one directorate and... So, we have all the airplanes [together]. (SP4, personal communication, Apr 08, 2021)

Emergent Theme 2: FPO Strategy

FPO strategy for VOR MON accomplishment is divided into the sub-themes work priorities, VOR MON program leadership and phasing. Study participant discussion on FPO work priorities revealed a hierarchy based on mission criticality. SPs 2, and 3 gave the most complete set of priorities.

Work Priorities

First FPO business priority is the critical event response. This mission includes supporting the NTSB investigative teams with airlift (FAA, 2020d). The crews are stationed at Washington DC Ronald Reagan National Airport in a unit referred to as Hangar 6. They also support the DOT and FAA senior executives and have reimbursable agreements with multiple other federal agencies.

SPs 2 and 3 described the Core 30 airports as next in the priority hierarchy. These airports support the majority of air-traffic in the US and are typically within Class B airspace (FAA, n.d.-a). The FAA places a high safety priority on service restoral at these locations as they have significant amount of infrastructure to support all weather day/night operations. The infrastructure includes items such as Special Category ILS systems supported by navigation azimuth and glide slope emitters including approach and touchdown lighting ensembles. Restoral to service includes FPO safety inspection following certified repairs. SP5 noted that "…if something happens, at DFW, guess what?" That's where we are going." (SP5, personal communication, Apr 09,2021).

Priority number three is the periodic review work throughout the NAS. This includes every IFP in the FAA inventory using the interval schedule depicted in Figure 11. Conservative estimation using number of RNAV and ILS IFPs ~ 8K (Table 2) and 540-day interval (385 working days) equated to over 20 instrument flight procedures per day. This does not include the equipment restoral at CORE 30 airports from the previous paragraph.

SPs 2, 3, 6, 7, and 8 all discussed the matter of IFP development and charting cycles. FPO is responsible for validating amendments to IFPs that are developed by AIS throughout the year on 28 and 56-day cycles. The IFP Gateway portal on the FAA web-site indicates over 2600 procedures in production for the terminal procedures publication (TPP) cycle dates beginning in May 2021 and ending in April 2022 (FAA, 2018c). If half

Table 4-1. Basic Schedule for Periodic Flight Inspection
(all intervals are in days)

Approach Obstacle Assessment	540
SIAP	540 (5)

Facility	Interval
ILS/ LDA/ SDF w/GS	540
Localizer Clearances at LSA	1,080
MLS	270
MMLS	180 (3)
GBAS	540 (6)
PAR	270
ASR or WAM system	540
DF	540
LDA/ SDF/ LOC only	540 (2)
NDB (UHF, LF/ MF)	540
VOR, VORTAC, TAC	540 (1)
VOR, VORTAC, TAC	1,080 (4)
VOT	540
DME, NDB facilities associated with an Instrument Approach Procedure, Marker Beacons, Communications, VGSI, and Approach Lighting Systems	Inspect these facilities at the same interval as the system or procedure they support.

NOTES:
(1) 540 days for facilities (VOR or TACAN of a VORTAC) which support a SIAP or receiver checkpoint. An alignment orbit is required every 1,080 days for all facilities.
(2) Monitors required every other inspection. See Paragraph 13 in Chapter 4.
(3) SIAP check required every 360 days.
(4) 1,080 days for facilities that do not support a SIAP or receiver checkpoint
(5) For all periodic SIAP inspections, the periodic obstacle assessment may be conducted independent of the SIAP inspection. Periodic inspections of RNAV or GBAS SIAP(s) do not require flying the actual procedure; however, an obstacle assessment must be conducted through the final and missed approach segments.
(6) See Paragraph 12 in Chapter 4

Figure 11-Excerpt from Flight inspection manual depicting periodic intervals for Navigation equipment and IFPs. Adapted from *United States standard flight inspection manual (8200.1D),* FAA, 2015b. Washington D.C. (https://www.faa.gov/documentLibrary/media/Order/8200.1D_USSFIM_with_CHG_1.pdf). In the public domain

of all IFPs in development are presumed to require FPO review, then the directorate needs to fly 5/day in addition to periodic interval work. The total FPO periodic review and procedure assessment workload then equates to 25/day. SP5 emphasized that the conversion of the NAS from predominately ground-based navigation with PBN procedures is an active endeavor in the current time frame. Specifically, “VOR MON program is competing with others [programs] whether it be WAAS or ADS-B implementation…" (SP5, personal communication, Apr 09, 2021). This statement aligns with the FAA strategy "Continuing to replace current conventional approach procedures with PBN procedures" (US Department of Transportation-Federal Aviation Administration [FAA], 2017, p. 22). SP 7 also indicated that the potential of an extended procedure development timelines due to re-routing of "V" Victor Airways to offset VOR decommissions can be very time-consuming due to the rulemaking requirements as directed in FAA JO 7400.2M "Procedures for Handling Airspace Matters".

One FPO assigned SP 5 noted that with reference to VOR MON sorties are "…right now, I kind of say it's a little more ancillary…" comparing with flights dispatched to handle periodic or IFP workload (personal communication, Apr 09, 2021). This was in similar alignment with SP7 who commented:

> …this work is being done in between your six-month periodic ILS checks of 900 or so ILS equipment around the NAS, as well as many other types of inspections that they do that sometimes are unforeseen. New ILS systems coming up on the air, periodics, and so many other things that they work on and this [VOR MON] had to be squeezed the in-between all those tasks. (SP7, personal communication, Apr 04, 2022)

With respect to scheduling priorities SP 7 stated that when asked how many hours you can allocate for the VOR MON program next year the answer was "…based on how many hours I had left over or if I had to get more hours could we afford to do that. Procedures [newly amended] were involved in that too" (SP7, personal communication, May 28, 2021).

Program Leadership

The next sub-theme that appeared within the FPO strategy was VOR MON program leadership. This topic was discussed by 13 of 14 SPs. SP2 advised that the FPO could benefit from an internal 'core team' to update personnel in FPO Operations with situational reporting on progress. The purpose of the 'core team' working group is "…basically provide the latest information on what the VOR MON strategy and requirements are going to be" (SP2 personal communication, Apr 01, 2021). This SP stated there was an FPO representative from the Operations directorate to attend program level meetings but that information such as VOR service volume assessment completions, remaining work to be accomplished, anticipated wrap-up timeframe based on current resourcing, was not always immediately visible. Five of the FPO SPs and one programming SP gave numbers ranging from 100 to 250 when discussing how many VORs had been validated at the 70 NM service volume extension by the time of the interviews. SPs 1 and 3 indicated they anticipated the service volume extensions on the remaining VORs scheduled for retention would be completed by end of FY22.

The FPO participants described that the FPO is organized to support the VOR MON program like the way it manages other national navigation initiatives. Their operations directorate has within it a group of personnel that handle technical support issues also known as policy development and implementation. Their main responsibility is to determine solutions for "how to" problems (SP1, personal communication, July 23, 2021). The policy is ultimately derived from procedures and responsibilities outlined in the 8200.1D "US Standard Flight Inspection Manual". They develop and refine the procedures for FPO personnel and equipment implementation. In the case of the VOR service volume expansion initiative the problem was “how to” in validating the 70 NM signal areas.

The other group discussed by SPs 1, 2, 4, 6, 11 and 13 and supporting the FPO connection to initiative programming is known as Aviation Technical branch. They handle hardware, software, and automation development to support the mission. The equipment that FPO operations utilizes to collect data on VOR signaling assessment was developed by this branch whereas the procedures used to implement the equipment were developed by the technical support branch.

The non-FPO assigned SP interview information pertaining to VOR MON program leadership indicated that FPO (previously Flight Inspection Services) was involved in development from the incipient phases of the initiative. SP9 indicated that in the period 2011-2013 they worked with flight inspection to determine the serviceable limits of VORs using their crews and aircraft to measure navigation performance and various radii distances during preliminary feasibility testing:

> …we call flight inspections[sic] to come to Washington DC to meet with us and we told them, "This is what we have the analysis. This is what the modeling at the lab shows." We want to pick up initially 15 sites in the nation, 15 sites with different locations because we want to have a different, at least, locations to have what's called a clear picture. (SP 9, personal communication, May 12, 2021)

Two of the five (20%) of non-FPO SPs reported having been with the VOR MON program development from the beginning in 2010. Of the FPO SPs only 1 of 9 (11%) had been involved of the program development as far back as the 15-site distance testing limit locations (2011-2013). SP 11 advised that “I became involved right when it got to flight inspection, when it was a lot of developing of, "How are we going to inspect this?" (SP 11, personal communication, May 11, 2011). The other eight FPO SPs all indicated they became involved with the VOR MON program significantly after the 2011-2013 testing site period. One FPO SP stated that they "…didn't get involved until maybe 2017 or so. I think from flight programs, I think one of the first people that was involved was… . he's retired now" (SP 12, personal communication, May 28, 2021). This SP also stated that they no longer work within FPO either. SP 8 noted:

> …that one of the issues that we found out is you might have a POC from an office, but if they don't communicate with their management or the next person that comes behind them. Then say they leave and somebody else comes….so sometimes the perspective is, "Oh, this is the first time you're talking to us". (personal communication, May 12, 2021)

Personnel turnover was noted considerably as a factor in the program for the FPO. SP 1 indicated they were assigned responsibility for bi-weekly meetings in Spring 2020. Although this SP was highly experienced with greater than 20 years in the FPO they had only recently been assigned to VOR MON policy development within FPO.

Phasing

The final sub-theme category making up the FPO organizational scheme pertains to phasing. The function was identified based on how SPs explained the evolvement of the program timeline. The phases identified by interview were VOR MON program development prior to FI involvement, FI supported model testing, phase1, and phase 2. SPs 8 and 9 were not assigned to the FPO but gave the most first-hand account of the inception of the program. This portion of the initiative appears to be immediately prior to

FPO involvement and what directly led to the publication of NPRM 76 FR 77939. Idea development and public outreach may be the best descriptors of the phase prior to FPO involvement. Idea development was conducted thru studies. SP 8 stated “First of all, you have to make sure what is it that you're trying to do, right? So, we need to understand, sure. Why are you doing it? Where are the reports? Where's the studies?” (SP 8, personal communication, May 12, 2021). Stakeholders included the flying public (commercial and private organizations) along with air-traffic control representatives. Public outreach is explained by SP 9 as advising the stakeholders:

> …"This is what is coming in 2012" And I have to tell you, there [were] a lot of people saying, "You're not going to remove my VOR. Not in my backyard."…but the FAA has done an excellent outreach program nationwide, and then after that they understand even though we're going to remove the equipment, the service is going to be better than before. (SP 9, personal communication, May 12, 2021)

The FPO supported modelling and testing phase was previously noted as having occurred between 2011-2013. The primary effort was to determine what extension of service volume was supportable. There were 3 apparent objectives of this phase. First was to determine how far beyond the standard 40 NMs was reasonable, There were efforts to test the original 15-sites as far out as 100 NMs later determined to be infeasible due to signal strength and frequency co-channel interference with other nearby VOR facilities. After reviewing the data from the FPO supported test flights and attempting multiple radii between 70-100 NMs it was determined that the signal strength was most supported at 70 NMs. Second apparent objective was to build a national picture of how many VORs would need to be expanded and retained and understanding which ones could be decommissioned. This was based on a multiple premises including seamless reception in the continental US at and above 5,000ft AGL and retention of most all of the VORs in the Western US. The last objective was understand the causes of signal anomolies to help build the picture of arc quadrants where the signals were not optimal.

Phase 1 is indicated on the FAA web-site and Figure 13 (Chapter V) as the time frame 2016-2020 (FAA, 2018d). This phase included approval and funding from the Joint Resources Council (JRC) to conduct airway and IFP redevelopments allowing for removal of 82 associated VORs. The purpose of the JRC program review was to connect program proposals, objectives, and milestones to justify FAA funding allocation (SP 8, personal communication, May 12, 2021). Although funding was allocated, the VOR MON program was a "competing priority" along with the other programs the FAA was working.

SPs 8 and 9 explained also that the JRC intended to develop a feasibility timeline for programming. The planning team was working with (FIS [now FPO]) to expand service volume on the list of 590 VORs planned for retention. FPO was commensurately tasked with flight reviewing all the associated re-designed IFPs in addition to the other procedure work (competing priorities) going on in the NAS that includes items such as airport runway construction and airspace re-designs in and around CORE 30, procedure and navaid periodic reviews at airports in the NAS.

SP 8 noted that there was significant number evolution with respect to VORs retained and decommissioned. SP 8 explained that before their assignment to the VOR MON:

> …the program was 500 VOR discontinued in five years. By the time I came in, it was three years and 300 VORs. Well, now we are at 15 years, 300 VORs.

> Because we learned that the FAA is approving other programs, the workforce is the same. (SP 8, personal communication, May 12, 2021)

By the time the Final Rule FR 81 FR 48694 published in 2016 there was an awareness of the retained VOR capabilities as far as effective signal transmission signal distances at and above 5K. A model was developed based on program management and flight inspection supported evidence to indicate the minimum number of VORs along with geographic locations for retention. The VORs that were not part of the forthcoming minimum operational network were then placed on a candidate decommission list (Provision of navigation services for the next generation air transportation system [NextGen] transition to performance-based navigation [PBN] [plan for establishing a VOR minimum operational network], 2016). Phase I is described as an operational test of how long it would take to remove VORs from the NAS based on available resources and timing. SP 8 described it as being a live test stating:

> …in the phase one, which was the first five years of the program, FY16 to FY20 we were trying to do again the sample once so we could learn. So, we could learn, are we doing this well? Is the system able to do this? (personal communication, May 12, 2021)

By the end of FY21 phase 1 was complete and actually exceeded the goal of 74 by 6 for a total of 82 VORs decommisstioned. SP 9 advises that although the number was exceeded there were still some problems to resolve.

One was the resourcing math. Given the current amount of allocated funding and mission priority for FPO it was taking approximately a year to accomplish about 17 VOR decomissions. The most that were removed from circulation in any one year was 31 in

2020. The concern was mission accomplishment by 2025 as originally planned in the published Final Rule 48694. With work left to be done on 220+ VOR decommissions it became necessary to consider timeline extension to completion. SP 9 stated that retaining the original 2025 completion timeline would have required at least 40 removals per year and more efficiency in procedure development. Also, the VORs selected during the learning phase were typically those that were least encumbered with commensurate airway and IFP associations. And last, FPO was still working the service volume expansion on 590+ VORs on the retention list.

Seven of the 14 SPs made note that there are two initiatives that are part of the same program. First is a VOR service volume verification and expansion. The other is the VOR decommissioning portion of the intiative. Reference the expansion portion of retained VORs:

> Once those service volumes are in place, even if there are extra VORs, the backup portion is complete, then we just focus all of the attention at mitigating, canceling, amending procedures and whatever that may take, then slowly turning off those VORs that can be turned off. (SP 3, personal communication, Apr 09, 2021)

The program to document expansion of the expanded service volumes is nearing the point of partial publication. SP 8 states that the FAA is approaching the step to start publishing some of the expanded service volumes in the chart supplement advising "actually [in] calendar year 22 we are going to have a lot of service volumes being [sic] published" (personal communication, May 12, 2021). The notional service volumes are already depicted in the Airman Information Manual as "New Service Volume" (FAA, 2021a, pp. 1-1-8). According to SP 3 it was database limitations and user issues that slowed the service volume announcements:

> …the only reason you haven't seen those is because our automation tools haven't caught up. Namely, NASR [National Airspace System Resource] is our official database that we use to interface with industry and chart producers, so we're completing software updates to that to allow promulgation of these new service volumes. (personal communication, Apr 09, 2021)

The decommissioning of VORs was described as a very challenging matter. Three of the fourteen SPs described this process to include supported procedure re-designs, flight inspections, then publication:

> But the biggest challenge is the 1,000-pound challenges we have and continue having is definitely procedures. First of all, the VOR used to use something called victor airways, and victor airways there were a lot of them in the NAS. (SP 9 personal communication, May 12, 2021)

SP 3 also agreed that "…the difficult work is in all the procedure mitigations, amendments, cancellations, all of that work, and that's what will take, we think, until 2030-ish or so" (personal communication, Apr 09, 2021). SP 8 comments that the time it takes to re-design and publish flight procedures supported by VORs marked for decommission was a significant factor in extending the program another 5 years from the previous 2025 programmed completion date.

Emergent Theme 3: VOR MON Data

The next emergent theme appearing from the interviews transcriptions was VOR MON Data with accompanying sub-themes FPO data collection mechanisms, data policy and external directorate support.

Data Collection Mechanisms

FPO data collection mechnanisms include aircraft, crews, on-site environment and associated measuring equipment. They currently have assigned 32 aircraft to the dedicated Flight Inspection missions within the FPO. The aircraft are spread throught the continental US at locations referred to as Flight Inspection Field Offices (FIFO)s. The FIFOs are located in Okalahoma City OK (OKC) Sacramento CA (SAC), Atlantic City NJ (ACY), Atlanta GA (ATL) Battle Creek MI (BTL). SPs 5 and 11 explained that the FIFOs are geographical extensions of the primary FIFO in Oklahoma City, OK and that each has dedicated support staff in the form of schedulers and dispatchers to allocate aircraft and crews for flight inspection missions. Each FIFO outside of OKC has some responsibility for VOR MON missions but their itineraries are primarily focused on "…their normal jobs [that is]…just for all their periodic inspections and adding any procedure package work or approach work or ILS inspections" (SP 5, personal communication, Apr 09, 2021).

SP 6 explained that any crew and aircraft can be utilized to fly VOR MON assessment sorties. The two main FI aircraft discussed were Beech King Air 300s and Learjet aircraft utilized for all FAA flight inspections including VOR MON. All the FPO SPs and one non-FPO program management staff (71%) explained the acquisition of 3 C90 (Beech King Air 90) aircraft dedicated solely to VOR MON assessment (service volume expansion) missions. Two of the FPO SPs maintained flying qualification in that airframe. All the FPO SPs were aware of the C90 and explained the airframes were acquired when the FPO assumed responsibility for the FI mission and specifically utilized for VOR signal strength recording only. SPs 4, 5 and 6 all indicated that although any of the dedicated flight inspection aircraft were capable of being utilized for VOR service volume assessment that not all inspectors were qualified in every aircraft. Some inspectors are qualified in multiple aircraft, but some are not.

The on-site environment is the locality where FPO flight inspection accomplishes their VOR assessment and validation. Currently the meaning of the assessment and validation appears to be a 70 NM signal recording circle around the facility at 5,000 feet. SPs 1, 2, 4, 5, 6, 7 and 13 all indicated the 70 NM orbits can take anywhere from 1+45 - 2+30 depending on the aircraft. The Learjets and King Air 300s are limited to 250 Knots True Airspeed (KTAS) below 10,000 ft equating to a 1+45 time to accomplish a 70 NM orbit. The C90 averages about 180 knots true and takes between 2- and 3-hours total for the same orbit.

The measuring equipment utilized to capture VOR signal emissions is an automation suite known as Flight Inspection Airborne Processor Application (FIAPA) (SP 6, personal communication, Mar 30, 2021). The automation is operated by a mission specialist crewmember except in the C90 aircraft where it is operated remotely yet autonomously by the pilots. In the C90 there is no mission specialist to accomplish in depth VOR signal assessment.

Data Policy

The next emergent sub-theme was data policy. The FPO SPs explained that there were regulatory and procedural standards with respect to the normal periodic inspections of VORs. Every 1080 days (Figure 11) requires an alignment orbit:

> …that's somewhere between six and 10 miles. So, it doesn't take very long to do that. The only time we ever go check the coverage, again, is if a different type antenna is installed or something is done to the facility that will affect coverage like significant change in power or they have to re-roof the facility, something like that, or they install a whole new facility, of course, then we'd have to go and check coverage. (SP 8, personal communication, April 08, 2021)

The alignment orbits were not as simple as flying a circle around the facility. With respect to a VOR:

> For it to be satisfactory, in flight inspection tolerance for the use in the NAS it's got to have satisfactory modulations, it's got to have satisfactory roughness and scalloping and signal strength. Signal strength is just one part of the required elements for it to pass, to be allowed to be used in the MON. (SP 11, personal communication, May 12, 2021)

To determine the other parameters additional to signal strength a process of flying out radials is used in addition to checking the orbit. This was explained by 7 of the 14 SPs (50%). The functionality of the VOR is not only determined by signal reception distance but by the signal quality. SPs 1, 6 and 11 explained that when there were determined to be out of tolerance signal modulations on the orbital data (speaking with respect to legacy

VOR periodic alignment inspections) radials making up the arc sectors considered unsatisfactory would be “probed”. SP6 describes how this is accomplished:

> When it's [orbital radials] unsatisfactory we generally go back, and we'll take radio flight through the areas that are out of tolerance. Say you had a 10-degree section that is unsat on the orbit, then [the crew]…would have to go back and do radial flight. You could split the 10 degrees right down the middle and fly that section inbound or outbound all the way from 40, the current existing service volume, out to 70. And if it was sat, then you would call that 10-degree section that was orbitally unsat. You could call it satisfactory using radio flight. (personal communication, Mar 30, 2021)

The probing process was mentioned as a significant investment in time that is not only discussed by the FPO validation practitioners but also one of the VOR MON programming (non-FPO) participants. SP 3 notes that “…if there's an area that is suspect, we would further refine that by doing radials, and those take some amount of time” (personal communication, APR 09, 2021). The additional time required to refine knowledge concerning out of tolerance sectors was also discussed with relation to it’s need and relationship to the VOR service volume expansion:

> First, we'll take that course approach, enlarge where we can and understand that there may be restrictions that are larger than they would be if we spent a lot of time looking at those, but the idea being that we'll look at that network coverage, if you will, and then determine which ones may need extra attention. Just because you have restrictions on one VOR, it could very well be that the adjacent VOR is

> already covering those areas or restrictions. That's something that we can look at a later date. (SP 3, personal communication, APR 09, 2021)

The effort to refine the VOR restrictions on VORs that have been assessed for 70 NM orbits appears to be in the incipient phases within the FPO as one FPO SP explained:

> …we have not restricted these facilities. We have not said that they are unusable or VOR between this radial and this radial since we've done our VOR MON coverage orbit. So, it's in the beginnings, we're beginning to work that, but we have not done that yet. And I expect towards the end of 2021, we'll be working towards that, which will be a huge thing because we got to go back. We have to take a look at all those reports and say, "Okay, now we're going to actually publish these in the chart supplement…. This is what it's going to look like." And we got to figure all that out. (SP 1, Apr 09, 2021)

External Support

The final sub-theme that appeared within the VOR MON data major theme was external directorate support. The methodology employed in this research was designed to make inquiry with knowledgeable FPO representatives on the strategic planning and automation leveraged to progress the VOR MON program ahead from their perspective. It was anticipated that perspective on the interaction and roles of other organizations leveraged to assist FPO would be necessary. FPO assigned SPs 1, 12 both advised that there was data and automation support provided by external directorates and advised contacting the VOR MON office for additional inquiry. The cross-sample interview pool emerged from the initial contact to a total of 5 SPs from outside the FPO. The cross-checking methodology incorporated context in relationships between VOR MON organizations within the FAA and FPO. Three organizations emerged in this cross sampling that supported the FPO data and processes. They are the VOR MON programming office, Navigation and Landing branch, and Aeronautical Information Services.

The VOR MON office worked with FPO heavily beginning in 2011 during the modelling and testing phase. SP 9 stated that a representative from FAA Spectrum Engineering along with a VOR MON assigned engineer flew with flight inspection during the effort to understand VOR signal environments. Determining signal propagation and interference characteristics were the thrust of this effort. Flight Inspection had the aircraft and the signal recording equipment but the VOR MON program engineers utilized their own computers to document their findings and ultimately build a model they could use to determine feasible distance parameters for the program. From the initial test group of 15-VORs they built a case for best service volume expansion distance for FAA Headquarters:

> And we showed them the data at 85 was almost no good. At 79, it was iffy. But at 70, it was acceptable. We showed them three sets of data. And then all of us, we say that 70 is the way to go. That's going to be the expansion of the VOR. (SP 9, personal communication, May 12, 2021)

The Navigation and Landing Branch aided FPO beginning during the FI supported modeling and with phase 1 and continuing to the time of the current research interview process. The two types of assistance were both based on modeling navigation radio signals. First was the raw data interpretation and visualization of the service volume expansion orbits. The main purpose was to display areas of presumed acceptable signal:

> …the first effort in the VOR MON program was to determine how much they were going to expand the service volume and they basically looked at, I believe three potential radius numbers….and flight inspection in coordination with the PMO as well as the spectrum group, they did some tests and they basically found that 70 nautical miles was the adequate number. And that's where we came in and basically looked at that data and provided this summary for the PMO. A summary that focused on technical merits and looking at the performance of the VORs That was the time that the PMO settled on that 70 nautical mile number. Initially it was 77, but through tests, they found that the VORs were not going to perform adequately at 77, so they had to reduce it down to 70. (SP 7, personal communication, APR 22, 2021)

The second effort was to identify areas (arc quadrants) where further evaluation of possible VOR restriction might be necessary. This occurred during Phase 1. The visualizations below (Figure 12) were built using recorded raw orbital data only from FPO service volume assessments. The examples are visualizations built with data objects that display the signal health of two VORs (Hibbing [HIB] and Traverse City [TVC]). The Navigation and Landing Branch developed this visual tool to assist with analysis of the VORs so the program office could ascertain the actual NAS coverage depicted in Figure 8 (Chapter II).

The most recent assistance effort (Phase 2) is to determine feasibility of flying reduced orbit distances with sufficient electronic evidentiary assurance that the signal would be usable at 70 NMs:

Recently, we're working with flight inspection to look at the feasibility of a reduced radius orbit for VOR MON instead of flying it at the limit of cover to 70 NMs. Seeing the feasibility of flying it closer in to save fuel and resources on that same elevation angle to that 70 NM 5000-foot point. At 49 NMs it comes down around to 2800 feet. So, flight inspections done some flight at three different sites and we analyze the data presented that yesterday at a working group meeting for VOR MON and the data looks very promising. So, we're looking at those type of initiatives to cover little special projects with the VOR MON to support the program office AJM-32. So that's kind of in a high level, the type of work that we're doing to support the project. (SP 10, personal communication, May 14, 2021)

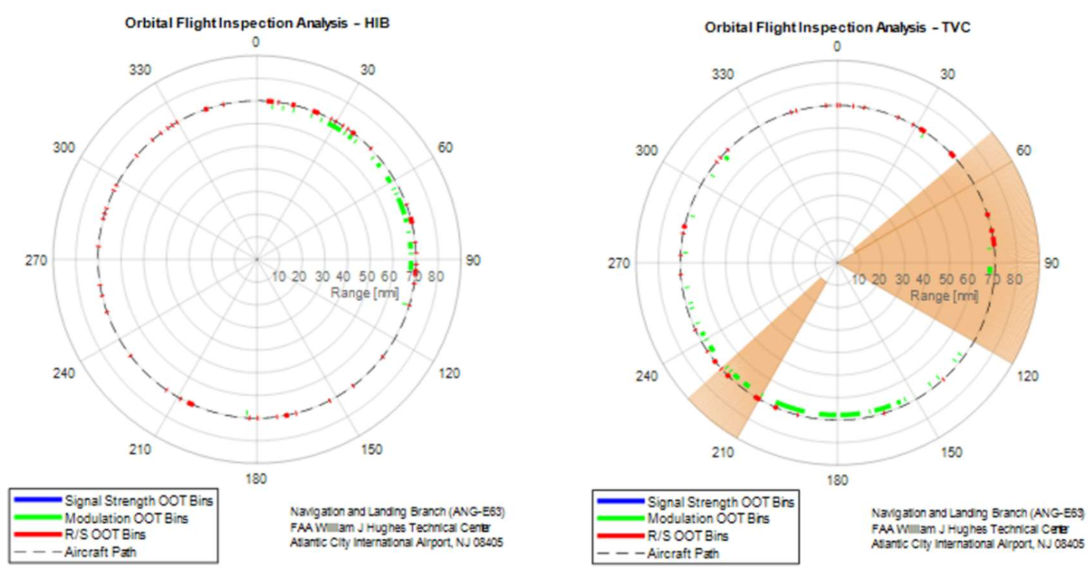


Figure 12-Example of orbital FAA flight inspection analysis at 70 NMs on two VORs (HIBBING [HIB] and TRAVERSE CITY [TVC]). Visual depicts signal strength and presumed out of tolerance (OOT) radials. (R/S - Roughness and Scalloping). Adapted from *VOR Polar plots,* FAA, 2021f. VOR MON Program AJM-324, Navigation Programs, Federal Aviation Administration, 800 Independence Avenue SW., Washington, DC 20591: FAA. Adapted with permission.

The Navigation and Landing branch's relationship with FPO is ongoing. They are assisting the FPO by theorizing possibilities, collecting data to build a resulting picture, and making inputs to improve efficiency in processes by reducing the time it takes to validate VOR expanded service volumes:

> Today, we know how to conservatively do that and, if there's a way we can do it that takes less time and we're confident that the results are transportable to the larger orbit, then we would do that. We have all the theory and the engineering behind it, but we don't do that without validation of some number of facilities to prove our theory, if you will. (SP 3, personal communication, Apr 08, 2021)

Emergent Theme 4: VOR MON Processes

The next emergent theme was VOR MON Processes with sub-themes aircraft and equipment constraints.

Aircraft

The Beech King Airs and Learjets are legacy flight inspection aircraft. Six of the nine (66%) FPO SPs advised that the King Air 300s and Learjets had been in the directorate for over 20 years. The Beech C90s were recently acquired in 2017. The FAA FPO owns a total of 9 Beech C90s housed and maintained at Fort Worth Alliance airport as part of the Aviation Safety Training (AST) for Aviation Safety Inspectors (ASI)s. Three aircraft were retrofitted to support the flight inspection mission as VOR MON support:

> That was just I think a utilization thing…They got nine of them down on the lines and we've modified three of those to put a new rack in with some receivers and that kind of stuff and taken the lower transponder antenna and made that a

> receiver for the DME. So, we just have extra. We didn't have to put any holes or anything in it. (SP 5, personal communication, Apr 09, 2021)

The Beech C90s do not possess the same capabilities as the legacy flight inspection aircraft but were considered as best suited for the 70 NM orbit assessment because of their mission efficiency:

> So, if you're taking one of our assets [legacy aircraft] that can do every flight inspection mission across the NAS and simply doing an orbit for two hours, that's not the most efficient use. So, we would like another platform. C90 seems like it would be a very good platform for this. AST, do you have any needs? And as I understand it, one of their needs was to increase the utilization of the C90. (SP 13, personal communication, Jun 06, 2021)

The C90s also do not have a crew position allocation for mission specialists that are utilized on legacy aircraft to probe radially as well as assess a much broader range of ground navigational equipment in addition to VOR orbital signal strength:

> But it doesn't have all the same capabilities, but it allows the aircraft to fly and orbit around a rotated a facility, to collect all the same [VOR orbit] data that a standard flight check aircraft does but does not require a mission specialist in the back. (SP 11, personal communication, May 14, 2021)

The C90s are employed only for VOR orbital assessment. SP 6 advises "The C-90 mission is so far just VOR orbits" (personal communication, Mar 30, 2021).

Employing the C90 as a VOR orbital signal assessment platform presented some additional responses pertaining to how the aircraft is utilized for the mission along with aircrew planning challenges. The 70 NM orbits typically require 2.5 hours of airborne time for VORs but there are factors that can significantly extend missions and, in some cases, nullify portions. First is the amount of airspace transited and pre-coordination requiring significant pre-planning by those pilots qualified to operate the C90. At 70 NMs the orbit is nearly 440 NMs and has the potential to cross multiple busy air-traffic control boundaries:

> It just becomes a really an exercise and a little bit of pain just because of where these orbits are crossing. You can imagine the arrival and approach corridors, departure corridors and here comes a little C90 doing 200 knots. Hopefully, you're not 180. That's going to spend five minutes just basically in the way, but that's just these orbits sometimes, just where they are, how they lay. And it's pre-coordinating, sending lots of emails, and taking pictures of what the orbits so people have a visual representation of what you're going to do. (SP 5, personal communication, Apr 09, 2021)

Weather was also noted as a significant factor that can cause a follow-up re-fly for segments impeded by low clouds and/or convective activity. The proper ground height (5,000ft AGL) is to be flown which means climbs and descents in areas of prevalent precipitous terrain. Most of the VORs in the Western US designated mountainous regions are on the retention list. This means significant altitude adjustments during orbital assessments where weather could force segment re-fly and completion delays.

Another challenge is unanticpated navaid maintenance. SP 5 noted that experientially they had planned a VOR orbital assesment sortie and were informed by the Air Route Traffic Control Center (ARTCC) after arrival in the airspace that the navaid was temporarily down for maintenance (personal communication, Apr 09, 2021). This created a situation whereby the VOR assessment was not completed on the originally planned sortie and had to be re-scheduled.

The final challenge noted with this sub-theme is the actual on-station difficulty of aircraft altitude and airspeed management. Since the VORs are required to be effective at and above 5,000ft AGL at 70 NMs that is where the orbital assessments must take place. This can make a normal duty day feel longer because:

> The King Air, it's doing it in about an hour and 50, an hour and 45 minutes to two hours, and that's really a crew comfort issue because at 5,000 feet AGL above sight or 7,000 in mountainous terrain, guess what? Guess where the bump is and guess what time of the year we're coming into? …we're at 5,000 in the mountains or 7,000 feet in the mountains, and that's where the turbulence is. (SP 5 personal communication, Apr 09, 2021)

Equipment

Infrastructure and vegatation that has evolved around the NAVAIDs over time has created equipment challenges. SPs 1, 2, 6, 9, 11 and 12 that the VORs have been in place for up to seventy years and ecroachment by vegation immediately surrounding the facility is presumed to restrict signal propogation at the elevation angle that equates to 5,000ft AGL at 70 NMs. An FPO SP notes "vegetation encroachment is a huge problem for data facilities…and guys keep planting big trees, or trees and they become big trees, that certainly affects the MON's facility service volume (SP 11, personal communication, May 14, 2021). Additionally, many of the retained VORs are situated on airport property. The proximity of large aircraft taxiing close by is also presumed to negatively impact the signal:

> And if you can picture airplanes come in and go out of that airport pre COVID, you're constantly blocking that VOR signal, axion by it. And these planes are getting larger, so you're flying around. You're 70 miles away. You can't see the airport environment. You don't know what's going on down there…. (SP 6, personal communication, Apr 30, 2021)

Emergent Theme 5: VOR MON Automation

The next emergent theme reference the SP interviews was VOR MON automation and included sub-themes legacy automation and automation lite.

Legacy Automation

The FPO SPs all noted the computer automation system they use to to assess navigational performance as the Flight Inspection Airborne Processor Application (FIAPA). The significance of the system has to do with the version differentiation between the Beech C90 aircraft and the legacy fleet of flight inspection aircraft. For the purposes of describing the differences the version on board the legacy flight inspection aircraft will be referred to as FIAPA while the version designed for the Beech C90 aircraft will be FIAPA lite.

The legacy FIAPA system that is installed on the legacy aircraft (Beech King Air 300s and Lears) is capable of handling all FPO flight inspection responsibilities. SP 6 explains that "If we were to do a VOR MON inspection using any of our other aircraft, it can do anything, radial flight, et cetera, but this current airplane [Beech C90] in the picture's only orbital qualified right now" (personal communication, Mar 30, 2021). The FIAPA lite was specifically designed for VOR MON:

> The C90 data, the concept there is that because nobody is looking at the data right at the time that it's flown, it's just being captured on the laptop. Sometime later when people are available, we have a Mission Specialist go through the data and look for those outages to see if that would affect any procedures. But it meantime, we send all that data on to the program office. (SP 4, personal communication, Apr 08, 2021)

SP 2 indicated that the FIAPA version installed on the C90 aircraft is "a very abbreviated version" of the flight inspection system used to collect data for review after the sortie (SP 2, personal communication, Apr 01, 2021.

FIAPA Lite

A current initiative in progress with the Aviation Technical Branch within the FPO is to improve the signal measurement accuracy of the equipment:

> …the measurement uncertainty, another way to say what I was saying is the measurement uncertainty of signal strength is very, very large. It's much larger than what we'd want it to be. And it turns out that it's on our aircraft and every other flight inspection aircraft in the world for that matter too, has got a measurement uncertainty on signal strength that greatly exceeds the ICAO Doc 8071 requirements. And so, it was about 10 years ago when I started looking at the measurement uncertainty of all of our parameters, not just signal strength. And in really, really short summary, everything looked pretty good except for signal strength… . …we were at about plus and minus 10dB. So, we've taken a number of steps to try to improve that. (SP 2, personal communication, Apr 01, 2021)

This initiative harmonized the development and utilization of the FIAPA lite system for VOR signal strength assessment accomplished aboard the Beech C90 aircraft. The overall effort to reduce signal strength uncertainty for VOR MON facility tests at 70 NMs but will also be employed presumably on forthcoming FIAPA revisions to improve the signal measurement for ILS and DME signals. This would carry over into future flight inspection workloads reference periodic inspections and the incipient NextGen DME program (SP 2, personal communication, Apr 01,2021).

Emergent Theme 6: Efficiency Improvement Recommendations

The final theme that emerged from the interview data was VOR MON efficiencies. The two sub-themes were program management and crew resourcing. Questions 4 and 5 on the qualitative question script were designed to engage SPs on what they perceived as possible improvement ideas to the VOR MON program from an FPO perspective.

Program Management

The first FPO program improvement proposal involved capital investment for replacement equipment and increased FPO crew workforce. SPs 1 and 3 both stated that the FPO is working on a study for airframe modernization in or around 2025 (FAA, 2020d, "FAA Aircraft Fleet"). SP 3 also noted that pilot retention is typically a cyclical problem and dependent on economic factors impacting the commercial flying sector of the US economy. The recent pandemic may have reduced that portion of turnover temporarily and normal retirements are always a factor. Although SP 1 spoke of the impending FPO flight inspection fleet modernization plans, SP 5 cautioned the amount of resourcing created by upscaling. Another layer of administration is necessary to manage training and currency for a larger and newer aircraft fleet as well as training cadre for additional crewmembers.

The next proposed improvement came in the form of process modernization. SP 1 stated that the commercial communication industry models signal coverage as a business methodology and cautiously postulated it as possible in a larger context for VOR MON. The overarching concern with modelling is to what level it's considered reliable. Safety is always a concern pertaining to navigational signals particularly important being part of a back-up network as the MON is intended. The context of the discussion was that there could be more modelling to reduce flying hours used to assess signaling already presumed to be sub-standard. SP 13 explained the principle involved in flying 70 NM orbits as varied terrain conditions. The example utilized was assessing signal on a retained VOR in the Western US where there are numerous intervening mountain ranges precluding line-of-sight signals from reaching farther and lower elevations. SP 14 counters that modelling cannot easily replace practical signal reception assessment in all scenarios because the propagation anomalies are not always predictable.

Staging Beech C90 aircraft longer term on either coast was also proposed as a potential operational improvement. Per the current FPO C90 scheduling criteria, the crews are currently flying sorties predominately from OKC when assigned weekly itineraries for VOR service volume expansion assessments. Many of the VORs that have already been assessed for service volume expansion are in the Central US because of accessibility when staging from OKC. That has created a noticeable disparity in VORs still needing review the further one travels from the Central US toward either the Eastern or Western US.

It seemed that the possibility of staging the Beech C90 aircraft for multiple weeks at a time to a west and east coast FIFO while commensurately scheduling crews for multiple week itineraries in those locations is a viable way forward. SP 4 advises that the FIFO aircrews assigned outside of OKC are checked out in the FPO legacy aircraft but not the C90. It would be efficient to schedule crews that are highly experienced flying the 70 NM orbital expansion to continue accomplishing this effort. This would save travel time on either end of an itinerary as SP 4 advised it takes a full day to go out and back traveling at the C90 cruising speed.

The next improvement proposal was centered on program management access to information. FPO SP 13 indicated that understanding the "charter" of the VOR MON group took some time when they were first assigned to work the VOR orbital assessments (SP 13 personal communication, Jun 05, 2021). SP 13 clarified that they are not certain it would have changed any their tactical employment of VOR MON service volume expansion but that having access to a centralized repository of communication and artifacts between the FPO and VOR MON program office would have been helpful during their initial assignment to the initiative.

SP 2 indicated that an FPO Program Management Office (PMO) would be a plausible way forward for the directorate but also noted that the operations directorate currently accounts for programming responsibility.

Both FPO SPs 5 and 13 noted that VOR assessment for the MON program has highlighted the need for further discussion, clarification, and possible re-current training emphasis on the process:

> We have classes and everything but until you get in the airplane and see what's going on, it's hard to learn about it from a book. So, we've lost a lot of experience. We were moving away from a lot of VOR stuff. And now we're being flooded with VOR issues and inspection. So, we really had to look at our training and look at passing on that information to the new people that we've been training and what to look for. So, it's impacted our training too because it's not something that we did a lot of, and now we're doing a lot of it and we're going to be doing a lot of it for some time to come. (SP 4, personal communication, Apr 08, 2021)

The main reason for this concern is that the FPO has reviewed a considerable number of PBN based approaches in the past 10 years.

SP 13 noted that the role of the co-located ground-based navigational facilities (Tactical Air Navigation [TACAN]) and DME was not fully understood at the time of VOR MON orbital expansion. As the DME, specifically is now part of another program (NextGen DME) initiative they posited whether there was any possible benefit to be made assessing the other additional navigational signals information when utilizing the legacy Lear and Beech 300 airframes:

> My point being as a program pilot, I would have wanted to know more clearly is this a requirement at all. If it's not, why are we doing it? If it is, then we need to do it better. We need to resolve our anomaly. (SP 13, personal communication, Jun 04, 2021)

Crew Resourcing

Along with the potential operational improvement associated with possibly scheduling C90 aircraft to remain staged for several weeks in an Eastern and Western US location there were two FPO SPs that mentioned the criticality of the FPO scheduler in the processing of everything flight inspection does. SP 5 stated that a dedicated scheduler to manage VOR orbit expansion itineraries could assist with managing the airspace and air-traffic coordination to help create synergy in planning. This would plausibly remove the last-minute phone calls by the C90 crews to air-traffic for itinerary changes requests based on weathered. SP 12 also posited the possibility of closing airspace off to accomplish multiple initiatives that could be occurring. An example of this might be if there is another airport infrastructure project going on and flight check is already there closing off portions of departures or arrivals to validate new instrument approach procedure it would be useful to commensurately expand the VOR service volume while the airspace is closed. SP 12 also noted that there is a lot of momentum against restricting busy airspace around large airports and that the “penalty box” for flight check aircraft yielding to arriving and departing traffic was part of the job (SP 12, personal communication, May 28, 2021).

Non-FPO SP 3 stated that from a programmatic perspective they believe that FPO needs to retain control of their own schedule:

> Then, with the pandemic, you think about overnight stays and all of those, but what I'm saying is flight inspection has kind of worked out how to maximize efficiency in scheduling. If the program office just says, "Here you go, work these into your schedule," they know how to do that, so it's pretty transparent. I think if the program office says, "I want you to do this one this week and this one this week," that would probably not work out well, so that's probably one of those efficiencies is letting the mechanism that flight inspection has already worked out

> to deal with this increased workflow. (SP 3, personal communication, Apr 09, 2021)

SP 2 advised that "The number of flight inspections that our operational command center now is, it used to be called central operations schedules, and monitors and tracks on a daily basis is staggering" (SP 2, personal communication, Apr 01, 2021).

Summary

The emergent themes in this chapter became apparent following review of the digital interview transcripts. The information was categorized by locating the common discussion topics following questions posed to the participants. There was a significant amount of data and during the collection process, information received from early interviews was utilized to further scrutinize later participants and gain more clarity. The participants were all provided copies of the themes in spreadsheet form and given the opportunity to re-clarify information and return.

There is a final note reference the validity of the data gained from the interview process. This study was dependent on participants with expertise and understanding of the VOR MON program. All the participants were forthcoming in the limits of their knowledge. The non-FPO VOR MON program participants all indicated whom to contact for additional information within the FPO. In all cases, the individuals either had already been interviewed or were scheduled.

The emergent themes are presented in Table 4 (Chapter V). The next chapter will present findings and implications of this study based on organization of the emergent themes.

CHAPTER V

FINDINGS DISCUSSION

The purpose of this dissertation was to explore how small sub-directorates within large organizations develop strategy to execute legacy infrastructure modernization programs. The FAA Flight Program Operations was the examined sub-organization within the larger framework of the FAA's initiative to convert the legacy ground-based navigation infrastructure. The FAA's Very High Frequency Omnidirectional Range Minimum Operational Network (VOR MON) was intended as the case. The program is multi-year large infrastructure modernization effort aimed at re-purposing the legacy instrument National Airspace System (NAS) to a safety backup-role in support of the performance-based navigation (PBN) architecture.

This dissertation assessed the following hypothesis:

> Hypothesis: A small sub-directorate inside the FAA will manage a nation-wide, multi-year initiative with a combination of tribal knowledge, subject matter expertise and business re-engineering practices

The research questions below were used to guide interview discussion with VOR MON experts within the FAA:

> RQ1: How does FAA Flight Program Operations (FPO) systematically develop an

organizational strategy for accomplishing VOR MON service volume expansion and verification in the NAS?

RQ2: How does FPO leverage computer automation to develop a VOR MON “information base” and inform organization decision-makers

RQ3: What new automation might FPO propose to gain efficiencies in balancing their normal instrument procedure validation workload with expanding retained VOR service volumes?

The lens utilized in this research was Sander’s (1999) explanation of the organizational information base. Users interrogate the information base and convert disordered unknowns into ordered knowledge for the benefit of organizational leaders to make decisions.

There is academic research on system modernization. Geels (2002) describes Technological Transitions (TT)s “…as major technological transformations in the way societal functions such as transportation, communication, housing, feeding, are fulfilled” ("Introduction"). The conversion of the ground-based instrument NAS to PBN appears to fit the definition of a TT. There are numerous academic inquiries on technological transitions. An example is the conversion of factory production from steam to electrical power between 1880 - 1930 (Devine, 1983).

There is also academic research on legacy infrastructure modernization with reference to software systems (Brooke & Ramage, 2001; Ramage & Bennett, 1998; Ransom et al., 1998). These studies refer to legacy system modernization from an information technology perspective by relating the software as a system or infrastructure.

This research study was intended to analyze legacy infrastructure modernization from the perspective of large-system infrastructure and was conducted primarily via qualitative interviews with SME. The VORs supporting the instrument NAS cover the entire geography of the US.

The interviews were analyzed and organized into emergent themes based on discussion data with the study participant's experiences in developing and executing the FAA VOR MON initiative. All three research questions were answered utilizing the emergent themes (Table 4) from the participant discussions.

Emergent Themes to Findings

The emergent themes were organized from the data gathered and presented in chapter IV. There were a total of 14 study participants and 700 minutes of transcribed discussion. There were 6 emergent themes and 14 sub-themes. A depiction of the emergent themes and sub-themes appears in Table 4. The findings are based on the emergent themes and Figure 12 (Chapter IV - VOR Polar Plot).

Findings (1 thru 3)	Emergent Themes	Sub-Themes
(1) Strategic	FPO Organization	Pre-consolidation Post-consolidation (2018)
	FPO VOR MON Strategy	Work Priorities VOR MON Program Leadership Phasing
(1 and 2) Operational	VOR MON DATA Strategy	FPO DATA Collection Mechanisms DATA Policy External Directorate Support
	VOR MON Process Strategy	Aircraft Equipment
(1 and 2) Tactical	VOR MON Automation Strategy	FIAPA FIAPA Lite
(3) Recommendations	VOR MON Efficiencies	Program Management Crew Resourcing

Table 4 - Themes and Findings

RQ1

How does FAA Flight Program Operations (FPO) systematically develop an organizational strategy for accomplishing VOR MON service volume expansion and verification in the NAS?

Finding 1: Strategic, Operational and Tactical Program Components

This finding was based on the arrangement of emergent themes that answered RQ1. It was arranged based on strategy development and implementation at three levels within the FPO. A strategic level programming strategy resonated throughout the entire organization from the executive level. Operational level programming strategy impacted the people and resources that were directly involved with the VOR MON initiative within the FPO. Tactical strategy programming impacted the smaller group of cadre within the FPO directly involved in VOR MON assessment sorties.

Strategic Components - FPO Organization and Strategy

The two strategic components that were emergent in the interviews answering this research question were FPO organization and strategy.

FPO Organization (2018).

The FAA concluded a realignment and consolidation process of six different flying organizations into one directorate named Flight Program Operations (FPO) in 2018. Most of the research participants in this study confirmed knowledge of that objective and that the re-alignment improved aircraft and crew utilization for multiple FAA programs. This was a strategic organization move to align for business process needs exemplified by initiatives such as the VOR MON.

By the time FPO began execution phase 1 of the first 70 NM expansion orbits on VORs identified for retention in 2017, the directorate had already begun the re-alignment.

They transitioned from Flight Inspection Services (FIS) to become part of the larger Air Traffic Organization (ATO) Flight Program Operations (FPO) by 2018. The VOR MON initiative was conceived by the FAA in approximately 2010-2011 with the publication of proposed rule 76 FR 77939. The FAA's VOR MON programming office conducted on-site feasibility studies of VOR service volume expansion from 2011-2013. The interview data indicated this to be the most visible initial involvement in the VOR MON program by the Flight Inspection Services (FIS) directorate. The VOR MON program office engineers utilized FIS support in the form of sorties on-board FAA inspection aircraft to conduct signal assessments on 15 VOR sites. This testing phase was exploratory and was not cited by any of the participants as a significant resourcing issue for FIS. FIS did not begin assessing service volumes in support of VOR MON again until 2017. This was the beginning of the execution Phase 1 to orbitally validate expanded service volumes and possible restrictions on VORs identified for retention at 70 NMs (Figure 13).

In the interim, the FAA VOR MON program office engineers, with support from the FAA Navigation and Landing Branch had modelled the proposed VOR MON system to develop an architecture that would support 93% VOR coverage throughout the continental US at 5,000 AGL (Figure 8 - Chapter II). The interview findings support that the VOR MON architecture model in terms of which VORs were to be retained was already decided by 2016 commensurate with Final Rule 81 FR 48694. The program constraints identified in chapter II (Legacy Infrastructure Modernization) were also determined by 2016. The VOR MON program was in Phase 1 execution by 2017 and the funding approval to remove the first 82 VORs from the NAS was received.

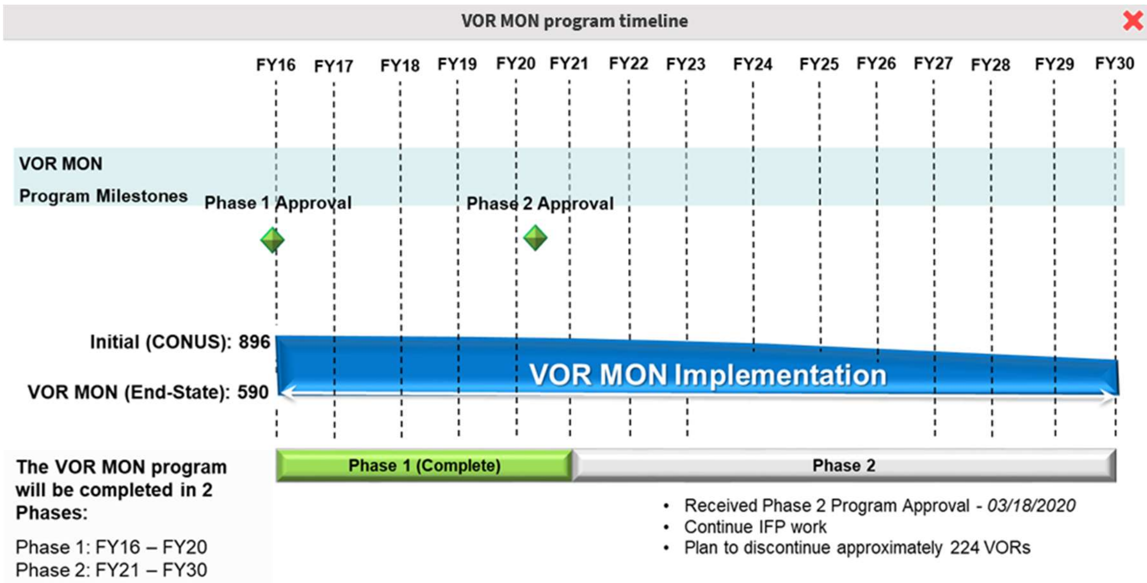


Figure 13-VOR MON programming timeline. Adapted from *Navigation Programs - Very High Frequency Omnidirectional Range Minimum Operational Network (VOR MON)*, FAA, 2021c. https://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/techops/navservices/transition_programs/vormon/. In the public domain.

The timing of the FPO re-alignment was in 2018 matches almost completely with the beginning of VOR MON execution Phase 1. SP 1 indicated uncertainty about the full spectrum of reasoning behind the re-align from FIS to incorporation within the FPO in 2018 but indicated the acquisition of C90 aircraft to support VOR MON expansion sorties was a significant benefit (personal communication, Oct 19, 2021).

FPO Strategy.

The three sub-components that emerged from the FPO strategy discussions were work priorities, VOR MON program leadership and scheduling. Several of the research participants described the work priorities with considerable detail. The safety of the NAS is always the highest priority.

Work Prioritization.

The first item pertaining to safety was critical event response/National Transportation Safety Board (NTSB) support. This safety priority is handled by a select group of aircraft and crews located at Ronald Reagan National Airport (FAA, 2020d). The interview participants described the next safety context in terms of high traffic density airports known as CORE 30 (FAA, n.d.-a).The FAA advises these locations support 70% of the passenger traffic in the US (mainly within Class B Airspace). The study participants further refined this to indicate that the navigational infrastructure in the form of Special Category Instrument Landing Systems (ILS) must be continuously operational to support all-weather access at these locations. The priority is such that any emergent need for an un-scheduled inspection of this navigational infrastructure would immediately curtail any prior scheduled FPO sorties. The last safety responsibility identification was the periodic maintenance due on navigation equipment maintained throughout the NAS. These preventative maintenance reviews appear to number in the range of approximately 20+ IFPs daily. This number was assessed based on Table 2 (Chapter II), Figure 11 (Chapter IV) and was not confirmed with an FPO scheduling authority. A detailed list of FPO priorities can be viewed in The United States Standard Flight Inspection Manual (8200-1D-April 2015) Chapter 4.7 (FAA, 2015b).

The safety and critical event support allotment of FPO sortie generation capability appeared mandatory and completely non-discretionary. The remainder of the FPO's work commitment appeared as discretionary and significantly more flexible. The commitments within the discretionary planning appeared to be procedure amendment reviews and programmatic initiatives such as VOR MON. The VOR MON consists of service volume expansion validation sorties and IFP reviews. The service volume expansion and the commensurate procedure amendment reviews to remove decommissioning VORs are handled based on a phased program scheduling that fits within the directorate's capabilities spread over years.

The research participants indicated that service volume expansions are anticipated to be complete by late 2022 or early 2023. The FPO service volume expansion effort began in mid-2017. The IFP procedure work to remove decommissioning VORs began in 2016 and is anticipated to be complete in 2030.

VOR MON Program Leadership.

The second emergent sub-component supporting FPO strategy was VOR MON program leadership. The VOR MON program office and the FPO both had personnel assigned to manage program responsibilities on behalf of their respective sub-organizations. The FPO separated their program support representation functions into technical support and aviation technical. The former referred to themselves as a policy branch of the FPO and the latter technical. The policy representative for FPO was responsible for operational issues revolving around all FPO internal procedures and processes. The technical branch was responsible for developing FPO hardware and software to automate FPO functionality with respect to the various missions within the work priorities. The policy branch maintained all the inter-office information pertaining to the VOR MON program. Key responsibilities of the policy branch were to regularly attend the overarching FAA VOR MON working group meetings and maintain the FPO program artifacts.

The first significant artifact was the list of VORs validated for published expansion and commensurate service volume restrictions as determined by operational FPO sorties. This was critical information for the VOR MON program office to evolve the retained VOR coverage across the US based on real-time assessed signal capability. The second artifact was a group consisting of the where, what, who, why when, and how of the program. This information was to be utilized by FPO VOR MON crews to understand their objectives for the overall program. One participant indicated that the location of both sets of artifacts was moved to a centralized to better serve the crews responsible for VOR service volume expansion sorties. This appears to indicate that within the FPO there was expertise at the policy level concerning the VOR MON program and that developing this connection with operational crews was a process that took some time. The technical complexity and expanse of the program were considerable factors.

The VOR MON program office confirmed FPO leadership interaction with their office at the incipient testing stages of the program from 2011-2013. Turnover was cited as being significant yet understandable due to the time span from testing to phase 1 execution (2013-2017).

Program Phasing.

Phasing was the third and last emergent FPO strategy sub-component. Testing, Phase 1, and Phase 2 were the three distinct phases that emerged from the interviews. Testing phase was occurred from 2011-2013. The Testing phase was a feasibility assessment on 15 VOR signal expansion candidates. Phase 1 was another ‘test’ phase of sorts but more focused on timeline and execution for the first grouping of 80+ VORs. Phase 2 began in

2021 and is the presumed final phase with expected completion in 2030. Refer to Figure 13 (previous) for the execution phase timelines.

A takeaway from this theme is that there are two similar but distinct programs within the VOR MON. One is the VOR Service volume expansion. Two is the IFP procedure re-development to remove decommissioned VORs from IFP publications. Both programs are very work intensive for FPO. The VOR service volume expansion and restriction assessments began in mid-2017 and are anticipated to be complete by end of calendar year 2022. This includes the 70 NM orbital flights by FPO on VORs totaling over 600. The IFP procedure re-development portion of the work is managed in conjunction with the FAA Aeronautical Information Services (AIS) directorate. This portion is anticipated to continue until 2030 (Figure 13). The timeline is due to FAA publication capacity at approximately 2600 procedures in any given year. Not all the 2600 annual publications are associated with VOR removals. The role of procedure publications is an area for possible future research as it involves an FAA directorate (AIS) that was not part of this case-study.

The next two takeaways from scheduling were modeling and resourcing. The FPO was able to leverage modeling of the VOR signal strength with the help of the FAA Navigation and Landing branch. The VOR signaling pattern at 70 NMs are complex and spread out over significant distances. This makes legacy methods of assessment very challenging. The Navigation and Landing Branch assisted with mathematical signal modelling and visualizations. Figure 12 (Chapter IV) is a visualization example. Several FPO research participants described a legacy signal assessment method known as 'probing'. This is a time intensive endeavor. The FPO worked with the Navigation and

Landing Branch to transition some of the workload to modelling reducing time utilized probing in-flight to verify VOR expanded service volume.

Resourcing component pertains to the discretionary nature of FPOs capacity. The discretionary FPO capacity after NAS safety responsibilities had to be determined. The FPO and VOR MON program office deduced this using the execution Phase 1 and arrived at that the annual number of 17 decommissions per year. Note that this is separate from FPO retained VOR service volume expansions. It is unknown how this number could change once FPO is complete with the service volume expansion assessments in 2022.

The FPO realignment was a managed strategic effort to improve discretionary FPO resourcing in the form of aircraft and crew scheduling, operations, and maintenance. This large programming step ensured the FPO had discretional capacity to accomplish VOR MON service volume expansion sorties while retaining their safety focus on CORE 30 airports and periodic NAS maintenance. The FPO Technical and Policy branches were organized to allow the FPO to separate processes from hardware development in accomplishing work. For the VOR MON the policy and technical branches determined how to fly the orbits and what equipment was plausible to develop in support of expansion orbit signal assessment. Last, the FPO coordinated with the VOR MON programming office to execute a Phase 1 and determine organization capacity. This not only validated their VOR signal assessment policy but gave the FPO and programming office an annual number of VOR decommissions they could accommodate based on published IFP amendment workload.

Operational Components - VOR MON DATA and Processes

The two operational components of FPO strategy development were VOR MON DATA and Processes.

VOR MON Data.

Elements of the interview data that supported operational VOR MON data were collection mechanisms, policy, and external directorate support.

FPO Data Collection Mechanisms.

The FPO acquired the use of and converted three C90 Beech King-Air 90 aircraft. The focus of this effort was to build a small force of aircraft to focus specifically on retained VOR service volume expansions. These aircraft were in additional to their legacy Beech King Air 300 series aircraft and Learjets. The legacy aircraft are all equipped to accomplish all FPO inspection missions. The C90s are limited to VOR MON expansion orbital assessments only. This was an operational efficiency measure to interrogate the information base and advise the FPO and VOR MON program office decisionmakers of actual retained VOR performance.

The C90 series aircraft are somewhat limited by speed at 180 knots. The orbital assessment time is approximately 2 hours and 45 minutes. This is compared to the legacy King Air 300s and Learjets that can accomplish the same orbit in 1 hour and 45 minutes. The trade-off in VOR MON discretionary capacity compared to sortie duration is considered a net gain for the FPO in terms of discretionary efficiency.

A last note on the C90 aircraft acquisition was the training necessary for the small cadre of FPO personnel assigned to the mission. The research participants indicated that training is a delicate balance. With more funding and aircraft, the FPO could accomplish a lot more work. The cost side is the training involved in terms of time and additional personnel. The FPO leveraged already qualified Training Aviation Safety Inspectors (TASI)s to manage this challenge internally and minimize cost. The FPO maintains a small cadre of personnel operating the C90 to balance personnel and aircraft utilization efficiency. The FPO cadre operating the C90 are dual-qualified in other FPO legacy aircraft. The FPO C90 cadre did appear to exclusively focus on VOR expansion orbits assessments using the C90.

Data Policy Evolution.

The second emergent sub-component within the Program Data Operation category is Data Policy Evolution.

Conducting 70 NM orbit assessments to determine signal strength on retained VORs was considered extremely resource intensive. The standard legacy procedure for validating VOR performance was an alignment orbit normally at 6-10 NMs. The legacy periodic alignment orbits included a procedure known as “probing”. The “probing” was to not only assess signal performance but also quality. The FPO participants described VOR signal quality with the terms roughness and scalloping. The usability of the signal thus had a reception and quality component. Attempting to probe facilities for roughness and scalloping at 70 NMs to determine exacting radial restrictions would significantly extend the completion time.

The policy to determine facility restrictions evolved into a signal verification first, restrictions later priority scheme. This meant that to resolve quality discrepancies, the FPO would defer to the program office and/or Navigation and Landing Branch. These external offices could make the decision that the radials in question were not necessary due to overlapping retained adjacent VOR signals nearby. This was very resource conserving as it ruled out any need to pursue redundant quality signal assessments. If it turns out that there is no overlapping nearby VOR signals, then the FPO, at the discretion of the program office would consider resourcing the probing activity. This policy appeared to be evolving at the time the interviews were conducted. This was an example modeling utilization by leveraging external directorate support.

External Directorate Support.

The FPO participants explained two major sources of support to their expansion initiative was the FAA VOR MON programming office and the FAA Navigation and Landing Branch. The VOR MON program architecture and constraints were determined during the testing phase predominantly by the program office staffers with support from FPO. This was to determine the acceptable distance the FAA could rely on for VOR Service volume expansion.

The Navigation and Landing Branch provided significant support to FPO beginning in 2017 in the incipient phases of the service volume expansion. They supported in two main areas. First was to collect and model signaling data on multiple VORs the FPO reviewed. They created visualizations (Figure 12 - Chapter IV) they referred to as polar plots. The visualization created an understanding from the mathematical signal data of each VORs performance. The Navigation and Landing Branch also depicted areas of concern around each VOR that indicate radials and quadrants that may need better refinement. This effort was intended to reduce the number of re-visits to VOR sites thus creating operational efficiencies and allowing legacy FPO aircraft to focus on other work priorities.

VOR MON Processes.

The two operational sub-components that comprised the FPO VOR MON processes were Aircraft and Equipment

Aircraft.

One of the consequences realized by the organizational re-alignment and standup of the FPO were aircraft utilization benefits. The flight inspection core business function of the newly formed directorate conducted VOR MON orbit testing utilizing available Beech King Air C90s There were initially 9 total aircraft of which 3 were retrofitted with newer versions of the Flight Inspection Airborne Processor Application (FIAPA-Lite) developed specifically for the sole purpose of VOR service volume assessment.

Although the aircraft had the effect of increasing FPOs equipment resourcing for the initiative, there were some challenges. One was training. The organization had to develop policy and train a small cadre of pilots to operate the C90. It was not clear from the interviews whether this new core mission translated into additional FPO personnel hired into the organization.

The newer version of FIAPA was significantly more hands-off in terms of operation and allowed for one pilot per aircraft per sortie without a mission specialist. Mission specialists are always utilized real-time on safety missions to assess and probe all types of ground-based navigation facilities ensuring the signal quality and adherence to operating specifications. A mission specialist was utilized post-mission on C90 sorties to review the 70 NM orbital signal data.

Second issue affecting the C90 type aircraft was transit speed. The 180 Knots cruising meant that a 70 NM orbit was a 2.5-hour endeavor. The transit time to and from the VOR sites was considerably longer than FPO sorties conducted in the Learjet or Beech King Air 300s. Many of the remaining VORs in need of orbital assessments are situated on the Eastern coast of the US. The C90s are based in OKC and require several hours to stage on the coast. This means a day in both directions used to situate the aircraft leaving approximately 3 days per week to fly VOR MON orbit assessments.

Equipment.

The VOR equipment is very mature. This meant there was considerable terrain and infrastructure encroachment around the facilities that was determined to complicate signal reception. FPO participants indicated the FAA is diligently working to remove vegetation around facilities where possible. This, in some cases, can mean coordinating with landowners nearby. In other cases, it may not be possible. VORs are on-airport facilities in many cases. Taxiways and aircraft can temporarily disrupt signal at airports that have grown-up around the legacy VORs.

Weather and airspace planning is also a challenge. C90 pilots stated that many ATC facility coordination phone calls can be necessary when flying an orbit that transits thru very busy flight corridors. Class B airspace was particularly problematic. In some cases, the pilot had to send diagrams of exactly where the FPO aircraft would be and when. If enroute weather or aircraft maintenance precluded the timing, ATC was not always able to release the airspace.

The operational process of managing the newly acquired C90 aircraft to support VOR MON expansion was FPO centric. They have applied expertise to not only operate within the aircraft capabilities and limitations but also manage the airspace, air-traffic, and weather factors as well.

Tactical Component - VOR MON Automation

The final component of FPO strategy development is VOR MON automation and was employed tactically.

VOR MON automation.

The sub-components of VOR MON automation were Legacy and Lite automation

Legacy Automation.

Flight Inspection Airborne Processing Application FIAPA has been the standard automation system for FAA airspace inspection since 2017 (SP 1, personal communication, Oct 24, 2021). The FIAPA automation suite described by the participants is tactically employed by mission specialists on all FPO inspection missions pertaining to electronic ground-based navigation infrastructure. This includes Instrument Landing Systems (ILS) and Tactical Air Navigation (TACAN) in addition to VORs within the NAS. The technology has been employed

Automation Lite.

The FIAPA Lite automation was developed and tactically leveraged specifically for VOR MON support. There are three units capable of VOR recordings only and specifically with the Beechcraft C90 aircraft. The advantage to the FIAPA Lite is its ability to run autonomously within the C90 while the pilot positions the aircraft and flies the 70 NM orbit. It allows for successful data collection without on-site mission crewmember management. The signaling data is collected and later reviewed using software playback. This tactical employment of hardware and software in existence since 2017 was cost effective in that it evolved from the FIAPA system already in use. It is resource effective in that it removed the need for mission specialists on-site thus allowing the C90 to conduct VOR MON sorties with only one FPO pilot (SP 1, personal communication, Apr 09, 2021; SP 6 personal communication, Mar 30, 2021; SP 11, personal communication, May 14, 2021)

RQ2

How does FPO leverage computer automation to develop a VOR MON "information base" and inform organization decision-makers

Finding 2: Automation and Visualization Informs Leadership on VOR performance

This finding was based on the arrangement of emergent themes that answered RQ2. It was conducted based on the premise that automation and subsequent visualization would be critical technology components to inform the FPO and consequently the VOR MON program office. The FPO would utilize this component to develop policy and processes to move forward with the execution of the VOR MON program on a forecast completion timeline. This finding is correlated to emergent themes VOR MON data and VOR MON automation strategies.

The automation evolved to support the FPO in conducting VOR MON expansion orbits was FIAPA Lite. SPs 2 and 3 both indicated it was developed specifically to assess retained VOR signal strength at 70 NMs without the necessity of a mission specialist crewmember operating the system real-time (personal communication, Apr 01, 2021; personal communication, Mar 30, 2021). The assessment recordings are reviewed by mission specialists post sortie.

The visualizations exemplified in Figure 12 (Chapter IV) were developed based on both FIAPA and FIAPA Lite automation (SP 10, personal communication, May 14, 2021). These visualizations were the result of modeling conducted by the FAA

Navigation and Landing Branch collaborating with the FPO (May 14, 2021). Signal recordings from the FPO automation were combined with the automation recordings to develop the visualizations. The visualizations are then used to visually advise the VOR MON program leadership on retained VOR performance to build the 93% coverage solution (GNSS back-up [Figure 8 - Chapter II]).

The expanded VOR restrictions are a critical component of building the 93% GNSS coverage back-up. The expanded VOR signal sectors that were considered questionable in terms of signal performance were not completely probed by FPO VOR MON sorties for refinement (SP 1, Personal Communication, Apr 09, 2021; SP 11, personal communication, May 14, 2021). The VOR MON program office was informed of the out-of-tolerance quadrants and is currently utilizing that information to build the bigger 93% coverage picture with relation to the other retained VORs in geographic proximity. Not every retained VOR is needed to perform perfectly at 70 NMs if there are others retained nearby that can overlap coverage gaps. This operational management of assessment resources exemplifies how automation that led to visualization informed program leaders in progressing the VOR MON program forward without excessive on-station probing.

RQ3

> What new automation might FPO propose to gain efficiencies in balancing their normal instrument procedure validation workload with expanding retained VOR service volumes?

Finding 3: Recommendations for Program Improvement

This finding was based on the arrangement of emergent themes that answered RQ3. It was determined based on the premise that the VOR MON program execution experts within the FPO understood what program improvements were possible. The emergent theme that correlated to this finding was improvement with sub-themes program management and crew resourcing.

The recommendations for program improvement were:

1. Aircraft fleet modernization
2. Process modernization
3. Aircraft staging
4. Information access
5. Reducing turnover
6. Internal scheduling
7. VOR MON sortie preparation responsibilities

Additional automation was not specifically mentioned by any of the SPs as most necessary for program improvement. SP 2 did state the FPO VOR assessment modeling was under review to better refine processes but did not mention any specific type of automation to accomplish this other than the FIAPA Lite system (personal communication, Apr 01, 2021). The last research question caused several of the participants to expand the discussion to programming improvements. All participants agreed that there was more to improvement than process automation. The two emergent themes in the FPO response data pertaining to programming improvements for efficiency were program management and crew resourcing.

Program Management.

The initial recommendation for program management improvement was aircraft fleet modernization. FPO fleet assessment/modernization study is currently in progress by the FAA (FAA, 2020d). SP 1 advised that fleet modernization is expected to begin by 2024 but that it is too early to know what the scope of the effort will be (personal communication, Apr 09, 2021).

Program management improvements additional to fleet modernization were process modernization, aircraft staging and information access. Process modernization was described as modeling to reduce the use of actual sorties and aircrew dispatched to review VOR expansion. The VOR MON program conducted significant modelling of service volume expansion limits during the test phase. The FPO collaboratively worked with the FAA Navigation and Landing Branch to develop visualizations of VOR MON service reception at 70 NMs (Figure 12 - Chapter IV). More modeling appears possible as the process to refine expanded VOR restrictions is still in development. A proposed process improvement is the possibility to feasibly reduce the orbit assessment distance from 70 NM down to 49 NM. This effort was under review by the FPO and Navigation and Landing Branch at the time of the interviews (SP 3, personal communication, Apr 09, 2021; SP 11, personal communication, May 14, 2021).

Aircraft staging was also discussed. Due to the enroute speed characteristics of the C90 aircraft it was posited that they could remain on either coast long-term to reduce the travel time to-and-from the VORs that remain. SP 5 noted that there are more VORs on either coast still requiring assessment than in the central US (personal communication, Apr 09, 2021). This circumstance was the result of the C90s staging from Oklahoma City at the beginning of duty week and returning by week’s end. It was unclear from the interviews whether the longer-term coastal deployment option is under review whereby C90 aircraft would remain in place for multiple weeks on either coast.

FPO VOR MON program information access was the last improvement suggestion. This was a recommendation to improve the location and labeling of the core documentation explaining the program objectives and methods for crews assigned to VOR MON assessment. SP 13 indicated better understanding of the VOR MON program objectives and limits by crews assigned could facilitate better VOR MON crew's understanding of how other initiatives could be combined and assessed on similar sorties (personal communication, Jun 06, 2021)

Crew Resourcing.

Aircrew turnover was identified as cyclical challenge. More aircrew would be a solution to the work volume challenge but would also mandate a larger fleet of aircraft. The participants advised that personnel turnover is different than volume and that increasing number of aircrews would tend to create training and currency challenges. Reducing turnover would best preserve the FPO organizational corporate knowledge base and have the same affect. The knowledge concerning efficiently assessing VORs has somewhat depleted due to turnover and heavy focus on PBN procedure development and assessment over the previous 10 years (SP 6, personal communication, Apr 08, 2021).

Another improvement proposed for crew resourcing included internal scheduling. The proposal was to commensurately schedule aircrews to swap out on the West or East coast in support of aircraft staging (see "Program Management" previous section). Another proposal was shift some of the sortie preparation responsibilities to a dedicated dispatch/scheduling position. The challenge of coordinating airspace usage with air-traffic control and managing an orbit completion during adverse weather is currently a tactical crew issue (SP 5, Apr 09, 2021). Related to this was the fact that some of the

VOR assessment fundamentals needed re-emphasis. This was due to the focus in FPO over the past 10 years on PBN procedures and the reduced emphasis on methods for managing VOR signal assessment and validation.

A last note on scheduling was the assertion from the VOR MON programming office was this is best left in the hands of FPO. The FPO has perfected the mechanisms to best manage their schedule (SP 3 personal communication, Apr 09, 2021). The program office can best manage the overall implementation timing based on FPO's advisement of VOR program sortie generation capability. The FPO has a better understanding of their own non-discretionary NAS safety commitments around which they can work (Apr 09, 2021).

Strategy Development for Legacy System Modernization-Hypothesis

The following hypothesis is analyzed for conclusions on how the FPO sub-organization within the larger FAA organization developed strategy to execute legacy infrastructure modernization program for the VOR MON initiative.

> A small sub-directorate inside the FAA will manage a nation-wide, multi-year initiative with a combination of tribal knowledge, subject matter expertise and business re-engineering practices

Tribal Knowledge

Tribal knowledge is "any unwritten information that is not commonly known by others within a company. This term is used most when referencing information that may need to be known by others to produce quality product or service" (Henderson, 2010, p. 12). For the purposes of this analysis unwritten information is assumed to be FPO's strategy development with respect to the VOR MON programming initiative. FPO has pre-existing regulatory guidance (Federal Aviation Administration Order 8200.1D) that explains all aspects flight inspection procedures (FAA, 2015b). The last revision of the manual was released on 11-06-2016. The regulation explains every aspect of a VOR inspection but does not specifically mention the service volume expansion effort with respect to new distance coverage within the MON program.

The existence of regulatory guidance to assess VORs on a periodic basis was not indicative of how to permanently expand low altitude service volume out to 70 NMs for the VOR MON initiative. The policy and technology for accomplishing the safe expansion of new published service volume had to evolve from the expertise within the FPO on what could constitute a final determination of safe service volume limits. SP1 referred to this process as a completely new coverage orbit and advised the FPO had to develop a process that was different than typical periodic alignment orbits (personal communication, Apr 09, 2021). The FPO's inherent knowledge on how the VOR MON expansion process could be designed was an inherent example of tribal knowledge in action.

Subject Matter Expertise

Subject matter expertise is an understanding of task criticality when accomplishing a process (Lievens et al., 2004). For the purposes of this analysis, this definition implies that the subject matter expertise is utilized to craft policy and procedures with respect to a program requiring formal guidance. In the FPO's VOR MON expansion case, it meant that the tribal knowledge had to evolve into formal policy and technological support based on understanding the critical tasks necessary to accomplish the expansion. The FAA could then demonstrate that signals would be safe at 70 NMs supporting users in case of regional GNSS outage.

Business Process Re-engineering Cycle

The four steps of a business process re-engineering cycle identified by Mohapatra (2013):

- Identify processes
- Review, update, analyze what is
- Design To-be
- Test & Implement To-Be

This framework is used for analysis of the FPO's process re-engineering practice with respect to the VOR MON initiative. It implies that the FPO had processes to conduct periodic alignment orbits on VORs but they would need to transition into an efficient process to fly completely new coverage orbits at 70 NMs. SPs 4, 9, 10, 11, and 12 all indicated that the focus on modern PBN procedure flight inspections means that all VORs in the NAS have been maintained thru the alignment orbit inspection process. Coverage orbits to validate service volume distance are only required in the case of major equipment replacement which is not often. One of the reasons the major equipment replacement is not often replaced is because these navaids were built with significant safety resiliency 70 years ago (SP9, personal communication, May 12, 2021). Therefore, the process to maintain had to evolve into a process to expand.

Application to FPO

SP 9 indicated that at the very inception of the VOR MON program in 2010 the program office engineers flew with flight inspection to determine the usable range of candidate VORs (personal communication, May 12, 2021). This testing phase to determine feasibility at various distances cemented the flight inspection directorate as the tribal knowledge experts within the FAA on matters pertaining to measurement of VOR signal health for safe aircraft navigation. Ultimately, the initial modeling conducted by the program office had to have practical evidence to support the retained VOR service volume expansion to the new radius distance.

Once the usable VOR service volume was confirmed at 70 NM, flight inspection has been the final authority in the signal assessment and confirmation of every VOR planned for retention. SPs 8 and 9 confirmed that flight inspection discretionary capacity to verify VOR expanded service volume and published IFP amendments to remove decommissioning VORs was a primary determinant in the development of the VOR MON program timeline presented in Figure 13 (personal communication, May 12, 2021; personal communication, May 12, 2021), FPO assumed responsibility for expanding every retained VOR in the NAS. The FPO personnel assigned to the VOR MON expansion effort had to understand the task criticality of components that supported each VOR's eventual publication for use to 70 NMs. The FPO had developed the subject matter expertise (criticality of tasks) to expand each VOR to 70 NM during the initial testing phase for application in execution Phase 1 (Figure 13).

The FPO has comprehensively re-engineered their processes tactically, operationally, and strategically to support the VOR MON programming since 2017 (Finding 1 - Table 4). The tactical components consisted of automation evolution from FIAPA to FIAPA Lite. The process evolution was automation re-design from all ground-based navigation assessment to tactically process VOR signal assessment only using revised hardware and software (FIAPA Lite).

Operational process re-engineering components included the FPO evolving their sub-directorate data collection policy and mechanisms to ensure more efficient and focused 70 NM signal confirmation. They improved their discretionary resourcing by retrofitting recently acquired C90 aircraft and re-developing their data collection process for signal strength with acceptance of broader VOR quadrant restrictions. It was not necessary to completely refine the restrictions as was typically the case when processing legacy periodic alignment orbits at 6-10 NMs. The FPO and VOR MON program office developed a resourceful plan to leverage the ‘system’ by utilizing other nearby VORs to fill in the GNSS back-up coverage. They collaborated with the FAA Navigation and Landing Branch to develop VOR performance visualizations (Figure 12 - Chapter IV) thus informing VOR MON program leaders using the information base (Sanders, 1999) The VOR MON program leaders are able to use this information to manage signal gaps and build forward to the back-up navigation coverage picture depicted in Figure 8 (Chapter II). The resource intensive probing process evolved into a more focused effort to assess the expanded VORs as a system rather than ensuring un-necessary signal perfection of each particular NAVAID.

Strategic FPO updates supported the operational and tactical process modernization efforts. SPs 1, 5, 7 and 13 all discussed the sub-directorate re-alignment to the Air Traffic Organization, fleet modernization, work prioritization, leadership, and program phasing as being aspects that facilitated changes at the operational level. Examples of this were the resource efficiencies intended to produce more discretionary capacity within the work prioritization along with acquisition of C90 aircraft for VOR MON orbital assessments.

The strategic updates were not entirely under the control of the VOR MON expert SPs within the FPO organization. SP 1 and 13 both noted that there are decisions reserved for upper management. SPs 1 and 13 provided advisory on the strategic issues however, they were certain that the VOR MON program was not the single catalyst for each of the themes (personal communication, Oct 19, 2021; personal communication, Jun 05, 2021). This is an indication that upper management was focused on forthcoming work for FPO beyond the VOR MON.

Therefore, the process to periodically review VORs at 6 - 10 NMs evolved. The new process was to expand the VOR coverage safely to 70 NMs. This evolutionary cycle was completely dependent on FPO tribal knowledge at its inception. The FAA VOR MON office connected with FPO on what was going to constitute safe signaling for the VOR MON. The process to fly the MON orbits was not explicitly stated in any of the regulatory guidance. SP 1 advised that the policy and technology branches within the FPO connected on the issue to develop and document Temporary Flight Inspection Guidance (TFIG)s that contained the accepted process for expanding the VORs. The TFIGs are indicative of FPO VOR MON subject matter expertise to develop policy based on critical tasks.

This was a complete evolution of the process. They identified the process to conduct periodic alignment of VOR facilities as it was explicitly documented in FAAO 8200.1D. At the incipient phases of the VOR MON program there was no process to expand retained VOR signal coverage to 70 NMs. The FPO utilized their tribal knowledge of VOR inspection to determine the critical tasks and identify a “to-be” process (Mohapatra, 2013). The FPO developed a TFIG that explained the process. The FPO tested the process in 2013 and implemented in 2016 to accomplish Phase 1 (Figure 13).

Hypothesis conclusion

The FPO organization demonstrated that their tribal knowledge evolved into formal business policy based on subject matter expertise; thus, validating the research hypothesis - all three components of the hypothesis were utilized synergistically to solve the VOR MON challenges - this evolution is a good example of the "whole (VOR MON program) exceeding the sum of its parts (tribal knowledge, SMEs, and business re-engineering practices)".

The evolved, formal policy was codified so that the process to periodically inspect VORs could be re-engineered into a process to expand the signaling to 70 NMs. The impact of the VOR MON program has cemented the FPO sub-directorate's role as tribal knowledge experts in VOR signal verification, allowed them to evolve their subject matter expertise of that verification, and precipitated strategic, operational, and tactical process changes throughout the sub-directorate.

This case indicates that the FPO, a small sub-directorate within a large organization (FAA) developed strategy to execute legacy infrastructure modernization by leveraging tribal knowledge first to determine critical tasks. They used their subject matter expertise to develop critical tasks then formulate policy and re-engineer existing processes into new ones. The FAA FPO is effectively re-engineered and re-purposed a large legacy VOR system to safely support TT as a safety back-up.

It is reasonable to use VOR MON as a template for future legacy infrastructure endeavors. Multiple, large, legacy system re-engineering endeavors on the horizon were discussed in chapter II. The presumed conversion of our national road system to support automated vehicles is a future case where geographically expansive architecture will be modernized. It is understood that the road and highway architecture will need to be modernized to support automated vehicles. That transition will likely require legacy road re-engineering to support transition to traditional safety back-ups during localized automated system outages to keep traffic flowing in a safe and efficient manner.

Another Department of Transportation Agency (Federal Highway Administration) will likely be at the center of that effort along with a similar group of user interests that include the private sector. They will collaboratively move forward with initiatives for safely managing the transition in a similar manner as the FAA and user groups demonstrate with the VOR MON. And there will be future opportunities for sub-directorates within large organizations to apply tribal, knowledge, subject matter expertise, and accepted business process re-engineering steps that facilitate large legacy infrastructure modernization.

Limitations

This study concludes that the FPO utilized tribal knowledge, subject matter expertise, and accepted business process re-engineering practices to accomplish a nationwide legacy infrastructure modernization effort. It is reasonable to consider these factors with respect to organizational strategy development in future nationwide legacy infrastructure modernization efforts. The limitations to this study should be considered before doing so.

This study was limited by timeline and resources. The VOR MON is anticipated to extend over a 20-year span. The interview participants were a relative snapshot in time occurring over a 3-month period. The effects of personnel turnover and further program evolution are not known. The interview data of 14 participants equated to 700 minutes of discussion. More interviews would have added considerable complexity to the task of data acquisition and interpretation.

The executive decisionmakers were not interviewed. This was an accessibility issue and the available VOR MON interview participants within the FPO were restricted by their daily professional duties. Understanding the fleet modernization and realignment from the executive management level could provide additional understanding of funding constraints and strategic decision-making.

Transferability to non-aviation and non-government infrastructure modernization endeavors is not known. The VOR MON is very specifically a government aviation endeavor. Examples of candidate endeavors for further legacy infrastructure study are available in chapter II "Example Infrastructure Modernization Cases".

As a result of the limitations above there are recommendations for future research.

Future Study Recommendations

The VOR MON case is a program currently projected to be complete in 2030. The interview participants indicated several areas of evolving strategy. Prominent areas of possible further inquiry that were visible in the interviews were:

- Modeling 49 NM orbits to conclude acceptable signal at 70 NMs
- Additional refinement of expanded VOR signal restrictions
- FPO aircraft fleet modernization
- What key determinants marked program completion?
    - What additional automation was developed and utilized?
- Periodic review policy of VORs successfully expanded

The previous could be investigated in 2027 and later to understand lessons learned.

It is also notable that the VOR MON is not the only large legacy navigation program that FAA sub-directorates modernizing. The NextGen DME program is part of PBN NAS modernization to provide resiliency to users during periods of GNSS outage also (US Department of Transportation-Federal Aviation Administration [FAA], 2017).

The forthcoming Technological Transition (TT) with respect to highway infrastructure supporting automated vehicles will produce a need for legacy infrastructure modernization. How the Federal Highway Administration (FHA) collaboratively manages the modernization of legacy technology to safely support future technology would provide greater understanding of strategy devolopment in sub-organizations re-developing legacy infrastructure (Saeed et al., 2021).

Summary

This chapter re-introduced the three research questions and hypothesis of the study. There were three findings, seven specific recommendations, and a conclusion that the hypothesis was valid in the case of the FPO's VOR MON legacy navigation system modernization effort. The FPO's strategy development to accomplish the VOR MON initiative had strategic, operational, tactical components. The development and use of automation was very visible at the operational and tactical levels of the organization. Tribal knowledge, subject matter expertise and business re-engineering steps were also visible in the FPO's strategy development to accomplish the VOR MON. The findings from this study could can be used to assist other organizations that will need to re-develop legacy infrastructure as safety support mechanisms for future technological transitions (TT)s.

Specifically, small directoratesgovernment organization embarking on a legacy infrastructure modernization program should consider:

1. Building related and clear strategic, operational, and tactical components
2. Computer automation must be value added, or do not employ
3. Care and management of resources (funding, personnel, and equipment) is critical to successful, on-time outcomes

Small sub-directorates within larger organizations are connected to executive level decision-makers that manage the overarching operation thru funding and resource allocation (strategic). These interactions produce the framework to develop and populate operational and tactical strategies. Smaller organizations can leverage benefit by connecting to similar size sub-directorates using operational strategies that capitalize on shared information and assets. Tactical strategy formulation is connected to job accomplishment. In the case of this dissertation, the job was the VOR MON initiative and how the FPO VOR MON aircrews tactically employed technology and policy to finalize results from recorded signal information. Automation can be a force multiplier but should be employed where development and usage are feasible to fund and technologically practical. Automation and visualization were operationally leveraged between the larger organization sub-directorates. Finally, small sub-organization can manage resources for legacy infrastructure modernization initiatives by connecting tribal knowledge to subject matter expertise and re-engineering processes.

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APPENDICES

APPENDIX A-IRB APPROVAL FORM

Oklahoma State University Institutional Review Board

Date:	11/23/2020
Application Number:	IRB-20-520
Proposal Title:	EFFICIENTLY IMPLEMENTING THE VOR MINIMUM OPERATING NETWORK
Principal Investigator:	Matt Vance
Co-Investigator(s):	Allan Will
Faculty Adviser:	Matt
VanceProject Coordinator:	
Research Assistant(s):	
Processed as:	Exempt
Exempt Category:	

Status Recommended by Reviewer(s): Approved

The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in 45CFR46.

This study meets criteria in the Revised Common Rule, as well as, one or more of the circumstances for which continuing review is not required. As Principal Investigator of this research, you will be required to submit a status report to the IRB triennially.

The final versions of any recruitment, consent and assent documents bearing the IRB approval stamp are available for download from IRBManager. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be approved by the IRB. Protocol modifications requiring approval may include changes to the title, PI, adviser, other research personnel, funding status or sponsor, subject population composition or size, recruitment, inclusion/exclusion criteria, research site, research procedures and consent/assent process or forms.
2. Submit a request for continuation if the study extends beyond the approval period. This continuation must receive IRB review and approval before the research can continue.
3. Report any unanticipated and/or adverse events to the IRB Office promptly.
4. Notify the IRB office when your research project is complete or when you are no longer affiliated with Oklahoma State University.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact the IRB Office at 405-744-3377 or irb@okstate.edu.

Sincerely,
Oklahoma State University IRB

APPENDIX B-PARTICPANT INVITATION

Will, Allan

Subject: Efficiently Implementing the VOR Minimum Operational Network (Study Candidate)

Dear Study Candidate:

As you are aware, FAA Flight Program Operations (FPO) is responsible for practical safety assessment of National Airspace System (NAS) navigational infrastructure. As such, the organization is tasked to responsibly ensure integrity of all published instrument flight procedures along with proper signal reception of all ground-based navigation aids and hardware.

The Agency, at the direction of the Administrator, is typically immersed in a constant transformation of the NAS. Many of these transformation activities are parceled and defined as "initiatives". The VOR Minimum Operational Network (VOR MON) is one such initiative focused on progressing our NAS to predominately Performance Based Navigation (PBN) architecture. The Agency initially informed the public of their intent to reduce the size of the legacy VOR Navigation network in 2011 and forthwith sought comments from industry.

The VOR MON project is a very large-scale and multi-year effort involving phased implementation and collaborative engagement from multiple directorates within the Agency. FPO appears to have a critical and long-term role in re-defining the VOR network throughout the NAS. The task includes reducing the VOR inventory from 896 to 585 while ensuring that the remaining navigation aids are able to continue supporting the geographic expanse of the NAS.

The purpose of the following research is to explore how a mid-size directorate with the Agency, FPO, methodologically develops an organizational strategy to accomplish VOR service volume expansion in support of the VOR MON. I have developed a survey to identify personnel with expertise within FPO accomplishing initiatives that typically require significant resourcing over extended periods of time. From the initial survey, I intend to interview a core group of individuals that are able to provide in-depth information on the FPO strategy development and practical accomplishment of the VOR MON initiative.

The results of this research could provide the Agency with a template for strategy and automation process development to progress large aviation infrastructure modernization initiatives. It can likewise assist Oklahoma State University in developing course curricula that entails aviation organizational strategy development.

Please take a moment to review the attached Informed Consent Document. It details the purpose and procedures of the study and explains participant confidentiality. If you would be willing to participate, request you sign and date document electronically, then return to me. If you have any questions reference the research, my contact information is allan.will@okstate.edu or cell (405) 203-3566.

Respectfully
Allan Will
AVED Graduate Student
OK State University (Stillwater)

Approved: 11/30/2020
Protocol #: IRB-20

APPENDIX C-INFORMED CONSENT

INFORMED CONSENT DOCUMENT

Efficiently Implementing the VOR Minimum Operational Network

Background Information

This intent of this research inquiry is to canvas survey FAA Flight Program Operations (FPO) for personnel that are able to discuss details pertaining to the directorate's methodology in developing strategy to accomplish the VOR MON transformation of the National Airspace System (NAS). The purpose is to examine the information from the interviews gaining understanding for developing an academic template into how aviation organizations develop strategy and automation to progress large multi-year infrastructure initiatives.
We ask that you read this form and ask any questions you may have before agreeing to be in the study. Inclusion in this research is at the participants discretion (voluntary). There is no penalty for refusal to participate or withdrawal. Further, participants and interview candidates are free to withdraw consent to participate at any time without consequence. You may skip any questions that make you uncomfortable and can stop the interview/survey at any time. Your decision whether or not to participate in this study has no impact on your day-to-day employment with the Agency.

This study is conducted by Allan Will, College of Educational Foundations, Leadership and Aviation, Oklahoma State University under the supervision of Dr. Matt Vance (AVED Faculty Professor), College of Educational Foundations, Leadership and Aviation, Oklahoma State University.

Procedures

The first segment of the study is included with this e-mail. It is a 7-question objective answer inquiry to determine participant knowledge of FPO methodology in accomplishing the VOR MON initiative. From this group, the researchers will invite a smaller group of candidate participants for one-on-one interviews within a 2-month period. The interviews are to gain in depth understanding into development of processes, procedures, automation and information organization used for practical accomplishment of this NAS initiative. The interview segment will be conducted and recorded by way of videoconferencing tool to minimize social contact and for the purpose of transcription followed by analysis.

The duration of the canvas survey is expected to take no more than 10 minutes. The follow-on interviews are anticipated to average 45-60 minutes.

Compensation

There is no compensation for participation in this study.

Risks

There are no known or foreseeable risks associated with this study beyond normal day-to-day interactional conversational activities. The researchers will confidentially maintain participant responses. The research team works to ensure confidentiality to the degree permitted by technology. It is possible, although unlikely, that unauthorized individuals could gain access to your responses because you are responding online. However, your participation in this online survey involves risks similar to a person's everyday use of the internet. If you have concerns,

Approved: 11/30/2020
Protocol #: IRB-20-520

you should consult the e-mail privacy policy at https://privacy.microsoft.com/en-us/privacystatement. TEAMS and ZOOM videoconferencing privacy are located at https://www.microsoft.com/en-us/microsoft-365/blog/2020/04/06/microsofts-commitment-privacy-security-microsoft-teams/ and https://zoom.us/privacy respectively.

Confidentiality

All e-mail messaging, electronic forms, and video conferences will be at participant permission. The researchers will confidentially maintain all electronic forms and media on the Oklahoma State University cloud server and password protected. The investigators listed above will be the only two individuals with access to the digital/electronic artifacts. The written research dissertation will de-identify participant responses thus reasonably restricting readers from associating responses with any respondents. Your identity will not be revealed in any publications, presentations, or reports resulting from this research study.

Contacts and Questions

The Institutional Review Board (IRB) for the protection of human research participants at Oklahoma State University has reviewed and approved this study. If you have questions about the research study itself, please contact the Principal or Co-Principal Investigator using the contact information displayed below. Questions about your rights as a research volunteer or would simply like to speak with someone other than the research team about concerns regarding this study, please contact the IRB at (405) 744-3377 or irb@okstate.edu. All reports or correspondence will be kept confidential.

Faculty Advisor:
Dr. Matt Vance
OSU AVED Professional Pilot Faculty
School of Educational Foundations, Leadership and Aviation
319 Willard, Stillwater, OK 74078
E-mail: matt.vance@okstate.edu

Co-Primary Investigator:
Allan Will
PO Box 31013
Edmond, OK 73003
Phone (W): (405) 954-6103
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Statement of Consent

I have read the above information. I have had the opportunity to ask questions and have my questions answered. I consent to participate in the study (electronic).

I give consent to be videotaped during this study:

☐ Yes ☐ No

Signature:____Date: __________

Signature of Investigator:____Date: _______________

APPENDIX D-RESEARCH SURVEY

Research Survey

The following questions are to assess FAA Flight Program Operations (FPO) research study candidate generalized experience and understanding reference operating procedures and VOR Minimum Operational Network (MON). Please place a check by the answer that best characterizes your response to the question.

Quantitative Questions

1. Please indicate your years of tenure/experience within Flight Program Operations (FPO):

- ☐ a. < 1
- ☐ b. 1 to 5
- ☐ c. 11 to 20
- ☐ d. 20+

2. Please describe your organizational role with respect to the FPO Aircraft Operations:

- ☐ a. Training
- ☐ b. Qualified
- ☐ c. Instructor
- ☐ d. Evaluator
- ☐ e. Supervisor
- ☐ f. Other (please specify)

3. Please identify your duty in FPO Aircraft operations:

- ☐ a. Mission Specialist
- ☐ b. Scheduler
- ☐ c. Aircraft Dispatch
- ☐ d. Pilot
- ☐ e. Procedures Specialist
- ☐ f. Procedures Developer
- ☐ g. Other (please specify)

4. Describe your understanding/experience with how the FPO develops strategy to accomplish work processes that will eventually become Standard Operating Procedures (SOPs)

- ☐ a. Significant experience developing SOPs (more than two SOPs)
- ☐ b. Some experience developing SOPs (one or two SOPs)
- ☐ c. Not experienced (familiar with SOPs, but not development)
- ☐ d. Unfamiliar with any SOPs pertaining to work processes

5. Which of the following best represents your knowledge level of the procedures and automation FIS utilizes to assess VHF Omnidirectional Radio Range (VORs) ground-basednavigation-aids for proper function?

- ☐ a. Can instruct/teach/demonstrate/explain most procedures/automation for assessment ofground-based navigational-aids
- ☐ b. Utilize procedures and automation but neither instruct nor teach
- ☐ c. Don't have practical knowledge of VOR assessment procedures or automation

6. Please select the option that best summarizes your knowledge of the FAA VOR MONinitiative:

- ☐ a. Understand in depth (what it is, how it might/will be accomplished, timeline forcompletion)
- ☐ b. Surface-level understanding (what it is but very little knowledge of the "how and when")
- ☐ c. Have heard of the initiative, but cannot explain its purpose
- ☐ d. Not familiar/no knowledge of initiative

7. Please select the option that best summarizes your knowledge of FPO's role in the VOR-MON

- ☐ a. Understand FPO's role in depth
- ☐ b. Surface-level understanding of FPO's role
- ☐ c. Am familiar with FPO's association/role, but cannot explain it
- ☐ d. Not familiar/no knowledge of FPO's association/role

APPENDIX E-INTERVIEW QUESTIONS

Qualitative Interview Questions for selected FPO Participants

Hello______________________(participant name), my name is Allan Will. I am conducting a qualitative study concerning FAA Flight Program Operations (FPO) role in the VOR Minimum Operational Network (MON) initiative. Thank you for participating in this interview.

The interview is composed of five research questions designed to explore the methodological strategy development and tools FPO uses to accomplish VOR service retention and expansion the National Airspace System.

As you are aware, the VOR MON is a large-scale multi-year Agency initiative to completely transform our legacy NAS to a predominately performance-based navigation (PBN) aviation architecture. The VOR MON initiative is one of many expansive multi-year efforts to modernize our NAS. Researching how FPO manages strategy, information and automation to accomplish can provide academic understanding and a possible template for planning large aviation infrastructure modernization efforts.

The informed consent document you previously signed gives a procedural description of this interview process and the confidentiality measures in place. This interview is designed to last from 45-60 minutes in duration.

Your insight and knowledge of FPO operations and procedures to accomplish it's mission are very valuable. I welcome you to share as much as you can. If you need a break during the interview, please advise.

If you don't feel comfortable with a question, please advise and we can either re-phrase or skip. Do you have any questions for me?

1. Beyond what was asked of you in the quantitative survey, please offer anything else you would like to discuss or describe concerning your position in FPO with respect to VOR-MON:

2. Discuss your understanding of the VOR MON methodology to extend service volume on retained VORs in the NAS.

3. How would you explain the automation processes used to support the flight test information and assessment of extending retained VOR service volume from 40NM to 70NM above 5,000 ft Above Ground Level (AGL)?

4. What (if any) VOR MON expanded service volume inspection solutions would you recommend for better efficiency (innovating to make aviation safer and smarter)? [refer to Airman's Information Manual Paragraph 1-1-8c.2. (12-31-2020)]

5. What process/es should a medium sized directorate (~150-200 full-time, assigned personnel) within the FAA utilize to develop a resourceful, methodological strategy tomanage accomplishment of a nationwide multi-year initiative?

VITA

Allan Will

Candidate for the Degree of

EdD Applied Educational Studies

Dissertation: AVIATION ORGANIZATION STRATEGY DEVELOPMENT IN NATIONAL AIRSPACE MODERNIZATION

Biographical:

Education:

Completed the requirements for Doctor of Education in Applied Educational Studies, Aviation and Space at Oklahoma State University, Stillwater, Oklahoma, 2022

Completed the requirements for Master of Aeronautical Science Embry-Riddle Aeronautical University, Daytona Beach, Florida Extended Campus, 1998

Completed the requirements for Bachelor of Science in Economics at United States Air Force Academy, Colorado Springs, Colorado, 1989

Experience:

United States Air Force Command Rated Pilot, 1989 – 2009

US Government Aeronautical Information Services Management Team, 2014 – present.

Oklahoma State University Aviation Education Adjunct Professor, 2019 – present

Professional Memberships:

National Order of Daedalians, 2000 - present