OVERCOMING TECHNICIAN INEXPERIENCE IN LOW-OBSERVABLE AIRCRAFT MAINTENANCE

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Honor Statement

On my honor as a student, I have neither given nor received unauthorized aid on this assignment.

Luke Pontzer

Disclaimers

This study was conducted and submitted in partial fulfillment of the requirements for the Master of Public Policy degree at the Frank Batten School of Leadership and Public Policy, University of Virginia. The opinions presented within this document are based on information from a variety of sources, including academic publications and informational interviews with professionals in the field. These opinions are the author's alone, and are not intended to represent the views, opinions, or positions of the Frank Batten School of Leadership and Public Policy, the University of Virginia, the United States Air Force, the Department of Defense, or any other government agency or private entity. Neither are any of these entities responsible for any loss suffered based on this brief's content or conclusions. Any mention of trade names, commercial products, or organizations does not constitute endorsement by the author or any of the aforementioned entities. All figures referenced in this report are best guess estimates and should not be taken as scientific fact.

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List of Relevant Acronyms

1 AMXS: The sister maintenance squadron of the 1 MXS, responsible for flightline maintenance tasks on the F-22, as well as launching and recovering the aircraft

1 MXS: The United States Air Force's 1st Maintenance Squadron, responsible for backshop maintenance of the F-22 at JBLE

2A3: The Air Force Specialty Code for crew chief, a general maintenance specialty responsible for many aspects of maintenance on fighter aircraft

ACC: Air Combat Command, the USAF component under which all active-duty fighter, bomber, and attack aircraft are assigned

AETC: Air Education and Training Command, the USAF Major Command responsible for all training and education of USAF personnel at all levels

AMT: Aircraft maintenance technician, a generic term for professionals who repair and maintain aircraft, especially in the commercial aviation sector

DCC: Dedicated crew chief, a more experienced 2A3 technician assigned to a specific aircraft and responsible for the paperwork, maintenance, and launch and recovery of that aircraft

F-22: A fifth generation, single-seat USAF stealth fighter aircraft

F-35: A fifth generation, single-seat stealth fighter aircraft in use by the U.S. Air Force, Navy, and Marine Corps, as well as several allied nations

JBER: Joint Base Elmendorf-Richardson, a U.S. Air Force and U.S. Army installation located near Anchorage, AK

JBLE: Joint Base Langley-Eustis, a U.S. Air Force and U.S. Army installation located near Hampton, VA

LO: Low-observable, referring to technologies that make it difficult for radar to detect an aircraft, or the aircraft which incorporate these types of technology in their designs

NCO: Non-commissioned officer, a mid-level designation in the enlisted ranks of the U.S. military, responsible for both technical work as well as leading, training, and mentoring other members

OTJ: On-the-job, specifically, training that is accomplished while performing real world tasks, as opposed to training that is conducted in a school or other environment specifically designated for learning

SNCO: The highest tier of enlisted personnel in the U.S. military, responsible for leading other enlisted members, training new members, and advising commanders and other officers on critical matters

USAF: The United States Air Force

Executive Summary

The increasingly technical world of military aviation has forced the United States Air Force to continually modernize its workforce to keep up with the maintenance and operations demands of some of the most sophisticated aircraft in the world. The 1st Maintenance Squadron at Joint Base Langley-Eustis is experiencing an ongoing dearth of experienced low observable maintenance technicians to work on F-22 aircraft, because of factors outside of the control of squadron leadership. This lack of experience is contributing to a sub-standard mission capable rate for the aircraft that this unit is tasked with maintaining. There are several options squadron leadership could pursue to alleviate this issue. They could attempt to incorporate dedicated crew chiefs from the 1st Aircraft Maintenance Squadron into low-skilled low-observable maintenance tasks, pursue the creation of e-learning content to alleviate some of the on-the-job training burden on the more experienced personnel, or they could develop a stock of continually maintained exterior panels to facilitate a quick swap and return to flight. Based on the costs and benefits of each of these options, it appears the most economical and simplest to implement option is to begin to develop spare panel stock to improve the mission capable rate of the F-22s at Joint Base Langley-Eustis.

Introduction

The rate of human technological advancement has fluctuated throughout history. Abundant evidence suggests that technology is currently advancing at a high rate, and this rate has the potential to increase even more in the next decade (Grinin et al., 2020). Although this rapid advancement brings many positive aspects, corresponding challenges also arise. As new technologies pervade all sectors of the economy, organizations are forced to recruit and retain increasingly skilled workforces to implement, operate, maintain, repair, and update such technologies.

This presents a challenge in many sectors. Technologically skilled workers require initial and often ongoing training to keep pace with the continually improving technology they are required to work with. These conditions represent heavily increased barriers to hiring and retaining workforces relative to those that past generations have experienced. These types of issues permeate all sectors of the economy, but especially those that are more reliant on technology to perform basic functions, including aviation and the military. The United States Air Force (USAF) experiences these issues just as any other technologically sophisticated organization does. Unfortunately, individual units have less freedom to address these issues than they might if they existed outside of the USAF organization. These units have much less control over the recruiting, retention, and training of the staff that work for them. Therefore, when they experience issues related to staffing, it is critical to work within their unique constraints to address such problems and ensure that they are still functioning as efficiently and effectively as possible.

Defining the Problem

Problem Statement

The 1st Maintenance Squadron (1 MXS) at Joint Base Langley-Eustis (JBLE) runs the risk of delayed low observable (LO) maintenance tasks resulting in sub-standard mission capable rate for F-22 interceptor aircraft.

The LO readiness standard set by the USAF Air Combat Command (ACC), under which all active-duty F-22 aircraft are assigned, is 60% (Devon Chatman, personal communication, 2021). What this means is that at any given time, 60% of the aircraft in an F-22 unit should be capable of carrying out their mission with respect to their low-observable (LO) components being in serviceable condition. Although leadership was unable to provide exact figures regarding shortfalls, the 1 MXS is currently unable to meet this standard. Jets are still flying and completing mission requirements, but there is a significant discrepancy between where they are and where they should be with respect to LO maintenance completion. In a complex organization like the 1 MXS, there are many factors that could contribute to such an issue. However, the leadership of the unit feels that they are severely inhibited by the inexperience of their workforce relative to that of other units responsible for maintaining F-22s. They believe that they are assigned an inordinate number of inexperienced LO technicians, and many of their more experienced technicians are transferred out of the unit to other units around the Air Force. This is the primary issue being addressed within this analysis.

This problem statement was synthesized based on an initial interview with the leadership of the 1 MXS, including the squadron commander and my point-of-contact (POC), the commander of the fabrication flight, a smaller unit within the 1 MXS. The fabrication flight includes the Low Observable (LO) maintenance shop. This means that the fabrication flight commander is the first commissioned officer in the chain of command for the LO shop and is tasked with thinking strategically about how LO maintenance is managed in the unit, while still being close enough to the action to have a good sense of daily issues experience within the LO shop. This makes him the ideal POC for this project. Although several other possible problems came up during this meeting, this one was the most interesting because of its roots in organizational dynamics and management. In addition, this problem presents the opportunity to attack the solution from many different angles, which is very attractive, especially as someone on track to enter aircraft maintenance following graduation from the Batten School. Finally, this problem is appropriately scoped to retain the 1 MXS as the client of this project. This means that it is most likely that the solutions proposed here will have the potential to be implemented at the unit level to work toward solving their problems.

Background

The 1 MXS is responsible for back shop (non-flightline) maintenance of an aircraft called the F-22 Raptor. The F-22 is the premier air-to-air interceptor fighter in the arsenal of the United States Air Force. While exact specifications are classified, the F-22 can travel more than twice the speed of sound and has supercruise capability, meaning it can travel at speeds in excess of the speed of sound without lighting its afterburners, which saves a great deal of fuel. This means it can fly further and faster than any other known fighter aircraft currently in service (*F-22 Raptor*, n.d.). However, the most important and innovative characteristic of the F-22 for American national defense is its stealth aspect.

Stealth aircraft, including the F-22, are constructed specifically to avoid detection by radar. Normally, radar signals leave the transmission station, bounce off an aircraft, and return to the receiver, allowing the radar system to detect and track the aircraft. However, stealth aircraft are shaped and coated in a manner which makes it much less likely that the transmitted signals can actually return to the receiver, making it more difficult for adversary radar to detect and track stealth aircraft. The diagram in Appendix A depicts the difference in reaction of radar signals to conventional aircraft versus stealth aircraft. For a better idea of how difficult it is for radar to detect the F-22, see Appendix B for a comparison of the radar cross-sections of various aircraft and animals. Although the F-22 is not specifically listed on this chart, the F-35 is a good comparison aircraft in this case. The ability to remain undetected or minimally detected by radar is critical to both the offensive and defensive capabilities of the F-22. It can enter hostile airspace and remain undetected, it can evade surface-to-air and air-to-air radar-guided missiles, and it is much easier for the F-22 to gain an advantageous position against adversaries in any type of dogfight. This makes it better at protecting the U.S. homeland and projecting power abroad, both of which are critical to the mission of the USAF.

The materials and coatings used in stealth construction, while highly advanced and effective at preventing detection, are very delicate and require continuous maintenance and care to remain effective. LO technicians are the primary subject matter experts in this area. They are responsible for fabrication and application of these coatings and materials to the aircraft and maintenance between each mission. LO technicians begin their careers like every other airman at Lackland Air Force Base with 8 weeks of basic military training. Following this, they are sent to 60 days of technical training to give them basic knowledge of how to care for LO aircraft components. Two months of training is not sufficient to become a fully capable maintainer, and the Air Force maintenance model relies heavily on on-the-job (OTJ) training and additional training courses throughout technician career progression. This means it is important to have plenty of more experienced technicians in operational units to supervise and continue training the more junior technicians (*U.S. Air Force - Career Detail - Low Observable Aircraft Structural Maintenance*, n.d.). This is where the root of the problem is encountered. The following table demonstrates the differences in enlisted staffing of the LO sections of JBLE in Virginia and Joint Base Elmendorf-Richardson (JBER) in Alaska.

Table 1: LO Staffing Comparison Between JBLE and JBER

	JBLE	JBER
Airmen	38	106
NCOs	19	56
SNCOs	3	6

(Devon Chatman, personal communication, 2021)

Airmen are the most junior technicians in the workforce, still learning their jobs through on-the-job training and mentoring. Non-commissioned officers (NCOs) are more senior but still doing mostly technical work on the aircraft, teaching airmen and ensuring that work is up to the quality standards of the Air Force. Senior non-commissioned officers (SNCOs) are the most experienced but are in supervisory positions rather than completing hands-on work. Besides being more than twice the size of the JBLE LO section, it is evident that there is a slightly better ratio of NCOs to airmen at JBER This is important because NCOs are the technician demographic primarily responsible for ensuring high quality work is completed in the LO shop. If there are too many airmen and not enough NCOs, manpower may not exist in the appropriate ratios to get work done that needs to be done. There is no “optimal mix” set by the Air Force, but a ratio closer to 1:1

rather than 2:1 of airmen to NCOs is more desirable so that NCOs can be more involved in the work of their airmen and help them to improve in their required duties.

The costs of this issue to the American people are significant. In this case, it is best to ascertain this cost through the value of national security affected by this deficiency. The value that the American people place on their national security is estimated using the annual national defense budget, dictating when and where American taxpayer dollars will be spent on defense. The Government Accountability Office (GAO) released a detailed report of military spending on specific weapons systems, including the F-22, in November 2020. Relevant excerpts from this report are contained in Appendix C. According to this report, in the year 2018, the Air Force spent $1.593 billion maintaining F-22s (*Weapon System Sustainment*, n.d.). This study is specifically examining maintenance on F-22s located at JBLE. There are 6 squadrons of F-22s across the Air Force, so we can assume that the maintenance costs associated with the aircraft at Langley are about 1/6 of the total costs. This means that the Air Force spent about $266 million on F-22 maintenance at JBLE in 2018. Now we can break down squadron personnel composition to determine what fraction of this budget is spent on LO maintenance on F-22s. In a maintenance unit of about 400 personnel, there are 60 personnel assigned to the LO section. This means that if we assume that the maintenance budget is divided proportionally to personnel breakdown, the Air Force spends about $39.9 million per year on LO maintenance at JBLE. Based on this figure, it is possible to deduce a direct cost of maintenance inefficiencies to the American taxpayer. If lack of experienced LO maintenance personnel causes LO maintenance processes to be 10% less efficient than they should be that means the American taxpayers are losing about $3.99 million per year in national security value. Stated a different way $3.99 million is about 0.05 percent of the $696 billion U.S. defense budget for 2018, which doesn't sound large, but this means that the security of about 164,000 Americans is affected, if every American benefits equally from the defense of the nation.

Context

The stealth technology maintained by the technicians of the 1 MXS is critical to the national security of the United States. The squadron of F-22s located at JBLE is the only squadron on the east coast of the United States. They constitute the only frontline 5th generation interceptor capability against any threat coming from east of the mainland U.S. This means that if they are not functioning at optimal levels, air defenses on the east coast of the U.S. are severely depleted and the American people are left significantly more vulnerable to an attack (Institute, 2020).

Regulatory Environment

The major regulator involved in this situation is the United States Air Force, which regulates on a systemic level. Various organizations within the Air Force are responsible for acquiring the aircraft, providing initial training to all technicians, and deciding when and where technicians move between the various bases around the country and around the world. Although turnover varies from year to year, the 1 MXS leadership has described experiencing a phenomenon wherein once technicians reach an intermediate level of experience, many are transferred from JBLE in Virginia to JBER in Alaska or other bases, taking their acquired LO maintenance experience with them. Additionally, squadron leadership believes that they receive more than their fair share of junior technicians to provide initial on-the-job training and mentorship for. The data provided in

Table 1 supports this conclusion, demonstrating that although larger, JBER also has a better ratio of experienced to inexperienced technicians in their workforce.

The systemic Air Force organization is the one that has created the generally undesirable ratio of experienced to junior technicians in the 1 MXS, but there is little latitude for change at that level, so the problem must be addressed at the unit level (*AFMAN 36-2102*, n.d.). However, the leadership of each squadron also has some latitude as to how they organize individual technicians within their squadrons and how they schedule shifts, etc., at the unit level. This means that potential solutions to this problem must be targeted at areas that the client, the 1 MXS, can address. Potential examples of this include modifying the breakdown of experienced to inexperienced technicians staffed on each shift and spray bay or changing the processes by which certain maintenance tasks are accomplished within the LO shop.

Literature Review

It is now clear that inefficient maintenance practices on the low-observable components of the F-22s at JBLE can result in great costs to the American people, both in terms of their tax dollars and threats to national security. It is time to examine the relevant literature to figure out how best to proceed with solving this problem and optimizing the scheduling of maintainers to ensure the best mission capable rate possible. In the interest of examining every potential solution, it is important to examine both commercial and military maintenance organization reactions to staffing shortages, as well as various maintenance process modifications that could increase maintenance efficiency. Following this examination, we should be able to produce a few viable policy alternatives for the leadership of the 1 MXS to potentially implement to be able to increase the mission capable rates of the F-22s that they maintain.

History of Military Aircraft Maintenance

Captain Barbara Harris' thesis, "Challenges to United States Tactical Air Force Aircraft Maintenance Personnel: Past, Present and Future" provides an excellent overview of challenges faced by the U.S. Air Force's aircraft maintenance organization over its entire history, from the inception of powered flight to the end of the Cold War. The USAF has reorganized its tactical aircraft maintenance structure eight times since it came to be its own service in 1947 (Harris, 1992). The most recent change brought the service to the organizational structure currently in place; operations, maintenance, support, and medical groups brought together under one wing. These changes were made in response to limited resources or mission changes, to make the maintenance organization the most efficient for carrying out its current mission. Since the problem at hand stems from limited personnel resources, we will necessarily focus on past changes made in response to limited resources, as opposed to mission changes.

Capt Harris' thesis was researched in a setting not unlike that of today's Air Force. The Cold War had recently ended, and Congress proposed a cut of 100,000 personnel from the Air Force in the 1990 Defense Authorization Bill. Similarly, today the United States Air Force is struggling somewhat to deal with the end of the two-decade war in Afghanistan as it works to realign its priorities to address the peer and near-peer threats that are rapidly arising. At the time of her writing, "Air Force leaders and managers, accustomed to working with more personnel, [were] searching for ways to cope with these reductions while retaining capability" (Harris, 1992). The most important parts of this paper are at the end of each chapter, labeled "Aircraft Maintenance

Issues in Summary." These sections contain knowledge which can inform current maintenance policy.

In the early days of aviation, the military faced the issue of losing its aircraft mechanics once they were trained by the government and became more valuable on the civilian market. While the 1 MXS is generally not losing its LO technicians to the civilian market, there may still be a lesson here. In the harsher climate of Alaska, the Air Force may have greater need of skilled LO maintainers than in the relatively milder climate of eastern Virginia. In the early days of aviation, the Army did not have much of a solution for this. In the same way, this issue is out of the control of the 1 MXS and is simply an obstacle that must be overcome.

In the interwar period, the concept of a "crew chief" was being explored more deeply. By the time maintainers reached this point in their careers, also known as a chief mechanic, they could perform almost all required maintenance tasks on the aircraft. This concept still exists in a similar form today. According to the Air Force Enlisted Classification Manual, technicians in the Tactical Aircraft Maintenance (TAM) Specialty "Performs…crew chief…and maintenance support functions" (*Air Force Enlisted Classification Guide*, n.d.) The Air Force Specialty Code identifier for this career field is 2A3. This document goes on to outline a long list of aircraft maintenance tasks that 2A3 technicians are expected to perform, including "end-of-runway, postflight, preflight, thru-flight, special inspections and phase inspections." In addition, these airmen are responsible for troubleshooting and maintaining various structures, systems, and components across the aircraft. Essentially, 2A3 airmen are a "jack of most trades" when it comes to maintenance of fighter aircraft, including F-22s. Currently, they do not do any work on LO components of the aircraft, but these technicians may prove themselves to be critical resources when developing solutions to the problem at hand.

In modern times, the Air Force has developed a position known as a Dedicated Crew Chief (DCC). These individuals are more experienced 2A3 technicians who are given the opportunity to be assigned to a specific aircraft at their base. A DCC is responsible for maintaining all paperwork and records on their assigned aircraft, and usually spend more time working on their aircraft than any other jet in their squadron's inventory (Airman 1st Class Heather Stanton, 2006). This type of assignment allows for DCCs to be able to detect maintenance patterns or issues more easily than general 2A3s who work on many aircraft and are not especially attuned to any one of them. DCCs take a great deal of pride in this assignment and are allowed to paint their names on the side of their jets to signify the ownership and responsibility they have accepted for the well-being of that aircraft.

The USAF and the RAND Corporation collaborated with Lockheed Martin, the manufacturer of the F-22, to run an experimental maintenance program in which maintainers are trained to specialize in broader areas of maintenance, rather than the more limited traditional specialties. This experiment is providing proof-of-concept that having maintainers perform low-skilled work outside of their normal area of specialty is not only not bad but could be extremely beneficial to Air Force maintenance outcomes. A few weeks of intensive training to generalize maintenance technicians was found to be very effective at broadening their skills. One iteration of the study even combined both LO maintenance and 2A3 duties into one "track," which demonstrates a high level of precedent for future overlap of this type. The study found that "concepts that aggressively consolidate [Air Force specialties] AFS have potential cost and readiness benefits, even when applied to only part of the force" (Wirth et al., 2020). This type of research could have serious implications, especially since the study was conducted on the F-35, another fighter with stealth capabilities that is very comparable to the F-22 in the realm of LO maintenance.

Comparisons in Commercial Applications

In determining optimal options to address technician inexperience, it is critical to examine viewpoints that may seem unconventional. Commercial aviation has been responsible for many innovations over the years, and it is reasonable to assume that there may be value in the responses of commercial airlines to staffing issues. The international aviation industry has recently been experiencing its own shortage of well-trained aircraft maintenance technicians (AMTs). Because of this, airlines and other commercial aviation organizations are increasingly likely to hire AMTs with less practical knowledge and experience. Serdar Dalkilic found that combining computer-based training with on-the-job practical training could increase the knowledge and skills of relatively inexperienced aircraft maintenance technicians and reduce the risk of accidents caused by maintenance mistakes (Dalkilic, 2017). In the early 2000s, the United States Navy decided to replace much of its hands-on, instructor led training with computer-based training. Researchers found that this change increased parts costs and necessary corrective maintenance actions, meaning the change to computer-based training had a negative effect on the system they examined, a type of sonar used on many U.S. Navy vessels (McNab & Angelis, 2014). It is important to note that this change is not analogous to the situation of the Air Force. In the Air Force, technicians still have in-person initial training, but receive supplemental training periodically throughout their career.

In Europe in 2007, a study examined how best to train airport security screeners. They received computer-based training attempting to help them become more proficient at detecting prohibited items using X-ray machines. This task is similar to those performed by LO maintenance technicians. It is relatively repetitive, but each iteration is unique or different in some way. Researchers found that this training improved the performance of screeners by about 15%, meaning that training of this type significantly improved their performance(Michel et al., 2007).

Another study was run comparing groups of medical students who received training in basic surgical skills through various methods. This study compared students who were taught using didactic, videotape, and computer-based methods. It found that computer-based training was as effective, and potentially more efficient, than the more traditional instruction methods it was compared to(Summers et al., 1999). This is an excellent sign for computer-based training and shows that it is not necessary to have a live instructor for students to learn effectively.

Finally, researchers in Malta ran a study to determine how various process improvements affect the functions of the tool crib, one of the tasks performed by technicians in the 1 MXS. They found that increasing the staff of the tool crib from two technicians to three average decreased wait times by about 92% (Gingell & Saliba, 2018). Although this task is not the same as on-aircraft LO servicing, it is a task performed by members of the LO section in their own tool crib and is relevant to increasing technician efficiency in that shop.

Non-Personnel Process Modifications

There is one more aspect of LO maintenance that could help alleviate strain on the 1 MXS due to inexperienced technicians. The 1 MXS engages in two major LO practices. They have two spray bays, in which an entire jet can be parked, taped up, and LO damages repaired on the aircraft. They also have one bay in which exterior panels that have been removed from the jets are individually repaired and reattached to the jet afterwards. A paper presented at the 2011 Winter Simulation Conference suggested that cultivating a supply of extra panels could help to reduce maintenance down time for the F-22s (Ysebaert et al., 2011). This study identified 6 distinct types of exterior panels for the F-22 and examined various combinations of panels and their potential to decrease maintenance downtime. They found an ideal six panel combination that decreased maintenance downtime the most, after which the effect of any additional panels in the supply dropped off. By collecting and repairing in advance extra panels, the LO shop could maintain a supply of readily available panels that could be immediately swapped out on jets where the identical panels were damaged. If the only LO maintenance required on a jet was on one of these panels, the panel could be quickly replaced and the jet returned to service in a matter of an hour or two, rather than many hours or even days spent taping and spraying the jet. When the simulation of this case was conducted, researchers ran two different simulations measuring improvements to aircraft availability as well as decreases in panel maintenance hours. Although the increase to aircraft availability was only found to be about 1.2%, the decrease in panel hour maintenance was found to be about 400 hours over ten years. This means that acquiring extra panels could save maintenance organizations about one week's worth of man hours each year, which may be important, especially in undermanned organizations.

Potential Solutions

Based on this research, several potential options emerge that could improve the LO experience shortage at the 1 MXS. The first solution involves modifying duties of personnel in order to better utilize the total maintenance workforce. The second option involves bolstering training resources to increase technicians' knowledge of their duties so they can perform maintenance at a higher level. The final option involves modifying workflow within the shop to utilize assigned personnel in a more efficient manner.

Alternative 1: Partial Integration of Dedicated Crew Chiefs into LO Maintenance

Every F-22 that enters the spray bays of the LO section has at least one DCC assigned to it within the 1st Aircraft Maintenance Squadron (1 AMXS). The 1 AMXS is the sister squadron of the 1 MXS responsible for more immediate flightline maintenance tasks on the jets. Since these DCCs are normally spending most of their time performing maintenance on their individual jets, or launching and recovering the jets from missions, they may be underutilized when their jets are occupied in the spray bays. This is because the jets cannot conduct any operations while they are in the spray bays. Although the DCCs are not formally qualified in LO maintenance, there is a great deal of manual labor involved in LO maintenance that is relatively tedious and low-skilled. For example, if LO technicians were able to identify imperfections in the LO coating, DCCs could be taping the jet for maintenance in one bay with more junior technicians while the more experienced technicians are performing the more skill-intensive work in the other spray bay and the panel bay. In this way, it might be possible to utilize the experienced and inexperienced technicians more efficiently than they currently are, while also utilizing potentially underused labor of DCCs who are waiting for their jets to come out of the spray bays. Additionally, it is possible that DCCs may be quite eager to have a hand in the LO maintenance process, as they are very involved in the maintenance of their aircraft, and this is one element that they normally have almost no visibility into.

Alternative 2: Integration of Electronic Distance Learning into LO Technician Training
The Air Force already uses a distance learning platform known as myLearning. It would be relatively simple to integrate additional content on this platform for junior LO technicians to complement the on-the-job training that the junior technicians receive from their more experienced colleagues. This would assist in training junior technicians faster so that they could work more efficiently and perform higher quality work than they currently are. Additionally, since they would require less assistance from senior technicians as they were learning, this would enable senior technicians to spend more time performing pure maintenance. This is a crucial difference, as the Air Force estimates technicians to be 100% efficient when performing pure maintenance on the aircraft, but only 85% efficient when training or being trained (Wirth et al., 2020).

Alternative 3: Spare Panel Swap
The final approach does not involve any changes to the actual manning of the bays. Rather, the 1 MXS will begin to develop a supply of spare panels which can be continuously maintained by the technicians in the panel bay, even if there are no jets in the spray bays that require off-aircraft panel maintenance. This supply of spare panels will be based somewhat on the simulation, but also on the panels that can most increase maintenance efficiency at JBLE, because the panels with the greatest effect at JBLE may be different than the panels found to have the greatest effect in the simulation. The supply would probably be composed of the same 6 types of panels that were outlined in the situation. These 6 types of panels are unique and cannot be cross-swapped, so the supply would have to be developed to accommodate this condition. This alternative will allow jets that only need maintenance on a few panels to have those panels swapped with pre-serviced panels and immediately returned to service. This avoids forcing aircraft to sit in the bays waiting for a few panels to be serviced when they could be flying if those panels had been swapped immediately.

Evaluative Criteria

Before deciding which policy option to pursue, it is essential to develop a set of criteria to evaluate the options in a more objective manner. This ensures that options can be evaluated scientifically and are less vulnerable to the personal biases of policymakers. Based on the complexity of the problem itself, as well as the policy context, the criteria used for evaluation of the potential alternatives will be administrative feasibility, cost-effectiveness, and technical feasibility.

Administrative Feasibility
Administrative feasibility is a necessary criterion because of the nature of the Air Force bureaucracy. Any large organization requiring multiple levels of review and approval makes policy implementation inherently more difficult. Therefore, in order to minimize the chance of wasted time and effort due to failed approval, administrative feasibility will be weighted the most heavily of the criteria, with a weight of 0.5. Factors that must be considered when assessing administrative feasibility are numerous. For example, it is necessary to consider how many units would need to be involved in a decision, how far up the chain of command a given decision must be forwarded,

and whether or not such an option would require reaching outside of the Air Force organization, which inherently creates more friction than interacting with other parts of the Air Force. Administrative feasibility will be assessed on a scale of 1 to 5, with 5 being the most feasible and 1 being the least feasible.

Cost-Effectiveness
Cost-effectiveness is a logical criterion because the policy problem is expressed in terms of taxpayer dollars, and the defense budget of the U.S., while cavernous, is ultimately finite. The F-22 is already an incredibly expensive weapon system, so improving mission capable rate should not cause a great increase on top of this high baseline. Therefore, cost-effectiveness is weighted second most heavily, with a weight of 0.3. Cost effectiveness will first be calculated as a dollar cost per percent change over the initial 5 years each alternative's implementation, then converted to a score of 1 to 5, with 5 being the most cost-effective and 1 being the least cost-effective. This conversion will allow for consistency across assessment of alternatives and covering 5 years will ensure that alternatives with high up-front costs and low recurring costs are not disadvantaged against alternatives that have relatively higher recurring costs but lower upfront investment.

Technical Feasibility
Technical feasibility is important because this is a problem involving skilled technicians and modern and sophisticated aircraft. The technicians involved attend extensive training to work on an aircraft that is arguably more technologically sophisticated than any of its class. This makes any problem relating to the arrangement inherently technical. However, it is also important to note that the military, including the Air Force, is accustomed to flexibility and making changes as needed in order to most effectively accomplish the mission at hand. Therefore, technical feasibility will be weighted the lowest, at 0.2. Technical feasibility will also be assessed on a scale of 1 to 5, with 5 being the most feasible and 1 being the least feasible.

Evaluation of Alternatives

Alternative 1: Integration of DCCs into LO maintenance
Crew chiefs are already integrated into the structure of the aircraft maintenance organization, albeit within a different squadron than the LO shop. Undertaking this alternative would require the leadership of the 1 MXS to come to a formal or informal agreement with the leadership of the 1 AMXS to allow unoccupied or underutilized DCCs to perform basic maintenance tasks in the LO shop with the supervision of LO technicians. There is no need to obtain permission from officials higher in the chain of command or reach outside of the Air Force organization, since all the necessary resources are already located at JBLE. Therefore, because this option does not require high level approval beyond a handshake agreement, it will score a 4 for administrative feasibility.

Cost effectiveness is the second factor that needs to be addressed. Because these crew chiefs are already working on F-22s, the only additional cost that would be required to implement this option would be basic OTJ training for DCCs that are brought over to work on their jets in the spray bays. The study performed by the RAND Corporation estimated an increase of roughly 25% upfront training costs in order to combine these two specialties (2A3 and LO) into one in the future.

However, the goal of this is not to create fully qualified LO technicians from DCCs, but to teach them to perform very basic low-skilled LO maintenance tasks. Therefore, it is reasonable to assume a 5% cost of initial LO maintenance training to provide OTJ training to these DCCs. This cost amounts to roughly $2500 per DCC, in a squadron with roughly 30 DCCs (*Weapon System Sustainment*, n.d.). This means it would cost the squadron about $75,000 to train these crew chiefs. The RAND study estimates an efficiency improvement of about 10% by combining these two specialties, but that is not happening in this case. It would be appropriate to estimate an effect of around 2% for this small change in manning. Assuming a 50% turnover rate per year based on Air Force manning schedules, there would be a $37,500 recurring cost each year to provide the training to new crew chiefs in the program. This would equate to an average cost effectiveness over five years of $22,500/1% increase in efficiency. This alternative has the lowest cost effectiveness, so it will receive a score of 3 for cost effectiveness.

Finally, this option presents moderate technical feasibility. These DCCs already have technical training and are quite familiar with the aircraft being maintained. In fact, they spend most of other time working around the skin of the aircraft in order to complete their primary duties. However, LO is an aspect of aircraft maintenance that they do not normally deal with, so there will be a learning curve, at least at the beginning, as they help lower level LO technicians with simple tasks. This means that technical feasibility will be given a rating of 2 for technical feasibility.

Alternative 2: Integration of E-Learning

This policy option will be relatively difficult administratively. Using the Air Force's existing e-learning system will require approval and coordination with Air Education and Training Command (AETC), a separate Air Force Major Command from ACC, the USAF Major Command within which the 1 MXS is located. Additionally, because other maintenance commanders would be likely to see the value in such training, the decision on what content to add, how to create it, and when to implement it would have to be made at the highest levels of both ACC and AETC, far above the level of the 1 MXS. Based on these considerations, this policy alternative will receive a score of 1 for administrative feasibility.

This alternative would require significant up-front investment. Although it would not cost the 1 MXS anything to use the Air Force e-learning system, the Air Force would probably have to hire an external provider to create the e-learning content. Successful implementation of this option would require creation of training content in a genre known as procedural e-learning, which teaches processes and requires demonstrations and assessments of skills. This is the type of training that would be appropriate for relatively inexperienced LO technicians to improve their job performance. Such training generally costs about $30,000/hour to produce (*The Cost to Have Elearning Developed by an External Provider*, 2014).

In order to estimate the total cost of such training for this situation, we must know how many hours of training will need to be created. This figure will be contingent upon how much of an airman's time on the job is spent being trained. The Air Force estimates that junior airmen (the target of this e-learning alternative) spend about 20% of their time on the job being trained (Wirth et al., 2020). This e-learning is not meant to replace all of this training (because much of it requires hands-on experience), but perhaps it could remove the burden of 10% of training time, which would be about

2% of overall work time each year. Since airmen earn 1 month of leave each year, this means they work about 48 weeks per year (assuming a few federal holidays a year and usage of most leave earned). This means that airmen work about 1920 hours per year, so 2% of this time is 38.4 hours, or about one week of training. The creation of 38 hours of training will cost about $1.14 million in initial investment.

The benefits of this alternative are primarily assessed in terms of senior technician time saved. This alternative would allow senior technicians to spend 10% less time each year training their junior technicians. The Air Force estimates that technicians are 100% efficient when they are not training others and only 85% efficient when they are engaged in training. This change would mean that senior technicians would be 1.5% more efficient each year. Since the manning figures show that the senior technicians make up exactly 33% of the "wrench-turning" workforce at JBLE, the efficiency gain each year would be about 0.5%. To summarize, this alternative would require an initial investment of about $1.14 million in initial investment for an efficiency gain of about 0.5% each year. Averaged over a 5-year period, this amounts to a cost-effectiveness of $456,000/1% gain in efficiency. Of course, this cost-effectiveness ratio would become much better if other maintenance squadrons started using this system to distribute the costs across larger populations of trainees. However, since the 1 MXS is the client of the assessment, it is only appropriate to examine their costs and benefits. This means it is the least cost-effective option and will receive a score of 1 for cost effectiveness, as it is the least cost-effective of any option.

This option has medium levels of technical feasibility. The e-learning system already exists, and after the content is created, it would just need to be uploaded to the system for consumption by the technicians. From there, the system would track who had completed the training and what level of expertise technicians are currently at. However, not all technicians have personal computers, so some may have to share a limited number of government computers at work with which to complete the training. Therefore, this option receives a 3 for technical feasibility.

Alternative 3: Spare Panel Swap

This policy option will require almost no administrative outreach. The commander of the 1 MXS may have to go to the commander of their maintenance group for approval to deviate from standard maintenance workflow, but this option should not require reaching outside of the Air Force at all or entering other silos of administration within the Air Force. Therefore, this option will receive a 4 for administrative feasibility, scoring it the highest of any of the policy options.

The simulation study that suggested the panel swap method specifically stated that this policy option does not require any additional materials or manpower but is simply converting in-service panels to stock panels instead of purging them from the inventory of the squadron. Because this option offers an increase in overall maintenance efficiency of about 1.2% with almost no additional costs over a single year or 5 years, it is demonstrably the most cost-effective option, even for the relatively small effect it generates relative to other options. Therefore, this option will also receive a score of 5 for cost effectiveness.

Finally, the maintainers who work in the panel bay already possess all the requisite LO panel repair skills to implement this option. The only technical hurdle is locating spare panels to act as the stock supply to be immediately swapped when the opportunity arises. This option presents moderate technical feasibility. Therefore, this option will receive a score of 4 for technical feasibility.

Recommendation

Outcomes Matrix

	Admin. Feasibility	Cost Effectiveness	Technical Feasibility	Total
Weight	**0.5**	**0.3**	**0.2**	
Alternative 1	**4**	**3**	**2**	**3.3**
Alternative 2	**1**	**1**	**3**	**1.4**
Alternative 3	**4**	**5**	**4**	**4.3**

Based on evaluation of each potential policy alternative by the appropriate criteria and the results of the outcomes matrix, Alternative 3: Spare Panel Swap, is most desirable alternative. It scores highly in all three categories and could be implemented relatively quickly to have a significant impact on the readiness of the jets at JBLE.

Implementation

If the leadership of the 1 MXS decides to proceed with the implementation of the recommended option of swapping panels to decrease maintenance downtime with similar manpower, the first step to accomplish is to begin the acquisition of additional stock panels. The exact details of how to go about this process are up to them, but the literature suggests techniques like keeping panels for longer service lives instead of disposing of them, or simply requesting replacements from suppliers in advance to build up a bigger supply.

Regardless of the manner in which the spare panels are acquired, once the supply is created, all the panels must be ready to be swapped on to an aircraft as soon as it enters the bay and it is determine that the panel needs to be serviced. This means that even when there are no jets in the LO shop for service, the technicians in the panel bay should be working to ensure that all spare panels are ready to be swapped out on a jet at any time. This will increase the efficiency with which jets can be pushed through LO maintenance and keep them flying to raise the mission capable rate, which is the end goal of the project.

Conclusion

After examining Air Force and commercial aviation maintenance data, it is clear that numerous responses to undermanning in aircraft maintenance have been attempted throughout the history of aviation. Based on data relevant to the specific issues facing the 1 MXS, three potential alternatives to the status quo became apparent. Performance estimates from other aircraft maintenance studies, as well as relevant estimates from similar industries, have suggested that cultivating and maintaining a supply of specific spare exterior panels is the best option for the 1 MXS to pursue in order to raise the mission capable rate of their jets and overcome staffing issues over which they have no control.

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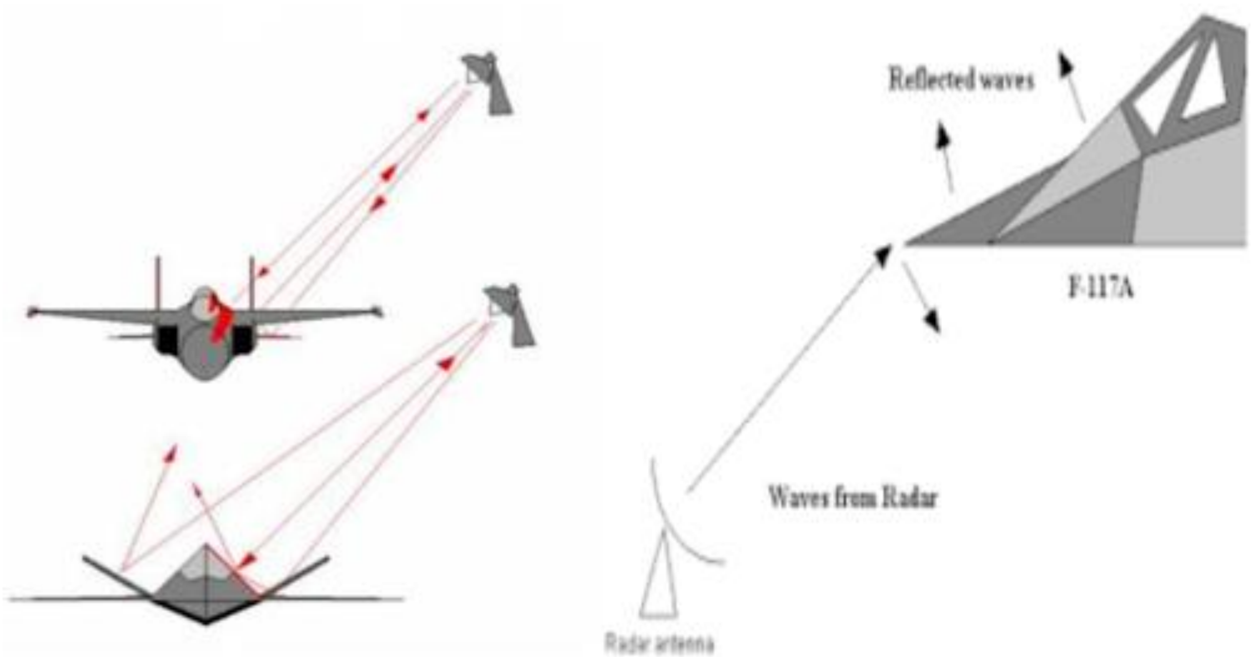
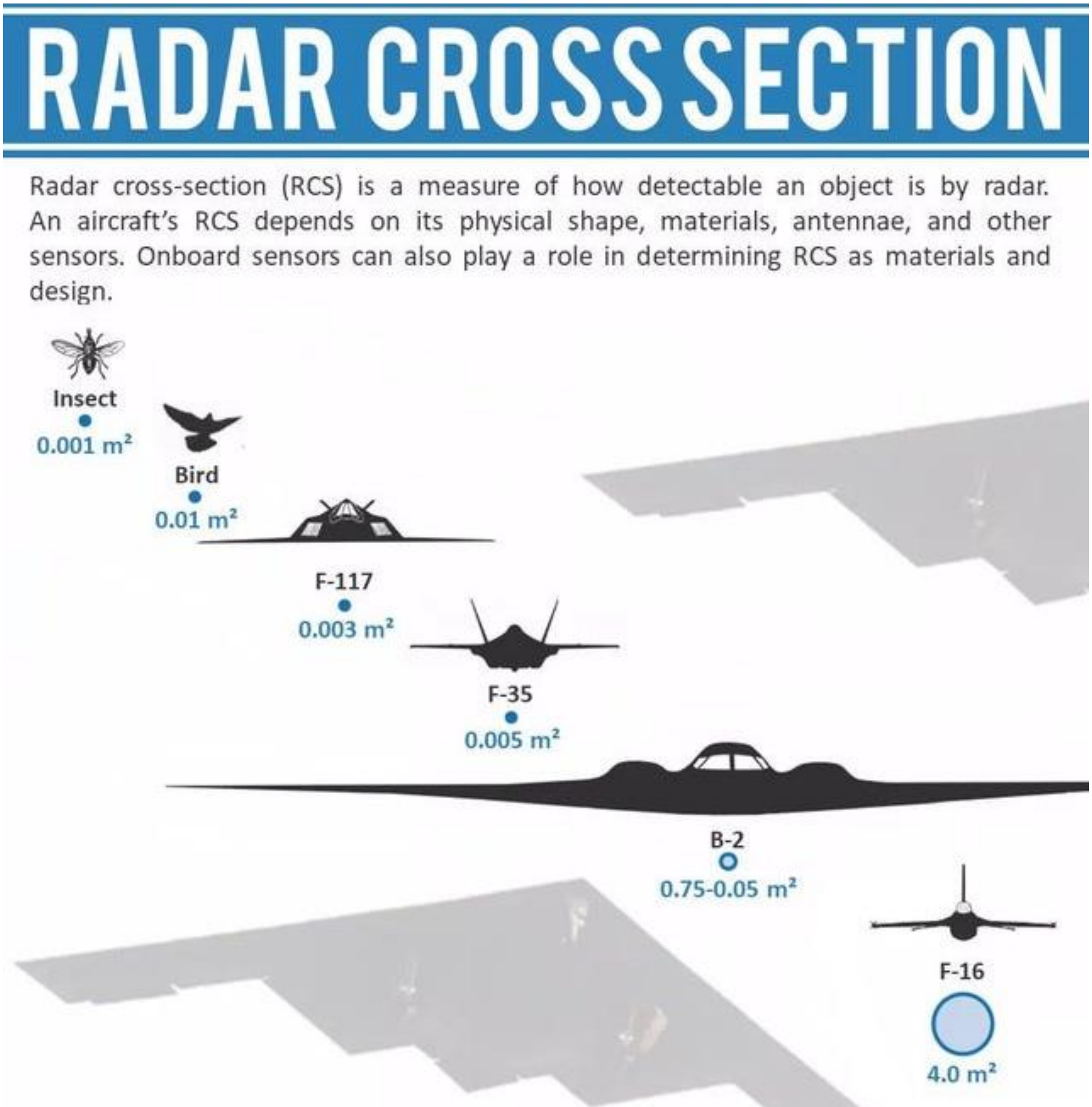
Appendix A: Basic Function Diagram of Stealth Technology

(*STEALTH Technology*, 2020)



Appendix B: Comparison Chart of Various Radar Cross-Sections

(Naegele et al., 2019)



Appendix C: 2018 F-22 Sustainment Costs

(*Weapon System Sustainment*, n.d.)

Source: U.S. Air Force/Tech. Sgt. Natasha Stannard. | GAO-21-101SP

Program Essentials

Manufacturer: Lockheed Martin and Pratt & Whitney (engines)

Sustainment: Lockheed Martin provides sustainment support. Ogden Air Logistics Complex, Utah, provides depot maintenance. Air Force maintainers provide field maintenance.

Program Office: Wright-Patterson Air Force Base, Ohio

Fiscal Year 2019 Data

Average age: 12 years

Average lifetime flying hours: 1,866 hours per aircraft

Depot maintenance activity and squadron locations:

Source: GAO. | GAO-21-101SP

Sustainment Challenges and Mitigation Actions

The F-22 faces challenges with its low-observable system and spare parts. The Air Force is contracting to increase low observable repair capacity and securing additional funding for spare parts.

F-22 Raptor Sustainment Quick Look

Common Name: F-22

Lead Service: Air Force

Background

The F-22 Raptor is one of the newest Air Force aircraft. The F-22 performs air-to-air and air-to-ground missions and is designed to attack enemy aircraft and ground targets at great distances.

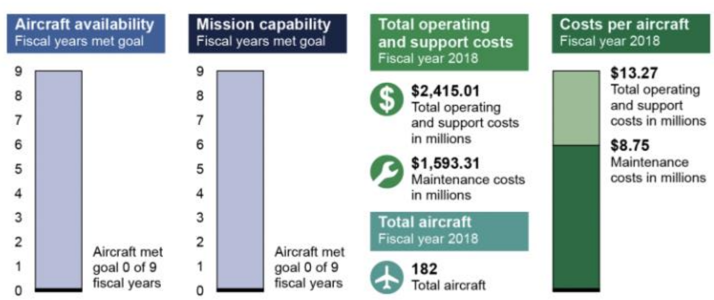
Life Cycle of the F-22

Source: GAO analysis of Air Force data. | GAO-21-101SP

Overview

The F-22 fleet did not meet its annual aircraft availability or mission capable goals for any year from fiscal years 2011 through 2019 and did not meet the Department of Defense's mission capable goal for fiscal year 2019. Both the F-22's aircraft availability and mission capable rates decreased during the nine year period. Total operating and support (O&S) costs increased from about $2.34 billion in fiscal year 2011 to about $2.42 billion in fiscal year 2018. Furthermore, maintenance costs—the largest share of O&S costs—increased by a total of $556.21 million during this period. Total O&S costs per aircraft decreased from $14.34 million in fiscal year 2011 to $13.27 million in fiscal year 2018 and an average of about 54 percent was dedicated to maintenance costs.

F-22 Sustainment Status



Source: GAO analysis of Air Force data. | GAO-21-101SP