The Road to the F-35

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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The Road to the F-35

The F-35 program is the most expensive project in the history of the United States military. It is expected to have a 60-year lifespan that would cost taxpayers over $1 trillion dollars (Insinna, 2019). The first supply of F-35s in 2006 cost nearly $241.2 million per plane; more than 3 times the slated $80 million target for the plane initially. As of June 2020, the F-35A variant was listed at $77.9 million per a contract between Lockheed Martin and the Department of Defense (Lockheed Martin, 2020). This reduction in cost is primarily the result of restructuring and negotiation between Congress and the Department of Defense (DOD) on the effectiveness of the F-35 Joint Strike Fighter program. What led the DOD to pursue a joint service approach and why has the F-35 been plagued by affordability and readiness issues? Various models of military innovation can explain the power structure and decision-making process that surrounds military technology development. This paper will analyze the development of various technologies throughout history to understand what drives military innovation through the lens of three models presented by Adam Grissom in *The Future of Military Innovation Studies (2006).* This paper will answer these questions by linking this historic analysis with a thorough assessment of the F-35's development. For the context of this paper, innovation is characterized by the stakeholders at the time of technology development.

Modeling Military Innovations

A framework of decision makers, power struggles, motivation, and competition can be outlined using three major models of innovation (Grissom, 2006). The interservice model states that chiefs of staff determine the best course forward and induce service bureaucracy to innovate accordingly. The intraservice model claims that senior service leaders imagine a new theory of victory and then leverage internal politics. The cultural model argues that senior officers position their organizations to achieve innovation that lines up with a personality which blinds some opportunities and gives prominence to others. All of the above-mentioned models feature top-down innovation, where a vision precedes capabilities. How to develop the technology is often figured out along the way. The history of two particular technologies, attack helicopters and cruise missiles, give some evidence to support Grissom's models of military innovation. It is important to note that weapons development is often viewed as a zero-sum game. Budgets are limited and funding can be reallocated each year to new projects, leading to service rivalry and competition.

These models are limited in that they exclude the existence of bottom-up innovation where existing technology was expanded upon. In *The Warthog and the Close Air Support Debate (2003),* Douglas Campbell claims that the Air Force built the A-10 in response to the Army developing the AH-56 Cheyenne attack helicopter because they were afraid that all close air support capabilities would be transferred to the Army. The interservice model of innovation could solely be used to explain this process however it fails to recognize that the A-10 is an aircraft in which an airframe was essentially built around a 30 mm cannon. The original use of the weapon was not designed as the main armament of an aircraft and yet it ended up flourishing in an air-to-ground combat role.

A History of Military Technology

In *From Hot Air to Hellfire: The History of Army Attack Aviation (1994)*, James W. Bradin explains that competition between the U.S. Air Force and the Army led the Army to establish its own aviation branch with a rigorous structure dedicated to attack helicopters like the AH-64 Apache. The 1949 Bradley-Vandenberg Agreement placed limitations on empty weight of Army fixed-wing aircraft and helicopters in an attempt to ensure the Air Force that the Army would not assume all responsibilities for close air support (Horwood, 2006). The Korean War then began to stimulate the expansion of the Army's aviation branch to the point where the Army pushed for heavier aircraft. In *The Army Gets an Air Force (1980)*, Frederic Bergerson highlights that many operational members of the Army felt that the Air Force was not effectively performing close air support missions such as delivering supporting fire, transporting ground troops around the battlefield, and evacuating the wounded. Despite the many interservice agreements limiting the Army's air capability, the Army expanded its aerial role. Bergerson attributes this expansion to a bureaucratic insurgency similar to a social movement. As higher-ranking officials were converted to the cause, such as Secretary of Defense Robert McNamara, the Army was given permission to develop its own helicopter, the AH-56 Cheyenne.

In the 1960s, carrier aviation was considered the centerpiece of the Navy. If carrier aviation could provide surface-to-surface capabilities, much of the Navy, as well as those in Congress, saw no need to pursue cruise missiles. Any technology that could hinder or compete with aircraft programs was bureaucratically opposed by the carrier community. Alliances between mid-level program officers and senior officers allowed cruise missile advocates to overcome resistance in the Navy's aviation branch (Engel, 1994). Since 1983, the Tomahawk cruise missile has served a significant role in the arsenal of the Navy for decades and would not have been possible without the intraservice connections forged between various cruise missile advocates.

A Transition to the Joint Service Approach

Rivalry and competition, while acting as a driver for weapons development, can interfere with the progression of new technology and the operational success of certain missions. A series of military disasters beginning around the end of The Vietnam War was deemed the result of "muddled and multiple chains of command, poor interservice planning and coordination, ad hoc responses to each new crisis, the inability of one service to communicate with another, and interservice rivalries and parochialism that hampered the services' ability to work in concert" (Nemfakos et al., 2009). These mission failures included the 1975 *SS Mayaguez* rescue attempt in 1975, the 1980 Iranian hostage rescue or Operation Eagle Claw, the 1983 Beirut barracks bombings in Lebanon, and Operation Urgent Fury in Grenada in 1983. The loss of life of many U.S. service personnel in this series of events pushed Congress to pass legislation to rectify these issues. The Goldwater-Nichols Act and National Defense Authorization Act of 1987 aimed to restructure the DOD and the U.S. military services. In 1993, the Clinton Administration conducted a Bottom-Up Review (BUR) of U.S. defense policy and programs. As a result of BUR, the Joint Advanced Strike Technology (JAST) program was established in 1995. (Gertler, 2020). JAST would provide a new carrier attack plane to replace the A-6 plane for the Navy and a multi-role fighter to replace the Air Force's F-16. Congress also incorporated an advanced short takeoff and landing aircraft being developed by the Defense Advanced Research Projects Agency (DARPA) into JAST opening the way for Marine Corps participation. The name of the program was then changed to the Joint Strike Fighter (JSF) to reflect this new direction for joint development. In 1996, Boeing and Lockheed Martin were chosen to build and test-fly two aircraft in competition for the program, with Lockheed Martin being selected as the winner in 2001.

Military Culture and the F-35

The development of the F-35 and its three variants seems to mostly align with Grissom's cultural model of innovation. In *The Masks of War: American Military Styles in Strategy and Analysis (1989)*, Carl Builder states there is "considerable evidence that the qualities of the U.S. military forces are determined more by cultural and institutional preferences for certain kinds of military forces than by the threat." The Air Force prefers fixed wing flying aircraft that demonstrate air superiority while the Navy prefers independent aircraft with standalone capabilities. These preferences have materialized in the form of unique variants of the F-35 JSF. The Air Force's conventional takeoff and landing (CTOL) variant is lighter and more agile than the Navy's heavier carrier variant (CV) which utilizes more payload and fuel. Designing for a threat that is not clearly defined amplifies the service's preferences in influencing the development of the technology.

In *Winning the Next War: Innovation and the Modern Military (1991)*, Stephen Peter Rosen states that "the fundamental problem of managing military research and development is that uncertainties about the enemy and about the costs and benefits of new technologies make it impossible to identify the single best route to innovation." Rosen continues on to explain that it pays to be flexible when the future is uncertain, especially in war. It might be a better plan to invest in technology that is flexible than the one weapon that would perform a specific task the best if built to the exact specifications at the expected cost. It may turn out eventually that the one weapon was no longer needed. Rosen points out that "the search for flexibility can easily turn into a search for weapons that will be useful in every possible contingency." Economists refer to this as Type I flexibility. The American military is willing to pay a higher price for multi-purpose weapons than for those optimized for a single mission only because they are unsure about the conditions of the next fight.

Assessing the Joint Strike Fighter

Many of the issues surrounding the F-35 program are the product of a lack of direction. The JSF is an attempt to design a jack of all trades, multi-purpose aircraft that could do everything as opposed to tackling one specific mission profile. The aircraft was initially proposed as the next-generation answer for many divisions of the U.S. military from the Air Force to the Marine Corps to the Navy (Hughes, 2017). The effort to share design and replacement parts across different branches of the military caused the cost of the program to skyrocket. Performance is also affected in an attempt to build an aircraft suited to the needs of each branch. One branch's demands for design specifications may conflict with the demands of another; leading to an aircraft that is suboptimal for each of the services it was originally intended for. A test flight revealed subpar results of the F-35's performance in a dogfight versus the F-16, an older generation aircraft. The pilot noted a lack of energy maneuverability, insufficient pitch rate, and unintuitive flying qualities when the angle of attack was between 20 and 26 degrees (Axe, 2016). This means that the pilot expected a certain roll rate when controlling the F-35 but the body of the plane itself did not actually achieve the desired input. Not only was commonality targeted across different military branches but also across the three F-35 variants. The initial need for compatibility resulted in compromises for variants in achieving their specific features. For example, the F-35B model was designed for short-takeoff-and-vertical-landing (SVTOL) abilities. However, marine pilots noticed thrust limitations when trying to land the variant onto a ship vertically on hot days when the temperature was over 90° Fahrenheit (Mehta et al., 2020).

The main purpose of a joint program is to save overall Life Cycle Cost (LCC). The RAND Corporation completed an analysis of the cost of joint service programs compared to single-service programs using research sponsored by the U.S. Air Force (Lorell et al., 2013). The results were compiled using a Selected Acquisition Report (SAR) database with information on more than 300 major defense acquisition programs. To properly account for inflation rates, cost growth was measured in dollars of constant purchasing power. RDT&E includes research, development, test, and evaluation while O&S includes operations and support.

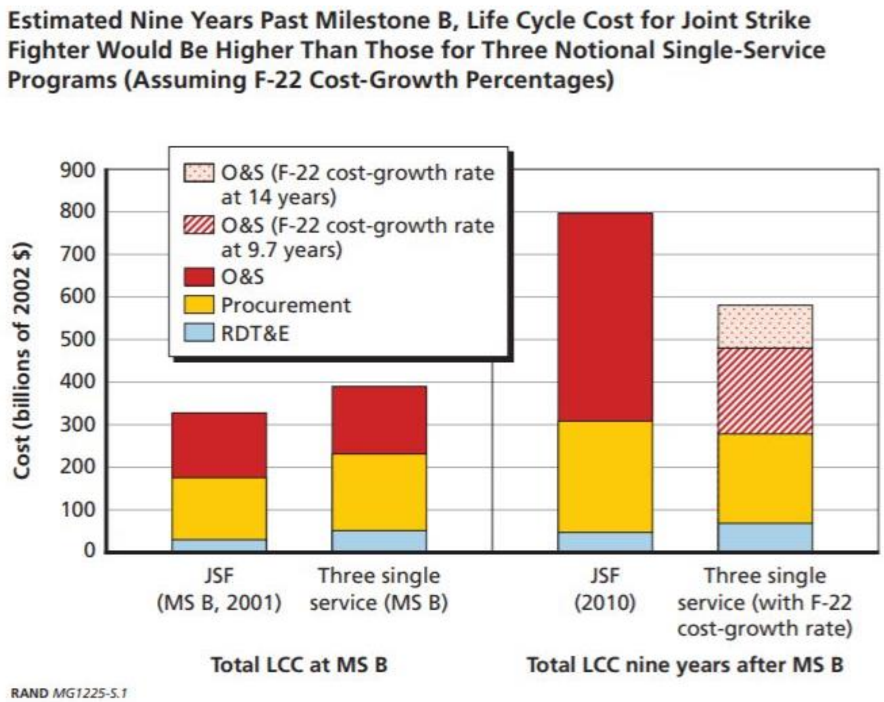

Figure 1: Life Cycle Cost Comparison (Lorell et al., 2013).

Figure 1 demonstrates that the JSF program has a significantly higher LCC than multiple single-service programs. RAND states that "the difficulty of reconciling diverse service requirements in a common design is a major factor in joint cost outcomes." Moreover, there was a 41% difference in average acquisition cost growth for joint service programs relative to single-service programs as seen in Figure 2.

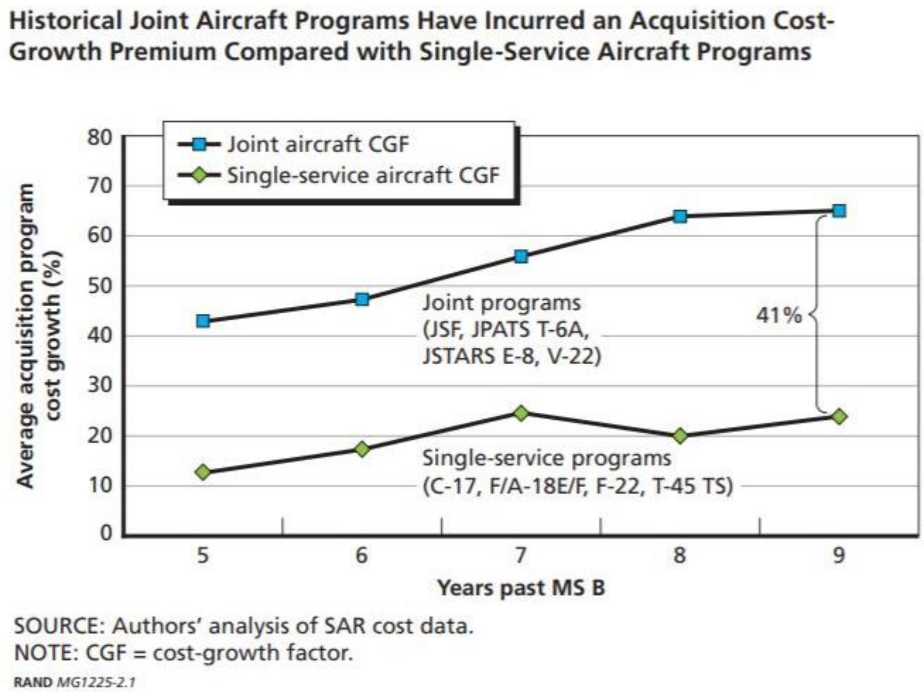

Figure 2: Cost Growth Comparison (Lorell et al., 2013).

These cost growths are largely in part due to the effort to resolve the different objectives across designs that become increasingly complex. Attempting to optimize variants for each service decreases commonality, shifting cost projections further. This trend is depicted for the F-35 program in Figure 3.

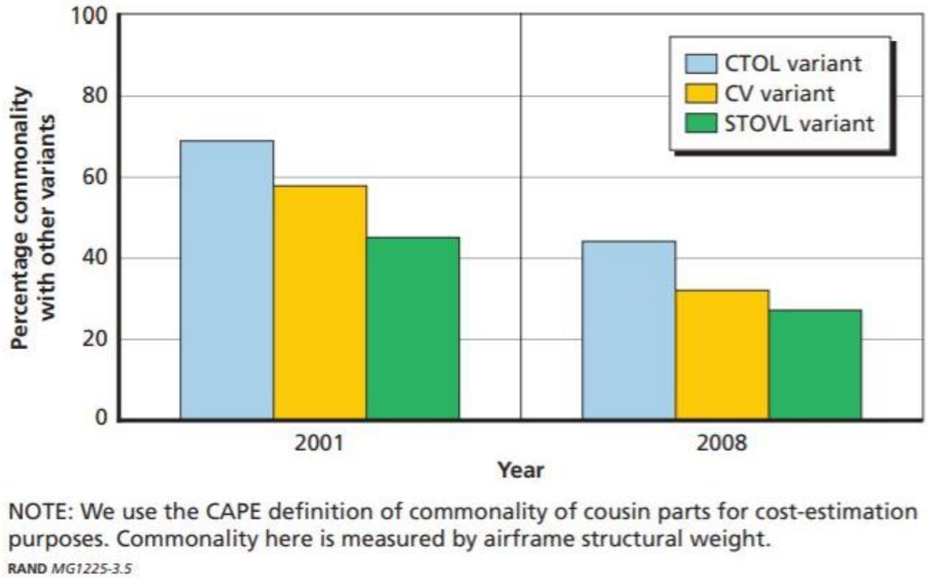

Figure 3: Decrease in Commonality (Lorell et al., 2013).

The F-35A was developed for the U.S. Air Force as a conventional takeoff and landing (CTOL) aircraft (Hubinger, 2019). It is intended to replace the F-16 and the A-10 for air-to-air and air-to-ground support. The SVTOL F-35B is intended to replace the AV-8B Harrier for the U.S. Marines. The F-35C is also a CTOL aircraft that acts as a carrier for the U.S. Navy. As the program progressed over the years, commonality simply became more challenging to maintain.

An Absence of Accurate Analysis

A key difference between the government and private industry provides some reasoning as to why the inaccurate cost claims and timelines at the proposal of the F-35 occurred. Unlike in government, the private industry typically uses various predictions of effectiveness and cost to place proposals at a common level. The government's lack of practical methods for evaluating the effectiveness of proposed weapon systems is a cause for frequent cost escalation and restructuring (Alic, 2013). These methods often mediate top-down approaches and the role of the service chiefs. This absence of analysis can be traced with evidence surrounding the innovations discussed in this paper. Until the publication of the Army Aviation Modernization Program (AAMP) in 1983, the Army did not have a comprehensive and definitive strategy for conducting life cycle analysis of attack helicopters (Becker, 1989). In 2014, the Government Accountability Office (GAO) submitted a report to the Committee on Armed Services within the House of Representatives and the DOD on the sustainment of the F-35 noting a need for a greater attention to risks and improved cost estimates. Weaknesses in the assumptions used to estimate O&S costs resulted in analysis that was not fully reliable (GAO-14-778, 2014). For example, the DOD used unreasonable assumptions of fuel burn rate, part replacement rates, and depot maintenance among other factors that were likely not reflective of the F-35 in the future.

Engine Cost Issues

The Congressional Research Service noted the difficulty of controlling cost in a sole-source environment in their recent update on the F-35 JSF program (Gertler, 2020). Pratt and Whitney, an American aerospace manufacturer, was selected as the sole provider of the engine for the F-35 by Congress in 2011. In 2014, the Pentagon informed Pratt and Whitney that they needed to continue driving down the cost of the engine (Shalal, 2014). The Pentagon claimed that since the decision was made to cancel General Electric's alternate engine for the F-35, Pratt and Whitney had slowed down the war on cost. Within the previous year, average acquisition cost rose by about 2% despite a decrease in estimated operating costs for the 2015 to 2065 lifetime by almost 9%, to $1.02 trillion. The engine cost specifically climbed 6.7% in this timeframe serving as a contributing factor to continued affordability issues (Cameron, 2014). Additionally, Pratt and Whitney cited percentage decreases in cost as opposed to actual dollar figures between Lots 10 and 11 in low-rate initial production reports, stating the CTOL and CV variant propulsion systems will be reduced 0.34% and the SVTOL propulsion system 3.39%. Congress questioned whether they could sufficiently provide useful oversight with this approach (Gertler, 2020). However, Pratt and Whitney claimed competitive privilege in the debate arguing they should not have to release engine information publicly because it could affect the company's ability to perform in next-generation procurement. Those in the military felt that a monopoly on engine production allowed Pratt and Whitney to dictate the level of effort placed on cost reduction. Moreover, transparency of engine cost became a clear issue for the government. Simply knowing the percent reduction in cost was less informative because it only notified the program office and Congress of relative improvements as opposed to actual improvements that could be compared across the board to other engines on the market. The Pratt and Whitney situation reflects a broader issue affecting defense programs, notably industry consolidation and fewer sources of advanced systems.

Software Development Troubles

The Autonomic Logistics Information System (ALIS) aboard the F-35 has been another key source of problems throughout the JSF program. ALIS serves as an extensive and complex software package at the core of operations and maintenance support for the F-35. The system tracks and records flight data for the F-35 reporting performance of the various other systems of the aircraft. It was intended to reduce life-cycle sustainment costs and improved readiness. In 2014, the Government Accountability Office (GAO) recommended that the DOD develop a performance measurement process specifically for ALIS as it only had a similar process with metrics and targets for the overall aircraft (GAO-20-316, 2014). The DOD was receiving data on availability of ALIS from Lockheed Martin while tracking development progress but was not tracking any other data that could assess the performance of the system relative to user requirements. In a 2020 weapon system sustainment report, the GAO stated that the DOD still had not developed a performance measurement process for ALIS (GAO-20-316, 2020). Problems identified by personnel who use ALIS included inaccurate or missing data, challenges deploying, and a poor user experience. The system would sometimes signal the F-35 should not be flown when there were no issues with the plane. Additionally, the hardware required for deployments was bulky and had poor internet connectivity (GAO-20-316, 2020). Lockheed Martin hoped ALIS would aid in better management of spare parts while detecting performance glitches (Tirpak, 2020). Instead of accurately predicting part failures, ALIS has been plagued by false alarms which have led to unnecessary maintenance. Moreover, ALIS has led to time-consuming manual workarounds, laborious data entry, and outdated interfacing. Many of these problems stem from a 1990s based architecture (Gertler, 2020). Rather than improve upon or redesign old hardware and software, the DOD has decided to replace ALIS with a new technology system called the Operational Data Integrated Network (ODIN) starting with acquisition Lot 15 in 2023. ODIN is designed using software improvements from recent years for real-time monitoring of system performance, automated collection of performance information, and a more user-friendly experience. Notably different from ALIS, ODIN leverages multiple government and industry partners including Kessel Run, the 309th Software Engineering Group, the Naval Information Warfare Center, Lockheed Martin, and Pratt and Whitney (F-35 Joint Program Office Public Affairs, 2020).

Discussion

In looking back at military technology development throughout history, competition was often the primary driver in sparking innovation and driving down cost. The military services operating separately on next generation weapons development may have been dysfunctional, but still worked to some degree. The struggle to cooperate was obviously an issue that needed to be resolved, hence the push for jointness. By merging multiple aircraft programs and offices together to form the JSF program, the DOD hoped to lower life-cycle cost while encouraging cooperation. The result was a highly expensive and unsustainable F-35 aircraft which did not meet expectations due to a lack of competition and poor performance analysis. Maintaining competition throughout the design process on the F-35 engine could have created incentive for providers to continue making improvements and lowering cost. Developing a comprehensive strategy and method for evaluating subsystems like ALIS could have resulted in greater awareness of deficiencies relative to customer requirements and a faster response to fix system glitches. Despite continuing to fund the most expensive program in the history of the military, readiness setbacks have persisted. Clearly, the DOD throwing money at the F-35 problem year after year has not been a viable solution. Unfortunately, the U.S. cannot afford to cancel the program as it needs the F-35's capabilities for future national security and defense.

Thus, improving maintenance and sustainment while reducing cost is of the utmost importance.

Moving to a performance-based logistics (PBL) arrangement could be a potential way forward to solving these issues (Cooper, 2020). Sustainment contracts are currently negotiated on an annual basis by the Pentagon requiring tremendous oversight and time investment. In 2019, Lockheed Martin proposed a new approach that would involve a five-year deal to supply F-35's in 2025. The deal would include an agreement by Lockheed Martin to invest $1.5 billion in subcontractors to ensure that 80% of replacement and spare parts would be ready for supply to keep the F-35 fleet up and running. This PBL approach gives Lockheed Martin the predictability of a longer contract while shifting the associated cost risk to the private industry, a win for both the government and the manufacturers. Additionally, it requires a readiness level of the incoming supply of maintenance parts that has not been seen throughout the course of the F-35 program. Instead of selling the F-35 and then selling replacement parts, Lockheed Martin will deliver the replacement parts with the system itself at certain agreed upon reliability and availability levels. In a PBL approach, the supplier-customer relationship shifts to a focus on outcomes rather than transactions (Marceau, 2018). Figure 4 displays the comparison of cost over time for traditional vs. performance-based contracts in a study by the Defense Acquisition University.

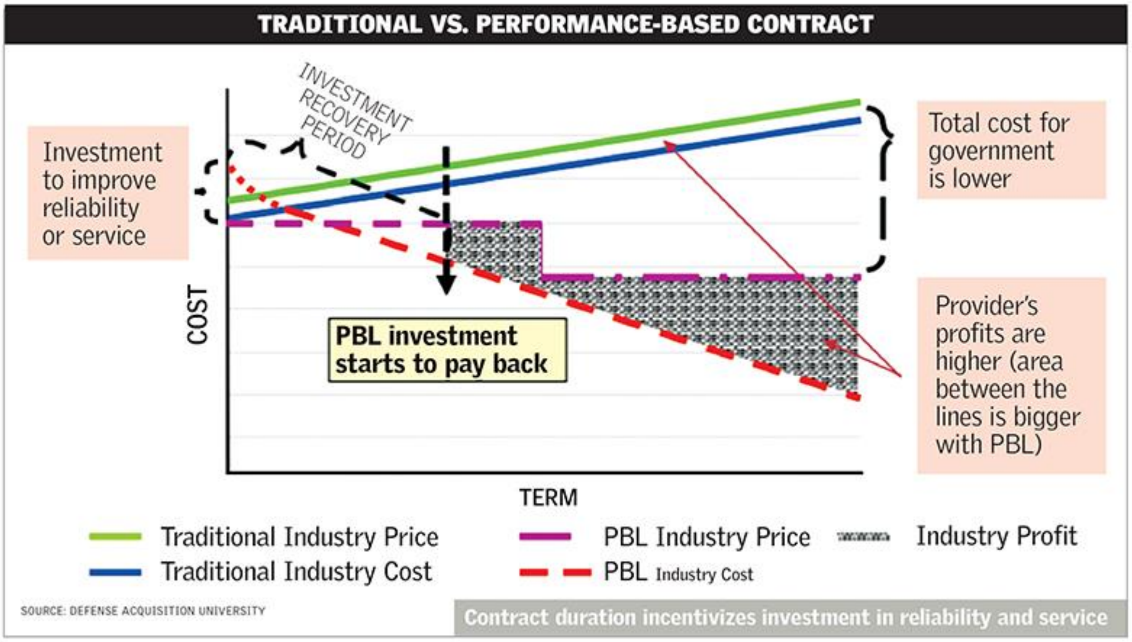

Figure 4: PBL Investment (Marceau, 2018).

PBL can drive down cost in the long run but making this change will require a cultural overhaul, as most suppliers' operating model, infrastructure, and supply chain have evolved to support a transactional approach. Some challenges with the PBL approach include business planning and analysis. A concrete, comprehensive plan for driving down cost and assessing progress of the F-35 and all of its subsystems must be developed to support this change. Typically, it can be difficult to convince and incentivize suppliers to conduct business in a new way. However, considering Lockheed Martin is already on board with the format, the new deal looks to be a possibility for lowering operating cost. In the coming summer, the F-35 Joint Program Office will deliver a sustainment strategy which will determine if PBL will be the way forward (Tirpak, 2021).

Conclusion

Well-defined business and program objectives, accountability, and availability of accurate data could have prevented much of the issues with the JSF's development. Comprehensive strategies for assessing how performance measures up to customer requirements will be critical to the future success of the F-35. Because competition is such a powerful driver of innovation, especially as it relates to cutting cost, sole-source provider environments should be avoided in the future development of subsystems for joint service programs. Comprehensive strategies for assessing how performance measures up to customer requirements will be critical to the future success of the F-35. A new-results driven approach may be the change that is needed to steer the F-35 program in a more sustainable direction in the coming years.

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