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Journal of Transportation Management

Volume 26 | Issue 2 Article 5

1-1-2016

# Organic or contract support? Investigating cost and performance in aircraft sustainment

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## Recommended Citation

Ritschel, Jonathan D., & Ritschel, Tamiko L. (2016). Organic or contract support? Investigating cost and performance in aircraft sustainment. Journal of Transportation Management, 26(2), 47-58. doi: 10.22237/jotm/1451606640

## ORGANIC OR CONTRACT SUPPORT?
## INVESTIGATING COST AND PERFORMANCE IN AIRCRAFT SUSTAINMENT

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### ABSTRACT

Over the past 15 years, the United States Air Force (USAF) has shifted toward utilizing more Contracted Logistics Support (CLS) and away from organic maintenance in their aircraft fleets. Given operating and support costs comprise 53-65% of total life-cycle costs for USAF aircraft, understanding the implications of these sustainment decisions is imperative. Utilizing a maintenance cost per flying hour metric and performing regression analysis, we find the maintenance strategy decision (CLS, mixed, or organic) is the most significant driver. We then examine performance metrics in relation to two established aircraft availability targets. Analysis of variance reveals statistically significant differences between maintenance strategies, with CLS outperforming organic in relation to the targets.

### INTRODUCTION

The decision to vertically integrate capability into a firm or contract-out for that capability is a fundamental economic question all large companies must answer. The economics discipline frames a theoretical answer through the *theory of the firm* with Ronald Coase's contribution in this area undergirding the literature (Coase, 1937). After visiting Ford Motor Company, Coase pondered why certain activities occurred within the firm (e.g. Ford built their own steel mills) rather than being purchased from the market. His answer revolutionized economists' understanding of why companies are created and the factors that determine their size and scope. Coase explains that there are costs to using the price mechanism (i.e. markets). These costs, commonly referred to as transaction costs, are the costs incurred by buyers and sellers in making an economic exchange. Thus, transaction costs are often ***the*** costs that matter in determining whether or not to make an activity internal to the firm (Coase, 1937).

The United States Air Force (USAF) is confronted with this strategic decision for each individual aircraft platform it owns. Complicating matters, the fundamental question of whether to build in-house or purchase in markets is relevant in all stages of a product's life-cycle: from development to production to operations and sustainment. Decisions to use the market for one stage of the life-cycle do not necessarily lead to the same decision in a subsequent phase. For example, production of a platform may be through the market mechanism, while sustainment of that same platform may be organic. This research focuses solely on the operations and support phase of the life-cycle for the USAF fleet of aircraft. Specifically, the focus of this paper is on the decision to provide aircraft maintenance organically or by Contractor Logistics Support (CLS).

While the underlying decision to conduct maintenance organically or through contracted support confronts all businesses from Southwest Airlines to FedEx, the unique aspects of Air Force aircraft is more clearly understood in the transaction cost framework detailed by Oliver Williamson. Williamson introduces the concept of "asset specificity" as a determinant of transaction costs (Williamson, 1981). Asset specificity is the extent to which investments made to support a particular transaction have a high value to that specific transaction and are not easily converted for other uses. The implication is a supplier may bid in a competitive environment for the rights to produce something. However, once the contract is awarded, the high degree of asset specificity changes the nature of the market environment from a competitive market to a de facto bilateral monopoly (a bilateral monopoly is defined as one supplier; the monopolist, and one purchaser; the monopsonist). Williamson argues that higher degrees of asset specificity raise transaction costs (Williamson, 1981). Given the unique nature of Air Force aircraft, it can be argued that there is high asset specificity in their maintenance. For example, the investments in equipment to maintain composite materials on a stealth aircraft are unlikely to be easily converted to commercial aircraft use.

This research analyzes organic maintenance support in comparison with CLS costs in Air Force aircraft. It seeks to determine whether one maintenance approach is more expensive than the alternative through regression analysis. However, considering cost alone removes the ability to truly assess value. As assessment of performance output allows the Air Force to understand if the dollars they spend produce the results they need to perform their mission. Analysis of Variance (ANOVA) assessment provides comparisons of performance metrics to determine statistical differences in maintenance strategy performance.

## BACKGROUND AND LITERATURE REVIEW

The life-cycle of USAF aircraft consists of four stages: research and development, procurement, operating and support, and disposal. Historically, researchers have focused on issues associated with the research and development or procurement stages of the life cycle. However, smaller defense budgets and recent legislation, such as the Weapon System Acquisition Reform Act of 2009, has highlighted the importance of total life-cycle cost analysis. Subsequent research determined that operating and support costs for USAF aircraft consist of 53-65% of the total life-cycle costs (Jones et al., 2014). See Figure 1. With platforms such as the joint strike fighter projected to cost over $1 trillion for operations and support, analysis of maintenance strategy decisions is needed (GAO, 2014).

The Air Force has a continuum of choices when determining the optimal strategy for maintaining and sustaining its fleet of aircraft. See Figure 2. On one end is the fully vertically integrated option – referred to as organic maintenance. Air Force organic maintenance occurs at three government run “depots” called Air Logistics Centers (ALCs)[1]. On the other end of the continuum is the market mechanism, referred to as Contractor Logistics Support (CLS), where all maintenance activity is conducted through a contractual relationship with private industry. In between either extremum is a mix of varying combinations of both organic and CLS maintenance.

Both organic and CLS maintenance strategies have benefits. Organic maintenance provides a guaranteed source of supply and endows the Air Force with complete control over when and how the maintenance is completed (Boito et. al, 2009). CLS offers the potential for lower costs due to market competition and possible economies of scale when the Original Equipment Manufacturer (OEM) is also selected to perform the sustainment function (Boito et. al, 2009). It is important to understand the Air Force sustainment strategy decision occurs at the individual aircraft platform level (e.g. B-2, C-17, F-22), rather than a single decision for the entire Air Force enterprise. These sustainment strategy decisions originate early in the program life-cycle with significant long-term operational and cost implications.

FIGURE 1
NOTIONAL AIRCRAFT LIFE-CYCLE

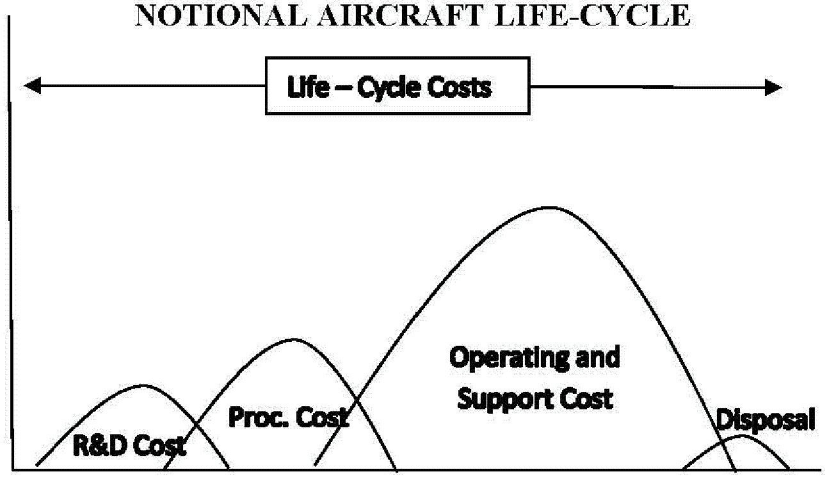
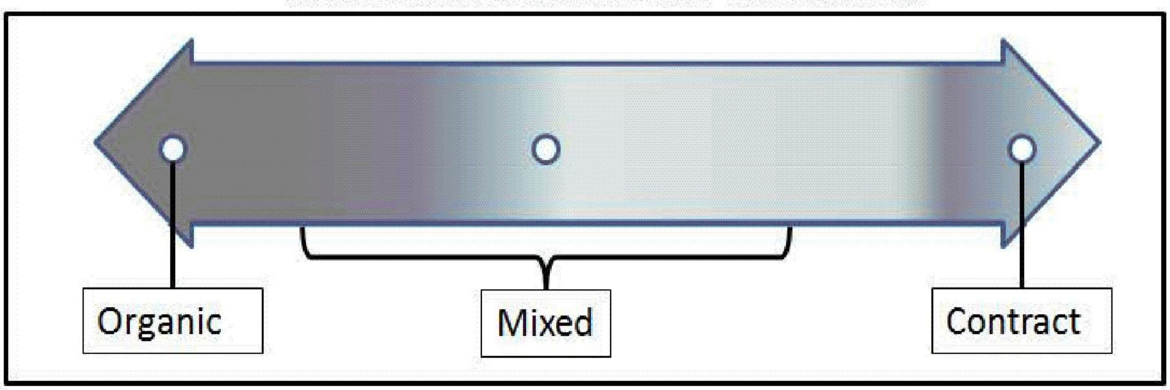



FIGURE 2
MAINTENANCE STRATEGY CONTINUUM




Historically, public-sector organic depots originated in the late 1930s and early 1940s to meet the need for weapon system maintenance as the private sector was fully utilized in producing new military equipment. This paradigm of primarily private sector military production of equipment and public sector maintenance of military systems continued through the Cold War (Heivlin, 1993). The 1984 National Defense Authorization Act set in motion legislative activism and a change in the underlying sustainment strategy of Air Force platforms. The 98th Congress passed 10 USC 2464 which mandates a "core logistics capability" be maintained that is government owned and operated. The "core" requirement is intended to ensure sufficient organic competency and resources for contingency and other emergency requirements (Solis, 2009). Subsequent legislation in 10 USC 2466 sets the limit for the amount of depot-level workload that can be performed by non-governmental personnel. While the initial 1988 legislation capped non-governmental maintenance at 40 percent, more recent legislation has raised the threshold to what is now commonly referred to as the 50/50 rule. Specifically, the 50/50 rule stipulates that a maximum of 50 percent of funds available in a given fiscal year can be used for contracted maintenance work (10 USC 2466, 2005).

*[1] Total Air Force aircraft maintenance is comprised of depot, intermediate, and flight line (unit level) maintenance. Flight line maintenance is excluded from this analysis.*

In addition to the legislative actions discussed above, decisions by the Department of Defense have affected organic aircraft maintenance capabilities. Program Budget Decision (PBD) 720 reduced total Air Force end strength manpower numbers by 40,000 personnel from 2006-2009. The aircraft maintenance career field took particularly large reductions with an approximately 9,000 person reduction (Drew et al., 2008). This reduction equates to approximately 11% of the total aircraft maintainer manning.

Figure 3 displays the longitudinal trajectories of total Air Force aircraft by maintenance type. For the purposes of this study, aircraft are categorized as either organic, contractor or mixed. Categorization of organic or contractor occurs when greater than 80 percent of the dollars are allocated to the specific type. Any combination less than 80 percent is categorized as "mixed." There is a clear shift over the last 20 years from an Air Force enterprise predominately organically maintained to one more dependent on contracted maintenance. This trend leads to two investigative questions. First, which maintenance type costs the Air Force more? Second, which approach provides greater value to the Air Force?

## MODEL DATA

The Air Force Total Ownership Cost (AFTOC) database provides operations and support data on Air Force aircraft platforms dating back to 1996. The Office of Secretary of Defense, Cost Analysis and Program Evaluation (OSD-CAPE) office provides broad policy guidance and executive oversight to the AFTOC system (DoD, 2014). OSD-CAPE promotes standardization of operations and support cost data collection through a published Cost Element Structure (CES) in its *Operating and Support Cost Estimating Guide*. Cost data for this analysis is extracted from AFTOC for the period 1996-2014 for those elements related to maintenance as defined in the OSD-CAPE guidance. See Table 1 for a list of the aircraft platforms by maintenance type.

Logistics Installations and Mission Support – Enterprise View (LIMS-EV), maintained by

**FIGURE 3**
**AIR FORCE TOTAL ACTIVE INVENTORY CATEGORIZED BY MAINTENANCE STRATEGY**

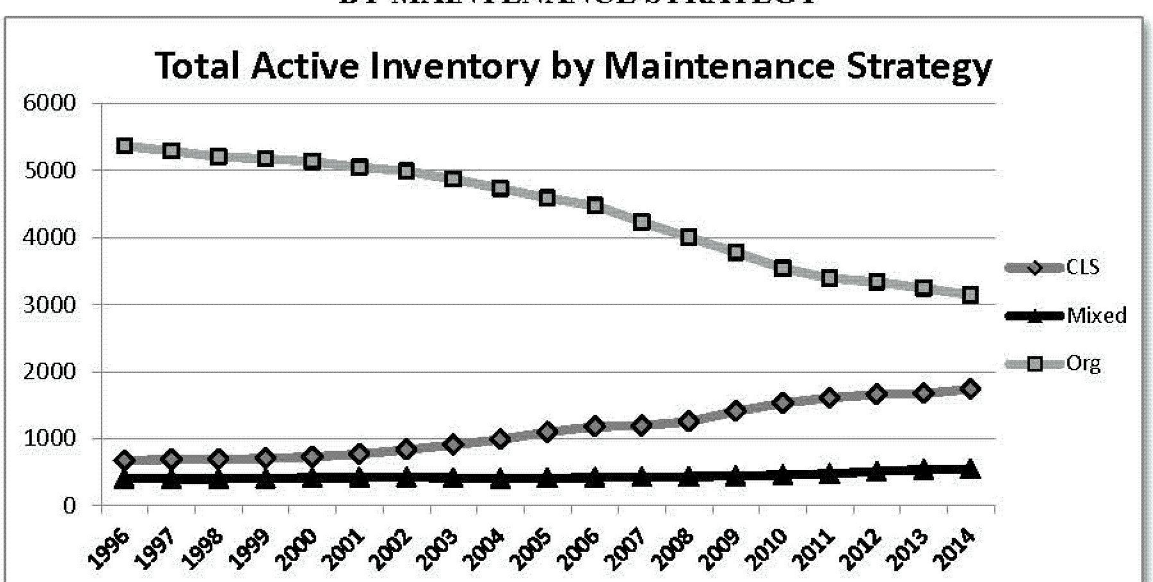


**TABLE 1**
**AIRCRAFT PLATFORMS**

| CLS | | Mixed | Organic | |
|---|---|---|---|---|
| F-117 | TU-2 | B-2 | B-1 | EF-111 |
| F-22 | C-12 | UC-26 | B-52 | MC-130E |
| F-35 | C-17 | UV-18 | A-10 | MC-130H |
| E-8 | C-20 | EC-130H | F-15 | MC-130P |
| MC-12 | C-21 | EC-130J | F-16A | MC-130W |
| RC-135 | C-22 | MC-130J | F-16B | NKC-135 |
| RC-26 | C-26 | WC-130 | F-16C | AT-38 |
| U-2 | C-27 | T-41 | F-16D | T-37 |
| E-4 | C-32 | TC-135 | F-4 | T-38 |
| E-9 | C-37 | TE-8 | HH-60 | TG-10 |
| U-28 | C-38 | TG-15 | MH-53 | TG-12 |
| WC-135 | C-40 | TG-4 | MH-60 | TG-14 |
| T-1 | C-9 | TG-7 | TH-53 | TH-1 |
| T-3 | KC-10 | C-130H | UH-1 | C-130E |
| T-43 | MQ-1 | C-130J | E-3 | C-135 |
| T-51 | MQ-9 | CV-22 | OC-135 | C-141 |
| T-6 | RQ-4 | HC-130 | AC-130H | C-5 |
| TC-130 | | | AC-130U | KC-135 |
| | | | AC-130W | KC-46 |
| | | | EC-130E | LC-130 |
| | | | EC-135 | |

Headquarters Air Force Logistics, provides flying hour data for each mission design series (MDS) in the Air Force enterprise. Flying hour data is combined with maintenance cost to create a total maintenance cost per flying hour metric for each aircraft platform. This metric is used as the dependent variable in the regression analysis.

The age of an aircraft can have a significant effect on maintenance costs. There are a multitude of studies examining the age effect (Kamins (1970), Hildebrandt and Sze (1990), Kiley (2001)). Pyles (2003) is the most comprehensive study completed on Air Force aircraft aging effects. Pyles found that late-life maintenance requirements generally exhibit increased growth as aircraft age. Dixon (2006) tested similar hypotheses as Pyles. Dixon, however, differs from Pyles in several ways. First, Dixon examines real dollars through the cost per flying hour dependent variable (rather than man-hours or requirements). Second, Dixon utilizes a different dataset as he analyzes commercial aircraft and then draws inferences for USAF aging aircraft. Dixon concludes that while there are significant aging effects early on, after year 12 the age effect is only 0.7 percent and not statistically significant from zero (Dixon, 2006).

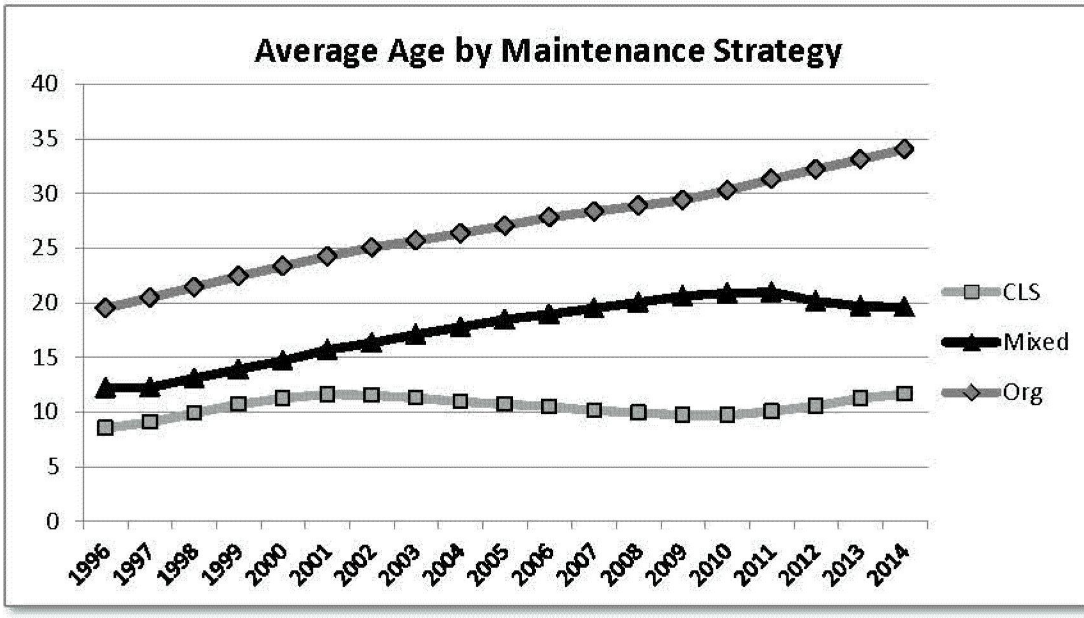
Data on age of aircraft is also collected from LIMS-EV. Figure 4 shows that the average age of organically maintained aircraft has increased significantly over the past 15 years. Thus, age of aircraft is utilized as a control variable in the model.

The remaining data, to include Total Active Inventory (TAI), number of sorties, number of landings, and availability metrics, is also collected from LIMS-EV.

## ANALYSIS AND DISCUSSION

The analytic approach seeks to first determine whether the maintenance strategy chosen (i.e. organic or CLS) is a driver of total maintenance costs. The naïve approach of comparing simple averages of maintenance costs per flying hour by maintenance strategy is rejected as other variables (e.g. technology, age of aircraft, etc.)

**FIGURE 4**
**AVERAGE AGE OF AIR FORCE FLEET CATEGORIZED BY MAINTENANCE STRATEGY**




are influential. Thus, multiple regression is utilized to answer the first question.

Finding a maintenance strategy to be more expensive does not, in itself, make it an undesirable choice. Instead, the output derived from the approach must be taken into account. Thus, the second stage of our research examines performance metrics. The literature reveals Aircraft Availability (AA) as the traditional performance metric analyzed. AA is defined as the mission capable hours divided by the total hours possessed. AA has been studied extensively since it became the cornerstone metric of internal Air Force logistics fleet evaluations (Rainey et. al, 2011). While Air Force agencies have therefore examined AA and its predecessor mission capable (MC) rates, we argue that AA is not the true metric of interest. The AA calculation gives a raw availability metric. But the real value to the Air Force is in meeting established *target*s, not a raw value of the AA metric.

The Air Force tracks two availability targets called the "standard" and "attainable." The "standard" is aircraft platform unique and represents the percentage of the aircraft fleet that is required to be available at any time to meet mission requirements. AA Standards are updated once a year based on the following formula:

Where $S_o$ – number of sorties needed to complete all aircrew contingency operations, $S_t$ – number of training mission requirements, $F_{do}$ - days available to fly, $F_{dt}$ – number of days available during the fiscal year to execute the flying training mission, $T_u$

$$\left[\frac{[(S]_o)}{F_{do}}\right] + \left[\frac{(S_t)}{F_{dt} \times T_u \times (1-a)}\right] + G + S + A + R = OR \text{ (Operational Requirement)}$$

– turn rate, $a$ – attrition rate, $G$ – ground schedule requirement, $S$ – spare requirement, $A$ – alert requirement, and $R$ – reserve requirement (Air Force Instruction 21-103, 2012)

The "attainable" metric represents the realistic availability of individual aircraft platforms given the resources that have been allocated to that platform. *The proper statistics of interest is therefore the* ***ratio*** *of AA to Standard and AA to Attainable, not AA itself.* It answers the question "which maintenance type hits closer to the established target?" Deviating below the ratio is undesirable as aircraft are not available to meet mission requirements. On the other hand, exceeding the ratio is also undesirable as resources are not being properly allocated. We conduct ANOVA analysis to test the mean differences for each maintenance strategy.

**Stage 1: Regression Model**

The first investigative question is whether the maintenance approach (organic or CLS) is a driver of costs per aircraft tail. If the approach is found to be a driver, then we investigate which maintenance strategy is more expensive. To analyze maintenance costs per flying hour, we relate measures of activity with maintenance costs over time using Ordinary Least Squares (OLS) multiple regression analysis.

The dependent variable is Total Maintenance Cost per Flying hour for platform *i* in year *j*. The cost data from AFTOC is normalized with Office of Secretary of Defense inflation indices to a Base Year 2014 dollar. The initial regression model violates the underlying OLS assumption of homoskedacity (constant variance). To correct this, the dependent variable is transformed with the natural log.

Independent variables are based on a review of the literature and subject matter experts in the USAF. An explanation for their inclusion in the model is as follows:

$Age\ of\ Aircraft_{ij}$ – The literature review finds age of aircraft as a theoretically important explanatory variable. Figure 4 demonstrates the age profile of organically, CLS, and mixed maintenance strategy as a function of time. As the figure indicates, organically maintained aircraft are older on average than CLS maintained aircraft and the enterprise as a whole is getting older.

$Platform_i$ – Platform is incorporated as a fixed effect in the regression model. It is a proxy variable for technology. There are likely to be significant maintenance cost differences based on the technology of the aircraft platform. For example, the sophisticated composite materials required for the F-22 is significantly more costly to maintain than the relatively simple materials of an A-10.

$Average\ Total\ Active\ Inventory_{ij}$ - Economic theory postulates that there are potential economies of scales (lower average costs) as the quantity of aircraft maintained increases. This variable controls for this effect.

$Year_j$ - Year is modeled as a fixed effect in the regression model. It covers 19 years from 1996-2014, with 1996 utilized as the year of comparison. Even with the data normalized for inflation, it is still necessary to control for other year to year changes.

$Percent\ CLS_{ij}$ – Percent CLS is calculated using AFTOC data. It provides the percentage of the platform that is CLS maintained, where 1 is fully CLS maintained, 0 is fully organically maintained, and numbers in between represent the mixture. *This is the crucial independent variable in the model.* Its significance (or lack thereof) in the model is the rosetta stone to answering the first research question concerning the costs of the maintenance strategies.

Other independent variables were considered in the model. These variables included number of landings, number of sorties and stealth technology. Multivariate correlation plots (and

**TABLE 2**
**REGRESSION MODEL VARIABLES**

| Attribute | Variable | Type of Variable | Hypothesized Sign |
|---|---|---|---|
| Fleet Size | Avg. Total Active Inventory | Direct | - |
| Age | Avg. Age of Aircraft Fleet | Direct | + |
| Technology | Platform Type | Indirect/Proxy | N/A |
| Support Type | Percent CLS | Direct | unknown |
| Time Series | Year | Direct | N/A |

VIF va
between the Landings, Sorties, and TAI independent variables. As a result, the landings and sorties variables were removed from the model. Table 2 summarizes the final set of independent variables, their attributes, the type of variable, and the *a priori* hypothesized sign of the coefficients. The hypothesized signs of the coefficients are theoretical, based upon the literature review.

The final form of the regression model is the following:

$$\ln (Cost_{ij}/FH_{ij}) = \beta_0 + \beta_1 Age_{ij} + \beta_2 Platform_i + \beta_3 Total\ Aircraft\ Inventory_{ij} + \beta_4 Year_j + \beta_5 Percent\ CLS_{ij} + \varepsilon_{ij}$$

where $\beta$ are the coefficients to be estimated, $i$ is the platform, $j$ is the year, and $\varepsilon$ is a standard residual term. The initial dataset contained 1111 data points. A data scrub and Cook's D analysis for influential data points resulted in removal of 13 data points for a final model with 1098 valid data lines.

Next, the models underlying OLS assumptions of normality, constant variance, and independence are verified. Two diagnostics are utilized to check for normality. First, a histogram of the studentized residuals is plotted to analyze the normality assumption with a normal curve imposed over the histogram. Second, the Shapiro-Wilk test is used as a quantitative diagnostic to evaluate the Goodness of Fit of the Normal Distribution. The constant variance assumption is verified with both a visual examination of the residual by predicted plot and also through the Breusch-Pagan test.

Model results are displayed in Table 3. Percent CLS is found to be highly significant with a positive coefficient sign. The interpretation is that as platforms move toward contracted logistics maintenance and away from organic maintenance the costs increase. Additionally, percent CLS has the highest standard beta indicating it is the most powerful explanatory variable. This is the first key finding of the research.

Results from other independent variables in the model provide further insights. The negative coefficient on average TAI demonstrates economies of scale. As the fleet size increases the average cost per unit decreases. These results are consistent with economic theory. The age of aircraft coefficient is positive indicating that as aircraft age, the sustainment costs increase. This empirical finding is consistent with the aging literature (Pyles, 2003). Finally, the platform variable is found to be significant. Platform is used as a fixed effect in the model and a proxy for technology. Thus, technology is correlated with an increased cost per flying hour.

**Stage 2: Performance Analysis**

Determining that a maintenance strategy is a driver of costs does not necessarily mean that past sustainment decisions were not in the best interest of the USAF. The performance achieved by the various approaches must also be considered. For USAF aircraft, availability is the primary performance characteristic associated with maintenance. Rather than analyzing raw availability, we evaluate the maintenance strategy's ability to

**TABLE 3**
**PARAMETER ESTIMATES**

| Term | Estimate | Std Error | t Ratio | Prob>[t] | Std Beta |
|---|---|---|---|---|---|
| Intercept | 8.4187221 | 0.213904 | 39.36 | <.0001 | 0 |
| Avg. Age of Aircraft Fleet | 0.2378726 | 0.034224 | 6.95 | <.0001 | 0.193578 |
| Avg. Total Active Inventory | -0.05965 | 0.025988 | -2.30 | 0.0219 | -0.08458 |
| Percent CLS | 1.1479219 | 0.113405 | 10.12 | <.0001 | 0.404605 |
| Platform Type | various | | | significant | |
| Year | various | | | significant | |
| **SUMMARY OF FIT** | | | | | |
| RSquare | 0.84461 | | | | |
| RSquare Adj | 0.83139 | | | | |
| Root Mean Square Error | 0.47983 | | | | |
| Observations | 1098 | | | | |

meet the two USAF specified targets for each platform. These targets are the "standard" and the "attainable". As discussed previously, the "standard" represents the percentage of the aircraft fleet that is required to be available at any time to meet mission requirements while the "attainable" metric is the resource constrained target. LIMS-EV contains the unique platform target data for both the "standard" and "attainable" metrics. The range of data, by platform, for the "standard" is 30%-90% and for the "attainable" is 30%-100%. It is malapropos to assess availability in the global sense as is often the proclivity amongst USAF leaders and analysts. Hypothetically, if aircraft "A" has a standard target of 55% and meets this with an AA rate of 55%; and aircraft "B" has a standard target of 75% but fails to meet this with an AA rate of 65%: how does averaging these AA rates to a global statistic give the USAF any indication that they are meeting their sustainment goals? Thus, a better performance parameter is to evaluate the availability of platforms in relation to their established targets. Specifically, we calculate this performance parameter through two ratios:

$$\% \text{ Aircraft Available}_i / \text{Standard Target } \%_i \quad \text{Equation (1)}$$

$$\% \text{ Aircraft Available}_i / \text{Attainable Target}\%_i \quad \text{Equation (2)}$$

where i represents individual aircraft platforms.

First, data is delineated into three groups: organic, mixed, and CLS as previously shown in Table 1. Next, Analysis of Variance (ANOVA) is utilized to compare the confidence intervals associated with the mean of each maintenance approach for the metric in Equation 1. We will refer to this as the Standard ratio. ANOVA analysis demonstrates all three maintenance types are statistically different from one another with regard to their ability to meet the Standard target (see Table 4). The lack of any overlap in the 95% confidence intervals demonstrates statistical differences between the organically, mixed, and CLS maintained groups. The CLS maintenance approach provides the greatest performance as it's mean of 0.9469 is closest to the ideal of 1.0. The

**TABLE 4**
**ANOVA RESULTS: STANDARD RATIO**

| | Mean | Lower 95% CI | Upper 95% CI | Standard Dev. |
|---|---|---|---|---|
| CLS | 0.9469 | **0.9377** | **0.9562** | 0.2138 |
| Mixed | 0.8602 | **0.8370** | **0.8833** | 0.2426 |
| Organic | 0.9160 | **0.9072** | **0.9247** | 0.2095 |

organic approach is the next best and the mixed approach lags significantly behind either of the other two.

Similarly, ANOVA analysis is conducted to compare the confidence intervals associated with organic, mixed, and CLS aircraft maintenance for the Attainable metric ratio as delineated in Equation 2. See Table 5. Organic and CLS aircraft maintenance are found to be statistically different with regard to their ability to meet established Attainable targets. However, the mixed maintenance group is not statistically different from either CLS or organic aircraft maintenance. The variance of the mixed group is quite large and may be partly due to the smaller sample size in this group. Interestingly, CLS again provides the highest mean ratio of all three groups.

Thus, we conclude that in regards to both standard and attainable ratios, CLS and organic maintenance strategies are statistically different.

## CONCLUSION

There has been a recent shift in USAF aircraft maintenance strategies away from organic maintenance and towards CLS aircraft maintenance. Program Budget Decision 720, which reduced the USAF organic maintenance capability, accelerated the shift from 2006-2009. One reason for this shift was the theory that CLS would result in cost savings through increased competition. The findings of this research indicate that the policy decision to conduct aircraft maintenance organically, mixed, or by CLS has significant implications. We find that maintenance strategy is not only a driving factor, but is actually correlated as the most significant factor in aircraft maintenance costs. Thus, the policy decisions on which maintenance strategy to pursue are extremely important.

The empirical findings in USAF aircraft maintenance that CLS costs more than organic maintenance refutes one of the initial claims cited in the literature (Boito et al, 2009) that introducing contractor maintenance should reduce costs through competition. While not definitive, we suggest that the counterbalancing effect is likely to be asset specificity. There are large unique costs to conducting maintenance for USAF aircraft. These costs do not transfer easily to other uses – hence there is a high degree of asset specificity. Economic transaction cost theory would postulate that due to the large transaction costs associated with high asset specificity, it would be more beneficial to provide the service organically (vertically integrate). Thus, we suggest the asset specificity phenomenon outweighs the benefits of competition. In this study, CLS is found to be more expensive than organic maintenance for USAF aircraft.

Cost, however, is only one side of the coin. The value inherent from the outcomes of the maintenance strategy must also be considered. Value, for USAF aircraft, manifests itself in aircraft availability to fly missions. More specifically, the penultimate valued performance is achieving the availability target established for individual USAF platforms. Our "standard" and "attainable" ratios model this value. The performance analysis provides several findings. First, the mixed approach to aircraft maintenance performs worse than either organic or CLS. The mixed standard ratio mean is more than five percent lower than organic and nine

**TABLE 5**
**ANOVA RESULTS: ATTAINABLE RATIO**

| | Mean | Lower 95% CI | Upper 95% CI | Standard Dev. |
|---|---|---|---|---|
| CLS | 1.0301 | **1.0218** | **1.0384** | 0.1811 |
| Mixed | 1.0187 | 0.9938 | 1.0436 | 0.2377 |
| Organic | 1.0084 | **1.0005** | **1.0163** | 0.1810 |

percent lower than CLS. Thus, the mixed approach provides the least amount of performance and should be employed as a last resort. Second, CLS and organic maintenance performance ratios demonstrate that the two approaches provide statistically significant performance differences. CLS average performance outperforms organic by over three percent for the *standard* ratio. The *attainable* ratio performance results are more complicated. Both organic and CLS achieve, on average, above the ideal ratio of 1.0. CLS maintains a higher mean value than organic for the *attainable* ratio. Recall that the attainable target takes into account availability of aircraft given the resources allocated. This naturally leads back to PBD 720 and the cutting of maintenance manpower. Our *attainable* ratio performance analysis shows that when resources are taken into account, organic can perform very well. Thus, USAF decision makers should take this into account when considering future PBD 720 type decisions.

In summary, we have found that the decision to sustain aircraft organically or through CLS contracts is the most significant driver behind USAF operating and support costs per flying hour. In addition, given that operating and support costs account for a historical average of 53-65% of the total aircraft life-cycle costs, the maintenance strategy decision has profound effects (Jones et al., 2014). Assessment of "standard" ratio calculations via ANOVA reveals CLS maintenance strategy is providing greater performance than organic. Additionally, the ANOVA reveals both CLS and organic strategies perform, in the aggregate, above targets for the "attainable" ratio and that their means are statistically different. This indicates the importance of appropriately resourcing across the enterprise to achieve necessary mission requirements.

**DISCLAIMER:** The views expressed in this article are those of the authors and do not necessarily reflect the official policy or position of the United States Air Force.

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