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contemporary issues

Analyzing Air Force Flying-Hour Costs
Improving Base Demand Levels Using COLT

Contemporary Issues presents two analytical articles in this edition—"Analyzing Air Force Flying-Hour Costs" and "Improving Base Demand Levels Using COLT."

In the first article Captains Kevin P. Dawson and Jeremy A. Howe, project managers at the Air Force Logistics Management Agency, examine the effect decreasing average sortie duration (ASD) would have on the cost per flying hour (CPFH) for the F-15C/D. Their research also included analyzing break rates and pilot-reported discrepancies in relation to ASD.

The research found little correlation between ASD and F-15C/D break rates, suggesting most aircraft failures are dependent on the number of sorties flown, not the sortie duration.

The analysis shows the impact changing ASD would have on five modes of failure, and demonstrated CPFH would increase as ASD was decreased.

The research suggests decreasing ASD to fly either more sorties totaling the same number of flying hours, or the same number of sorties totaling less flying hours was not cost effective.

The second article outlines COLT (customer-oriented leveling technique) implementation. COLT is a relatively new system that determines Air Force base stock levels for Defense Logistics Agency–managed consumable parts. It overrides the Standard Base Supply System (SBSS) demand level for most consumable and some low-cost equipment items. The goal is to improve supply support by reducing customer back orders and wait time.

When COLT was first implemented, it used fixed adjusted stock levels (ASL) to ensure the COLT level overrides the demand level. Although using fixed ASLs worked, it took more effort to load and did not allow COLT to consider items with minimum ASLs. In early 2006, COLT switched to readiness-based leveling-type levels. This will allow COLT to eventually push levels through the Defense Automated Addressing System and include items with minimum ASLs. COLT, in theory, is superior to the SBSS demand level and has shown, in practice, to provide better results.

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Analyzing Air Force Flying-Hour Costs

Captain Kevin P. Dawson, USAF
Captain Jeremy A. Howe, USAF

Introduction

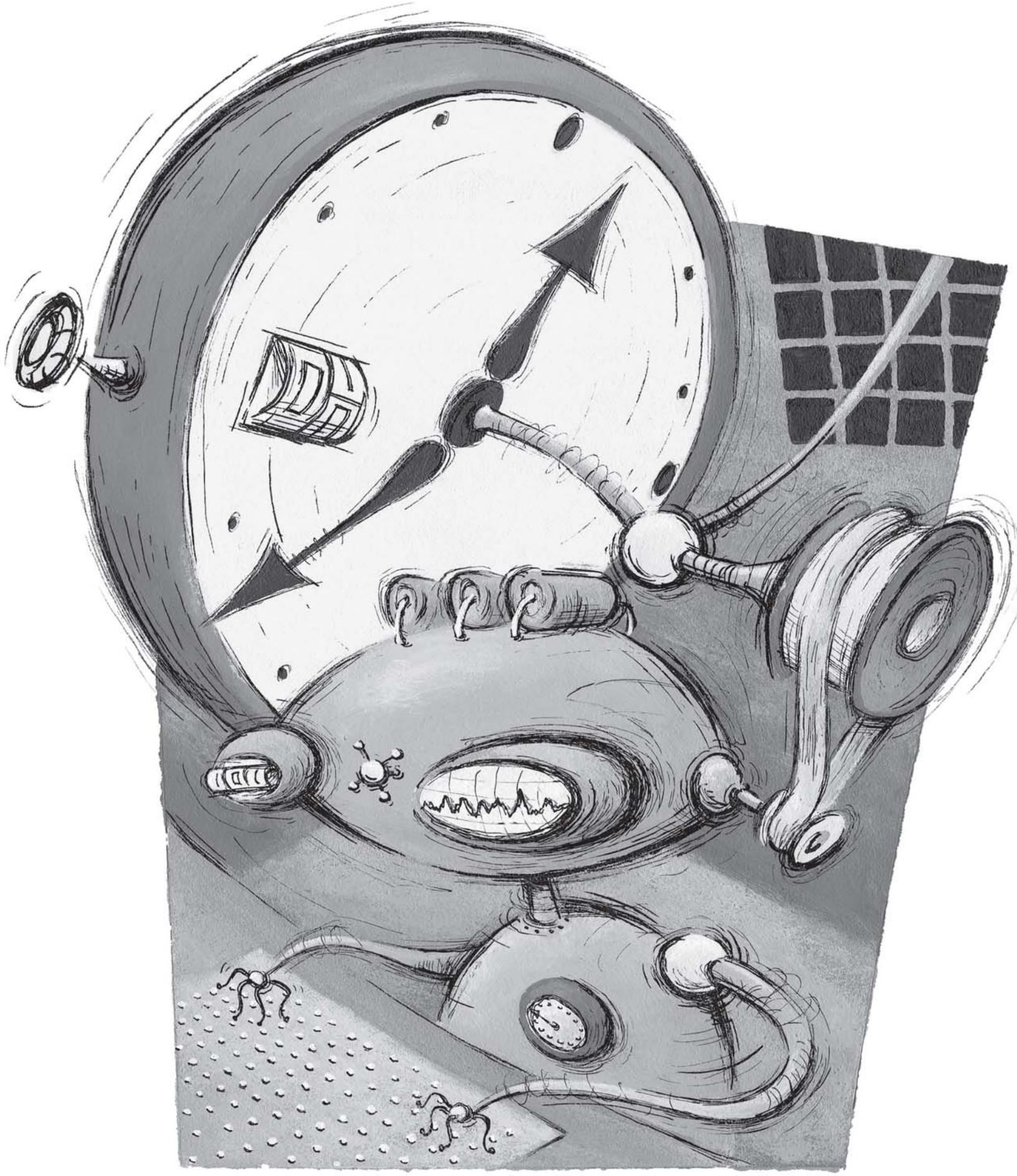
We've all, at one time or another, walked into a room and flipped on the light switch, only to hear the *pop* of a light bulb going out. In terms of wear and tear, is leaving a light turned on day and night a quicker route to failure than turning the switch on and off excessively? The light bulb is a good example of certain components that are more likely to fail when being turned on and off than operating continuously. This phenomenon is known as *failure on demand*. When Headquarters Pacific Air Forces (PACAF) asked the Air Force Logistics Management Agency (AFLMA) to evaluate the idea of flying more F-15C/D sorties at reduced average sortie duration (ASD), *failure on demand* was just one of a variety of component failure modes considered. In less than 1 month's time, the AFLMA team illustrated not only the proposed sortie duration change's impact to the cost per flying hour (CPFH), but also how varied modes of failure influence the nature of aircraft breaks.

In the end, the study team would identify five ways in which aircraft and parts fail, as well as the effect varying sortie durations have on each failure mode. The analysis indicated that CPFH will increase as ASD decreases, irrespective of the amount of sorties or hours flown. The research and findings contributed to PACAF's design of the Kadena AB F-15C/D flying-hour program. The results proved to be both rapid and beneficial, including most notably an 18 percent improvement in the mission capable rate after just 2 months time.

Background

When the study team was first approached, Kadena AB was experiencing a higher number of F-15 C/D maintenance issues than other F-15 C/D bases. For some time, mission capable (MC) rates had been approximately 20 percent lower than other F-15 C/D units, and Kadena AB had failed to meet any (all ten) Air Force F-15 C/D maintenance standards from May through June 2005.[1] With the intent of reducing an already heavy maintenance burden, Headquarters PACAF was considering the idea of reducing Kadena's F-15 C/D average sortie duration to reduce the overall number of flying hours accrued by each aircraft. However, PACAF maintenance leadership believed that reducing ASD would have a negative effect (increase) on the CPFH for Kadena's F-15 C/D fleet. In the absence of any measurable data that directly addressed this claim, the study team would need to address the following items:

- Define the CPFH model and the data used to compute hourly costs
- Identify Air Force maintenance metrics used to represent component failures
- Evaluate the factors contributing to component failure and reduced aircraft reliability
- Through statistical analysis, establish a lack of correlation between ASD and component failures



While the first three items could be accomplished through a review of existing literature and Air Force regulations, the last would require more extensive analysis. This analysis was necessary since illustrating a lack of correlation between ASD and component failures would validate the following sequence of logic:

- If component failures are not correlated to ASD, then an airframe can be expected to experience the same number of component failures per sortie, regardless of sortie duration.
- If an airframe experiences the same number of component failures per sortie, the same number of repair parts (consumable and repairable) will be required.
- If the same number of repair parts is required, the cost of parts will remain unchanged.

Once these assumptions were validated, changes in CPFH could be calculated, factoring in the following general assumptions:

- Modification costs will remain unchanged across all ASDs.
- The cost of aviation fuel will change linearly with changes in ASD. This assumption suggests that if ASD decreases by 10 percent, fuel consumption will also decrease by 10 percent and the resulting fuel costs will decrease by 10 percent. This assumption accounts for a worst-case scenario as fuel consumption will most likely not be linearly related to ASD because of the fact that excessive fuel burn is encountered during the takeoff phase of flight.
- For the purposes of valid cost comparison, paired scenarios must hold constant either the number of sorties or the number of hours flown. This is to ensure a fair comparison in the spirit of *apples to apples*. For example, it would not be valid to compare a 1.65 ASD, 500-sortie scenario (825 flying hours) with a scenario of 1.5 ASD, 600 sorties (900 flying hours).

Article Acronyms

AFLMA - Air Force Logistics Management Agency
ASD - Average Sortie Duration
CPFH - Cost per Flying Hour
PACAF - Pacific Air Forces
PRD - Pilot-Reported Discrepancies
TNMCM - Total Not Mission Capable Maintenance

$$\frac{\text{Parts + Fuel + Modifications}}{\text{Hours Flown}} = \text{CPFH}$$

Equation 1. CPFH Calculation

Analysis and Research

Kimbrough identified the three major cost variables of the aircraft CPFH calculation model to be:

- Aircraft parts
- Aviation fuel
- Modifications and sustainment costs.[2]

Aircraft part costs for each fiscal year are broken down into consumable and repairable parts; however, this research aggregated these categories to simply *aircraft parts*. Aviation fuel represents the cost of fuel used throughout the fiscal year. Modifications and sustainment costs represent planned depot modifications and weapon system upgrades. CPFH is calculated by adding the three major cost variables and dividing by the number of hours flown throughout the fiscal year. Equation 1 illustrates this calculation.

Manuel discovered that 70 percent of total aircraft flying program costs were attributed to repair parts, 19 percent were attributed to aviation fuel, and 11 percent were attributed to modifications and sustainment.[3] Assuming these ratios can be applied to strategic CPFH models across any weapon system, we are able to estimate CPFH changes based on ASD and the number of sorties flown.

Ebeling identified five different methods of inducing a failure:

- Hourly operation time
- Operating cycles
- Clock time
- Failures on demand
- Maintenance-induced failures[4]

Component failures attributed to *hourly operation time* should experience fewer failures per sortie as ASD (and the resulting total operating time) is reduced. However, if the number of *low ASD* sorties is increased to achieve the same number of flying hours as the baseline ASD, the number of *hourly operation time* failures will remain unchanged. Components failing based on an *operating cycle* failure distribution, fail based on the number of uses. Therefore, flying the same number of sorties with a lower ASD will result in approximately the same number of operating cycle failures. However, increasing the number of sorties will result in increased failures based on operating cycles. Components failing on a clock time failure distribution should experience the same number of failures regardless of ASD or the number of sorties flown.

Failures on demand may occur when a system is turned on. Sometimes referred to as the *light bulb theory*, this failure mode pertains to light bulbs and many other electrical components that

Failure Rate Distribution	Lower ASD, Same Sorties (Reduced Flying Hrs)	Lower ASD, More Sorties (Constant Flying Hrs)
Operating Hours	Less	Same
Operating Cycles	Same	Increased
Clock Time	Same	Same
Failures on Demand	Same	Increased
Maintenance Induced	Same	Increased

Table 1. Impact of ASD, Sorties Flown, and Flying Hours on Component Failures

have a higher probability of failure when activated as opposed to normal operational loads.[5] In terms of applying this failure logic to aircraft sorties, if the number of sorties remains unchanged, the number of failures on demand—in this case, electrical failures as well as physical failures incurred during the event demands of aircraft takeoffs and landings—should remain unchanged as well. It follows then, that increasing the number of sorties will yield an increased number of failures on demand. Likewise, the number of maintenance-induced failures should increase, because more maintenance is required to repair an increased number of component failures and perform additional through-flight actions. A maintenance-induced failure is defined as a maintainer damaging a component during repair. The number of maintenance-induced failures increases as the amount of either scheduled or unscheduled maintenance increases. With more sorties, maintenance will increase.

Table 1 summarizes the effect of reducing ASD with respect to the number of component failures based on the different methods of inducing failures described above.

It can be seen from Table 1 that reducing ASD only results in a lower number of component failures when the number of sorties flown remains unchanged. Increasing the number of *low ASD sorties* to achieve the baseline flying-hour program will result in an increased number of component failures for three of the five different failure induction methods.

The number of failures will remain unchanged for components failing on an operating hour distribution; therefore, these failures will not increase total aircraft operating costs for comparable flying hours. Next, it is important to identify metrics capable of providing measurable data that would allow for the examination of failures based on operating cycles, failures on demand, and maintenance-induced failures.

Of the numerous maintenance metrics tracked by the Air Force, three are of primary interest:

- Break rate
- Pilot-reported discrepancies (PRD)
- Ground abort rate

A secondary maintenance metric of interest is total not mission capable maintenance (TNMCM) time.

Aircraft break rate represents the number of Code 3 breaks divided by the total number of sorties flown.[6] A Code 3 break indicates that an aircraft has a major discrepancy in mission-essential equipment that may require repair or replacement prior to further mission tasking. The break rate is "an indicator of aircraft system reliability ... and is an excellent predictor of parts demand."[7] A sortie is considered to be one operational cycle for an aircraft at the strategic level, and break rates capture the number of grounding breaks per sortie. Break rates convey an expected number of *breaks* per operational cycle, and can supply data for components failing on an operating cycle failure distribution. PRDs can also be used as an indicator of breaks, and account for most Code 2 breaks and delayed discrepancies. A Code 2 break is one in which an aircraft has a minor discrepancy, but the aircraft is capable of further mission assignments.

When an aircrew accepts an aircraft and then encounters a grounding maintenance condition, a ground abort occurs. Basically, this scenario indicates that an aircraft subsystem did not fail until it was placed under an operational load by the aircrew. Preflights and through-flights will test most systems for operability, however many systems will be powered down until crew arrival. Therefore, ground abort rates are the most suitable data source for identifying failures on demand.

Based on the reliability theory depicted in Table 1, the number of component failures should increase as the number of sorties flown increases. The study team hypothesized that the number of failures would increase at an amount proportional to the break rate. For example, a unit flying 100 sorties with a 15 percent break rate can expect to experience 15 failures. Likewise, flying 200 sorties should then result in approximately 30 failures. As the number of sorties increases, PRDs should also increase. TNMCM time should increase as well due to the added repair actions resulting from an increased number of component failures.

A critical piece of this analysis pertained to establishing that ASD has little to no impact on the break rate and number of PRDs reported. If ASD is correlated to break rate and PRDs, we cannot safely assume that aircraft, strategically speaking, fail on a cyclical basis (per sortie), as extended sorties may induce additional wear and tear on components. However, a lack of correlation between ASD and both break rate and PRDs would validate the aforementioned assumption.

Figure 1 shows the correlation matrices for PACAF F-15 C/D maintenance data delineated by command and base. These matrices show no direct relationship between ASD and break rate, nor do they show a direct relationship between ASD and the number of PRDs. Regression analysis confirmed a lack of correlation with an R^2 value of .1851 for ASD to break rate, and an R^2 of .0079 for ASD to PRDs. Therefore, it can be said that changes to ASD are unlikely to bear witness to significant changes in break rate or the number of PRDs. In other words, while the number of breaks will increase as the number of sorties increases, the rate at which the aircraft break remains unchanged.

With the statistical analysis complete, we are able to examine and discuss the specific impact of failures to CPFH under two distinct scenarios. The first is one in which the total number of flying hours is held constant; the second is one in which the total number of sorties is held constant.

Flying Hours Held Constant

If ASD is reduced but the number of sorties is increased to maintain a desired flying-hour program, the number of *breaks* (Codes 2 and 3) will increase and the parts required to repair these breaks will also increase. The presumed increase would be linear and proportional to the increased number of breaks. Having established that the break rate remains relatively unaffected by ASD, it is valid to assume it will remain unchanged and produce additional breaks proportional to the increase in sorties flown. For this model, the assumption is that the cost of parts will increase proportionally to sorties flown. Depot modifications and equipment upgrades are planned and scheduled on a fiscal year basis, independent of sorties and flying hours. Therefore, the assumption can be safely made that the cost of modifications will also remain more or less the same over time regardless of ASD or number of sorties flown. Because the number of flying hours remains constant, we will assume the cost for fuel remains unchanged; however, we believe that, realistically, this cost should increase given the greater amount of fuel being expended during the increased number of takeoffs. Referring to equation

ELMENDORF & KADENA COMBINED

	ASD	*Sorties*	*Hours*	*NMCM*	*PRDs*	*Break Rate*	*Fix Rate*	*GA Rate*
ASD	1							
Sorties	-0.423329	1						
Hours	0.459953	0.576527	1					
NMCM	-0.045099	0.100756	0.056012	1				
PRDs	-0.089061	0.432281	0.33525	0.825703	1			
Break Rate	0.430272	-0.51202	-0.131974	0.438816	0.244312	1		
Fix Rate	0.084292	-0.039852	0.059803	-0.876954	-0.726926	-0.394789	1	
GA Rate	0.209038	-0.383863	-0.1771	0.467582	0.293111	0.455907	-0.536551	1

ELMENDORF

	ASD	*Sorties*	*Hours*	*NMCM*	*PRDs*	*Break Rate*	*Fix Rate*	*GA Rate*
ASD	1							
Sorties	-0.437363	1						
Hours	0.383377	0.639519	1					
NMCM	-0.048088	0.184529	0.144108	1				
PRDs	-0.048227	0.457789	0.423036	0.471886	1			
Break Rate	0.545413	-0.507781	-0.107503	0.047028	0.142843	1		
Fix Rate	0.086518	0.016116	0.095437	-0.533626	-0.261427	-0.083821	1	
GA Rate	0.228785	-0.3941	-0.202464	0.267789	0.131635	0.240222	-0.500488	1

KADENA

	ASD	*Sorties*	*Hours*	*NMCM*	*PRDs*	*Break Rate*	*Fix Rate*	*GA Rate*
ASD	1							
Sorties	-0.419614	1						
Hours	0.516478	0.52428	1					
NMCM	-0.118738	-0.089334	-0.150463	1				
PRDs	-0.2127	0.655179	0.436042	0.422141	1			
Break Rate	0.36924	-0.654058	-0.231923	0.543617	-0.079104	1		
Fix Rate	0.202313	0.185897	0.377599	-0.655427	-0.161726	-0.430747	1	
GA Rate	0.230726	-0.581919	-0.291922	0.49828	-0.071508	0.633967	-0.447102	1

KEY

Green Values Approaching 1
Positive Correlation

Red Values Approaching -1
Negative Correlation

Values near zero

No Correlation

Note: correlation does not indicate causality, merely that a linear trend may exist between two variables

Historical data does not indicate strong correlation between ASD and any performance measures

Figure 1. Correlation Matrices for PACAF F-15 C/D Maintenance Data

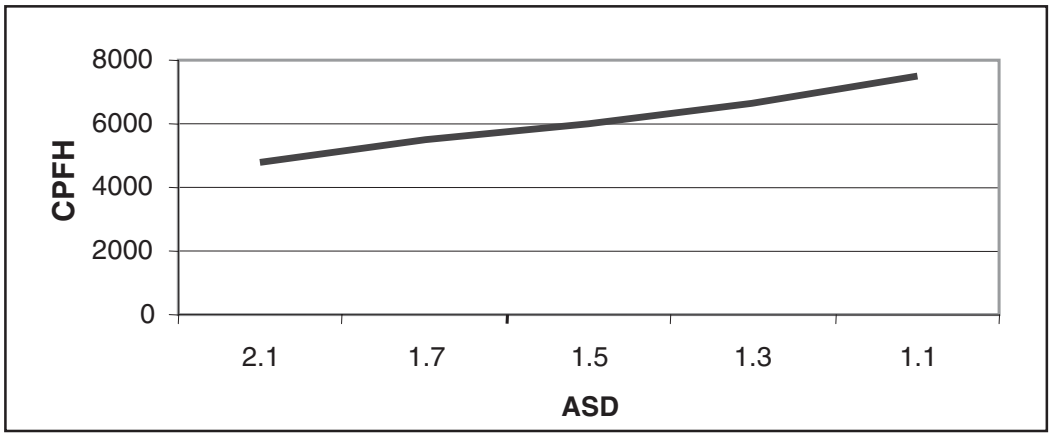


Figure 2. CPFH Estimates: Variable ASD, Variable Number of Sorties, Same Flying Hours

1, the increased cost for repair parts will raise the numerator value while all other variables (including the denominator) remain unchanged. With the numerator increasing, and the denominator held constant, we see an increase in CPFH. This model is represented in Figure 2, and although the data used in this research was notional ($6,000 original CPFH for a 1.5 ASD), the same trends are experienced regardless of the cost data used: CPFH increased as ASD was reduced.

Sorties Held Constant

If the same number of sorties is flown over different ASDs, the number of *breaks* (Codes 2 and 3) will remain unchanged and the parts required to repair these *breaks* will also remain unchanged. Furthermore, if the repair parts required remain unaffected by changes in ASD, the cost of parts should remain relatively the same. Depot modifications and equipment upgrades are planned and scheduled on a fiscal year basis independent of sorties and flying hours. Therefore, we can safely make the assumption that the cost of modifications will also remain more or less the same over time regardless of ASD or number of sorties flown. As such, when measuring the effect of ASD changes on CPFH, we can hold constant the cost of parts and cost of modifications. With reduced ASDs, it follows that we will observe reductions in quantity of fuel consumed and total hours flown. Under a worst-case scenario, we could assume a perfectly linear relationship between fuel used (and consequently, cost of fuel) and hours flown. For this model, the cost of fuel was assumed to decrease proportionally to the reduction in flying hours (for example, 10 percent fewer flying hours would result in 10 percent lower fuel costs). Realistically, more fuel is likely expended at takeoff versus level flight, but for the purposes of this analysis, we assumed a linear relationship. Since the number of flying hours is simply a manipulation of ASD (that is, the product of ASD and the number of sorties), the same logic can be applied to ASD reduction. Referring to Equation 1 under this scenario, the numerator is decreasing while

the denominator is also decreasing. CPFH will increase in this scenario as the numerator is not decreasing at the same rate as the denominator. Therefore, a direct comparison can be made between CPFH calculations for different ASDs. Due to the lack of operational data, notional cost data was used to populate the model represented in Figure 3. The numerical values of the CPFH change; however, the trend established in Figure 2 remains constant—CPFH increased as ASD was reduced.

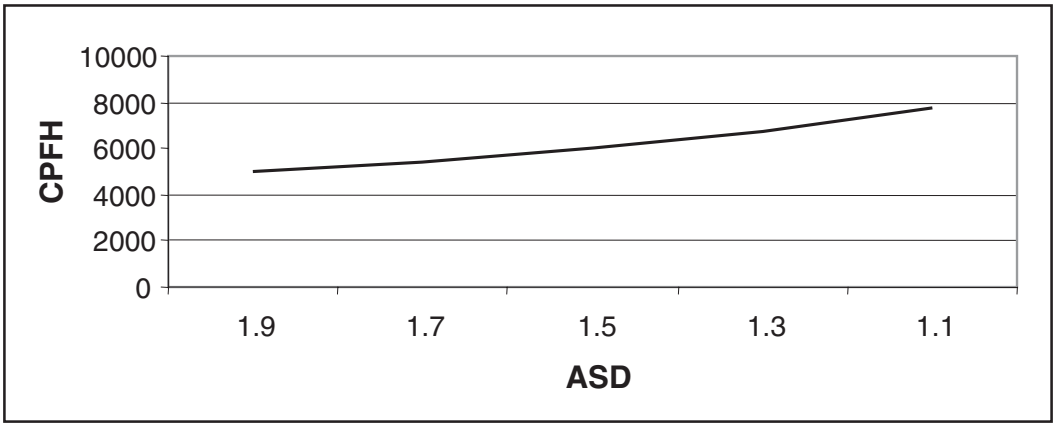


Figure 3. CPFH Estimates: Variable ASD, Same Number of Sorties, Variable Flying Hours

Conclusions and Recommendations

The findings of this research show that CPFH will increase as ASD decreases irrespective of the number of sorties or hours flown. The analysis indicates that reducing ASD cannot decrease the cost of aircraft repair parts, which accounts for approximately 70 percent of the total flying-hour program costs. Reducing ASD and pursuing the same flying-hour program increases the cost of repair parts and significantly contributes to an increased CPFH. This scenario will require more maintenance effort to generate additional sorties and will require more maintenance effort to repair the additional aircraft breaks.

Notes

1. "PACAF REDCAP" report, [online] Available: https://redcap.hickam.af.mil/REDCAP2/welcome.aspx
2. Anthony Kimbrough, "Developing Cost per Flying-Hour Factors for the Operations and Maintenance Phase of the Satellite Cost Cycle," Air Force Institute of Technology Thesis, Mar 2003.
3. Anthony Manuel, OPNAV N43 Flying-Hour Program, unpublished presentation from the ASO/ASC Conference, 3–5 May 2005.
4. Charles E. Ebeling, *An Introduction to Reliability and Maintainability Engineering*. McGraw-Hill Book Co, 1997.
5. *Ibid*.
6 *Maintenance Metrics U.S. Air Force*, Gunter Annex, Maxwell AFB, AL: Air Force Logistics Management Agency, 20 Dec 2001.
7. *Ibid*.

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notable quotes

The onus of supply rests equally on the giver and the taker.

—General George S. Patton, Jr, USA

Logistics sets the campaign's operational limits.

—Joint Pub 1, *Joint Warfare of the Armed Forces of the United States*

Planning is everything—plans are nothing.

—Field Marshal Helmuth von Moltke

The final dictum of history must be that whatever excellence Lee possessed as a strategist or as a tactician, he was the worst Quartermaster General in history, and that, consequently, his strategy had no foundations, with the result that his tactics never once resulted in an overwhelming and decisive victory.

—Major General J. C. Fuller, USA