Cost and Safety Benefits when Implementing the Analytical Condition Inspection (ACI) Program on the F-35A (Lightning II) Fleet

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Abstract *- In 2012 [1], the first F-35A's (conventional takeoff and landing) [2] fighter jets took off the production line to join the US Air Force (USAF) fleet. Since then, this weapons system has flown in multiple missions within the US nation and foreign countries. Meanwhile, as more hours are added to the air vehicle, more maintenance hours are required in order keep them in the air. Even though maintenance looks at the natural wear caused by the environment, air speed, external load, maneuvers and other factors, the analytical condition inspection (ACI) program supports and complements this effort by revealing flaws or imperfections that probably may not otherwise be visually noticed through normal unit level maintenance, intermediate level maintenance and programmed depot maintenance (PDM) inspections [3]. As a result, this process acts as a proactive approach which ensures the USAF a safer taskforce while assuring the taxpayer a more economic & effective system.*

Key Terms *– ACI, ASIP, PDM, SPD, USAF.*

PROJECT STATEMENT

As the USAF steps into the operations & support phase (O&S) [4] "also known as sustainment phase" (Figure 1 [4] highlights the last step of the acquisition process), it's required to perform more robust maintenance and detailed inspections. The O&S's major focus within ACI is to discover unknown issues on parts and components before becoming a fleet wide problem. Now that the F-35A fleet has surpassed the minimum flight hour and years in service it can to be considered in the selection. The F-35 joint program office (JPO) has started to plan the ACI program for the fleet. By the year 2020, 200+ [5] field operational capability jets will be ready to participate in the predetermined inspections.

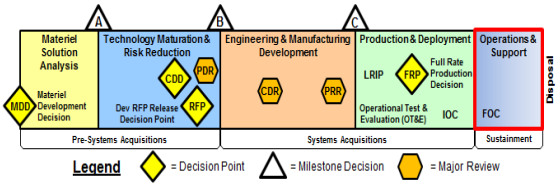

Figure 1
Acquisition Process

PROJECT OBJECTIVE

The objective of this research is to calculate and determine the cost benefit of the ACI program. After the ACI inspection criteria have been successfully established, an approximate amount of the cost can be compared. This step will provide a clear view of cost differences when performing these maintenance inspections alone or during the depot phase inspections. Furthermore, as maintenance improves, cost decreases while issues are reduced, making the maintenance community and end users work in a safer environment.

Major Cost and Safety Benefit of the ACI program:

- Proactively looks for different approaches to search for the unexpected.
- Finds damage early, before becoming a fleet wide problem.
- Mitigates negative finding which can result in possible part redesign or retrofit.
- Identify challenges early on the life of the fleet.
- Sample the fleet instead of a fleet wide inspection.
- Can be combined with depot level maintenance for efficiencies.
- Reduces risk, maintenance load and cost.

LITERATURE REVIEW

Since 1947, the United States Air Force has provided the USA and other countries with the air power needed to protect and defend them from foreign and domestic enemies. In today's world, everyone is looking to grow their technical capability and develop their technological power. USAF's main objective is to be the leaders in global observance and aeronautical power in order to achieve the mission successfully. For this reason, the U.S. Air Force is considered the world's distinguished force in air and space.

As a fact, aircrafts are the Air Force's meaning of existence. These being a fighter, bomber, tanker, cargo, attack, UAV, surveillance, reconnaissance aircraft's or rescue helicopters, all have an important mission profile they must achieved. For this reason, during the late 1990's, the Department of Defense (DoD) was looking at the option to exchange their legacy aircraft [6] [7] with more advance jets. Not only the Air Force's F-16 & A-10, but the Navy's F/A-18 and US Marines Corps' F/A-18 & AV-8B Harrier [8] were also searching for replacements. Therefore, in 2001 the Lockheed Martin F-35 A/B/C model with Northrop Grumman and BAE Systems were chosen as the winners of the concept demonstration phase competition. While USAF F-16 & A-10 purchase are fairly close in the number built to the 5th generation birds (1733 vs 1763 [9] as shown in Table 1 & Figure 3), the F-35 is approximate 5 times the legacy aircraft cost. But even though it's the costliest [10], this highly advanced stealth jet is what make United States Air Force the most powerful force in the league.

Table 1
Planned Aircraft Purchase per Countries (Alfa Models only shown)

ARMED FORCES	AIRCRAFT (Planned Purchase)	
USAF	1763	71%
UK	138	6%
ITALY	60	2%
NETHERLANDS	37	1%
TURKEY	100	4%
AUSTRALIA	100	4%
NORWAY	52	2%
DENMARK	27	1%
CANADA	88	4%
ISRAEL	50	2%
JAPAN	42	2%
REPUBLIC OF KOREA	40	2%
TOTAL	2497	100%

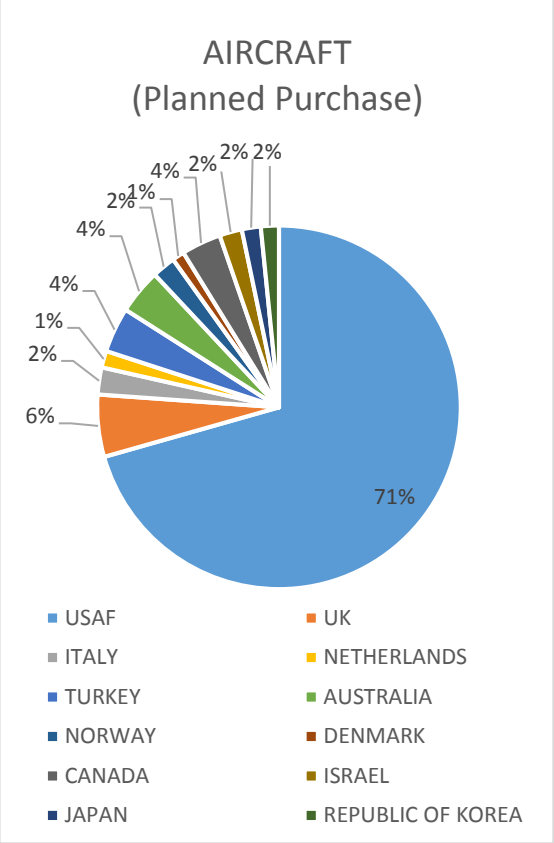

Figure 2
Planned Aircraft Purchase per Countries (Alfa Model only shown)

METHODOLOGY

As stated by DoD "MIL-STD-1530 is a standard which describes the USAF Aircraft Structural Integrity Program (ASIP). This program is use to define the requirements necessary to achieve structural integrity in USAF aircraft while managing cost and schedule risks through a series of disciplined, time-phased tasks" [11].

ASIP has two key goals within the military; making the weapon system safe and operational

ready. This program encompasses 5 primary tasks which need to be perform in order to ensure the goals of the aircraft's entire life cycle are reached. Task 1 through 4 (Acquisition Phase) carries out the design, analysis, testing, certification and the force management development. While task V (5.5) or Force Management Execution [11] (Sustainment Phase) as seen Figure 3 focuses on the duties which keep the structural integrity and the certifications up-to-date.

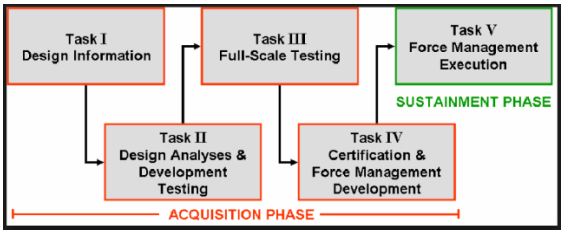

Figure 3
ASIP's 5 Primary Task

In paragraph 5.5.8, it specifically calls out the Air Force material command instruction (AFMCI-21-102) for the ACI. This section will be our reference in the source selection of the aircraft that will be participating in the program.

INITIATING ACI PROGRAM

The majority of the inspections are selected based on reports provided by the Aircraft Structural Integrity Program (ASIP). Failure statistics, material property deficiency, mishaps & incident reports, are some of the main factors used to determine the selection and priority of the inspections. In addition, high stressed areas, critical points and corrosion issues among others (which could be causes by durability & damage tolerance (DADT) or Static loads) are also closely looked at, as done in previous platforms.

Table 2 [3] shows the minimum requirement that the fleet most achieve in order to initiate the ACI program. The F-35 being that is a fighter jet, it's recommended the ACI program be initiated after completing the 3 years in service or have 1,000+ of actual flight hours (AFH). Generally, high time (accumulated flight hours) aircraft are selected for the program, over the more "mature" (calendar days) airplanes.

Table 2
Aircraft Consideration Guideline

Aircraft Classification	Year in service	or	Hour of service
Trainers or Fighters	3	or	1,000
Bombers, Cargo or Tankers	5	or	6,000
Non-Expendable UAV	N/A		

ACI SAMPLING

Sampling can sometimes be simple and straight forward, but in some cases, it can be complicated (mostly when having a small sample). For example, if the 2012 procurement quantities found in Figure 4 [5] reveal that 19 (excluding the previous years) F-35A can be considered in the ACI program, but only 25% (using the primary sample) of the force (ref. Table 3) [3] could be selected, it can be determined that 19 x 0.25 = 4.75 or approximately 5 jets should be initiated in the program. Although, this amount seems small, the system program director (SPD) may not agree. So, before the SPD can approve this amount, they must overlook the necessity of the fleet by; checking the overall condition of the aircrafts by evaluating all maintenance records & negative reports and calculating total budget available to complete the inspections.

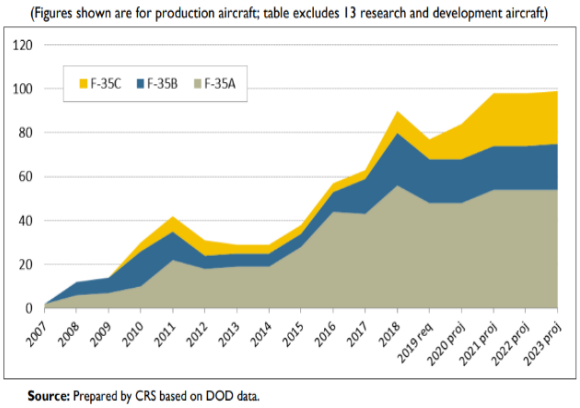

Figure 4
F-35 Procurement Quantities

Table 3
Samples Selection Guideline

Force Size	Primary Sample	Secondary Sample*
1-36	25% of force	Additional 25% of force
37-199	10	13
200+	11	13

*Note: The secondary sample must be considered if at least one defect was found (in same location) and it represents 20% or more of the fleet.

ACI Reporting Guideline

All reported ACI defects can be classified into 3 different categories see Figure 5; Minor, Major and Critical [3] (As stated in AFMCI 21-102).

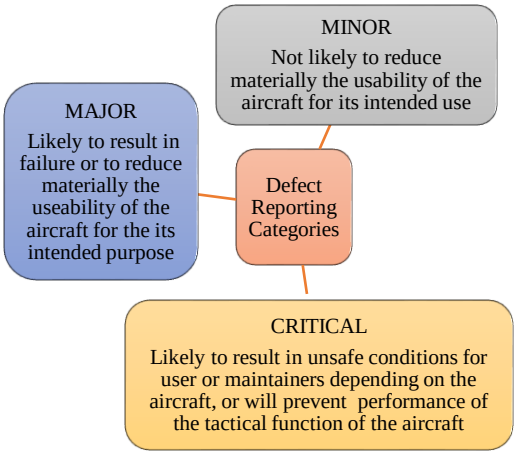

Figure 5
Defect Reporting Categories

These categories are normally established by the SPD, in order to understand what level of engineering evaluation should be completed. If a defect is found to be safety-critical in the ACI, a time compliance technical order (TCTO) will be written for fleet wide inspection disposition.

Examples of ACI Findings and Resulting Interventions on Other Platforms [12]

KC-135 (Tanker):

- ACI has resulted in numerous corrosion write-ups and reports of cracked secondary structure members (all minor) with two of them leading to a force-wide replacement or inspection of the affected part.

C-17 (Cargo):

- Wear in the control surface joints - through ACI they determined that wear progresses to an unacceptable condition after roughly six to seven years. As a result, they are replacing part every five years (coincident with the C-17 paint cycle).
- Corrosion in the galley, toilet and kitchen areas - periodic ACI inspections were used to establish required maintenance interval for each component.
- Corrosion on the fuselage under the wing fillet to fuselage connection - resulted in an attachment design change and retrofit.
- While inspecting electrical system inside engine pylons, they found corrosion in connectors - response was to clean connectors every two years and apply corrosion inhibitors.

B-52 (Bomber):

- ACI program revealed corrosion in the window post and lower truss member attachment bolt.
- Additionally, cracking was discovered in other structural components.
- The wear and tear discovered in these ACI tasks was used to determine further preventative actions.
- Specifically, the window post corrosion resulted in the force-wide replacement of the component at the next PDM. Also, the work specification for future PDM cycles was changed to include an inspection of the window post. Cracking issues were handled through Timed Compliance Technical Order (TCTO) inspections.

E-3 (Airborne early warning and control):

- The most significant defect discovered in the E-3 ACI program was a cracked main landing gear trunnion support fitting. Most of the other defects found were classified as minor.
- Corrosion-related findings are normally moved to the E-3 PDM

F-117 (Fighter):

- Found less severe damage than anticipated.

SAMPLE INSPECTION ANALYSIS

Fictional Scenario: During a scheduled inspection on an F-35A, cracks were found close to main landing gear support. A root cause analysis was conducted by the engineering team. Due to complex loads in the area, it was difficult to determine if the cracking was isolated to this aircraft. Everything was pointing to a hard landing event but could not be confirmed. The aircraft was repaired and the project engineer recommended this point to be added to the ACI program. The ACI was conducted and it helped the engineers to identify this issue as a fleet wide problem. A business case analysis was performed by engineers and program managers and it was concluded that conducting the ACI on this area while at depot will save cost and schedule to the program. Table 4 displays the total time to complete inspection "XY". These hours will be used to calculate the total cost of the inspection during stand-alone maintenance vs programmed depot maintenance.

Table 4
Cost as a Stand-Alone ACI

Work Phases	Hours	Cost / hr. ($230.00 per hr.)
Coating Removal	62	$14,260.00
Disassembly	22	$5,060.00
Inspection	8	$1,840.00
Installation	22	$5,060.00
Adhesive Cure	48	$11,040.00
Assembly	21	$4,830.00
Coating Recovery	78	$17,940.00
TOTALS FOR INSPECTION "XY"	261	$60,030.00*

Table 5
ACI in Conjunction with Depot Maintenance

Work Phases	Hours	Cost / hr. ($230.00 per hr.)
Coating Removal	N/A	$0.00
Disassembly	N/A	$0.00
Inspection	8	$1,840.00
Installation	N/A	$0.00
Adhesive Cure	N/A	$0.00
Assembly	N/A	$0.00
Coating Recovery	N/A	$0.00
TOTALS FOR INSPECTION "XY"	8	$1,840.00*

*Note (for table 4 & 5): Material and equipment cost were excluded.

Even though downtime cost was not included in Table 4, it has been estimated to be around $15,000 per day (downtime cost provided by DoD source). For inspection "XY", the total cost can be calculated by taking the days (Equation 1) and then multiplying it by the downtime cost (Equation 2).

Equation 1: 261 hrs. ÷ 24 hrs. /day (3 shifts per day) = 10.875 days

Equation 2: 10.875 (days) x $15,000 (per/day) = $163K

RESULTS AND EVALUATION

Maintenance can be performed in two different ways; as a stand-alone inspection or in conjunction with depot maintenance. If the PDM is well managed, lots of money and schedule can be saved by using the ACI program. The DoD can take advantage work done in depot to reduce cost. While the aircraft in being serviced in the PDM phase (Table 5), the user will only have to pay for the inspection cost = $1,840 (this taking into consideration that all panels, covers, coatings, sealants, etc. have been removed first). On the other hand, if inspection "XY" is performed as stand-alone, it could add up to $223K or 121x the total cost of doing it during the PDM phase. For easy access inspections, the stand-alone option could be the option of choice.

CONCLUSION

The Analytical Condition Inspection (ACI) program is a tool that provides the ability to reduce

cost and increase the aircrafts availability. This process is super-efficient and reliable when it is combined with the programmed depot maintenance (PDM) inspection. It will allow performing sampling inspection instead of evaluating the whole fleet. It can help identify damages before they become a fleet wide problem, and provide the data required to proactively plan redesigns and retrofits. ACI has the capability to avoid having interruptions down the road, by proactively determining the maintenance due date, but also supporting the pre-order of parts or the design of repair procedures. Last but not least, it can reduce the maintenance load and cost.

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