A System Engineering Reliability Study of the A-10 Attack Aircraft using 2004 – 2008 data

The NDIA 18th Annual System Engineering Conference

October 29, 2015

Joseph Brady

Dissertation Topic
Department of Engineering Management and Systems Engineering
School of Engineering and Applied Science

The George Washington University
1176 G Street NW Washington, DC 20052 1

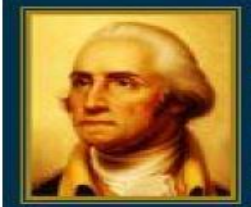


Table of Content

- Introduction
- Background
- Overview
- Methodology
- Analysis
- Initial Results
- Next Steps

Introduction

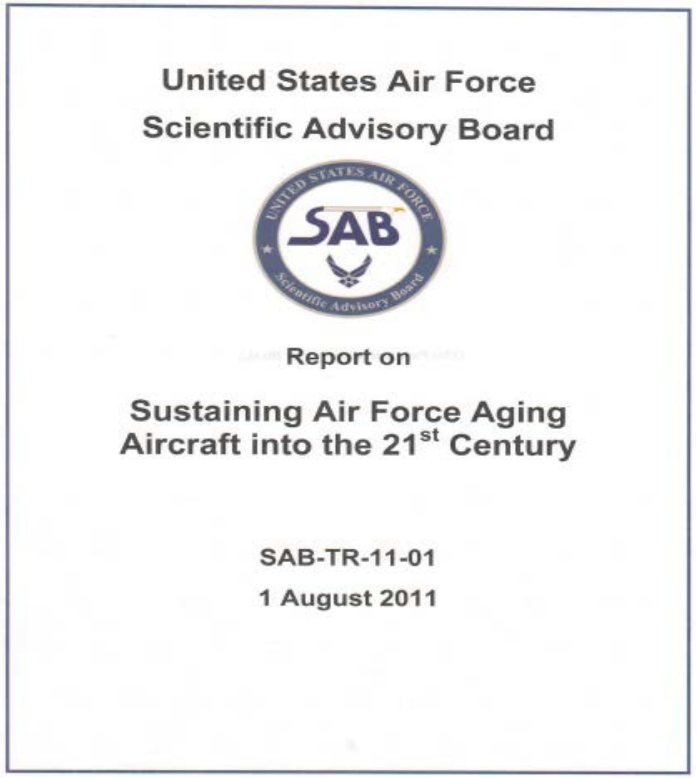
A-10 Warthog “Ownership” cost-per-flight-hour - $17,716 (2013)

A reliability analysis to develop a statistical methodology approach that reduces the cost of corrective maintenance (CM), by lowering the cost of failures. By finding a alternative maintenance replacement schedule that improves preventive maintenance (PM) schedule replacements more accurately.

Background

This A-10 reliability analyze is important that it follows the recommendations of the USAF Scientific Advisory Board (SAB) 2001 study: Sustaining Air Force Aging Aircraft into the 21st Century by emphasizing reliability data collection and analysis to schedule maintenance actions.

The SAB study identified technology needs and approaches that can be developed to extend the life or ease maintenance on aircraft systems.



SAB calls for a statistical approach to determine an effective maintenance interval based on statistical analysis that optimizes schedule maintenance and parts replacement.

Overview

➢ **Similar studies related to this topic:**

- **A Monte Carlo Method for Estimating Reliability Parameters of a Complex Repairable Technical System With Inter-Component Dependencies** (March 2013; Malinowski J.) – involves exponential distributions and Monte Carlo Simulations.

- **Reliability Analysis of Systems With Operation-Time Management** (March 2002; Ramesh, A., Twigg, D., Sandadi, U., & Sharma, T.) – involves equations derived from the Markov Chain based method, probability analysis of flight operation time management (FOTM).

- **A Statistical Method for Detection of Sensor Abrupt Faults in Aircraft Control Systems** (July 2008; Samara, P., Fouskitakis, G., Sakellariou, J., & Fassois, S.) – involves a statistical time series framework and test case study using Monte Carlo simulation experiments.

- **Improving Avionics Fiber Optic Network Reliability & Maintainability** (May 2007;Beranek, M., & Avak, A.) - involves BIT technology to provide operational availability and attentiveness to reliability and maintenance metrics to reduce failure rate and mean time to repair by predicting link failures.

- **Reliability Analysis of Aeroplane Brakes** (November 1998; Al-Garni, A., Sahin, A., Al-Ghamdi, A., & Al-kaabi, S.) – involves wear/failure data of brake assemblies on commercial aeroplane using the Weibull model.

Overview (Cont.)

I’m performing a Reliability Analysis study on historical (2004 – 2008) A-10 attack aircraft maintenance failure data, by developing a statistical methodology approach that can more precisely predict the mean time to failure (MTTF) then presently the Military Handbook 217 procedures and refinement of the mean time between failures (MTBF) maintenance predictions.

- This analysis brings value by using actual A-10 data:
  - Five (5) consecutive years of collected A-10 systems/units data
  - Using collected failure rate data & total systems/units yearly failure counts
  - A-10 (million) operating hours of the 357 aircraft in service
  - Using a combination of Avionics equipment – the inertial navigation system & fire control computer, injunction with the Weapon delivery system – head-up & umbilical displays, and angle of attack transmitter.
  - Analyzing mission critical units reliability
  - Comparing systems/units reliability calculations versus a perform Monte Carlo simulations of the data

Methodology

Using multiple years of historical A-10 data to conduct Monte Carlo Simulations and Statistical Analysis with Reliability Block Diagram (RBD) analysis to develop an alternative maintenance replacement schedule for some A-10 systems/subsystems.

Strengths

- Using actual historical data to perform the analysis
- Modeling non-repairable components using exponential distributions in-line with industrial practices
- Modeling over-all system performance using Monte Carlo simulations of the five (5) subsystems
- Modeling the system design with a Block Reliability Diagram (RBD) under system reliability evaluation
- Reliability analysis provides a finer level of fidelity for schedule maintenance intervals

Limitations

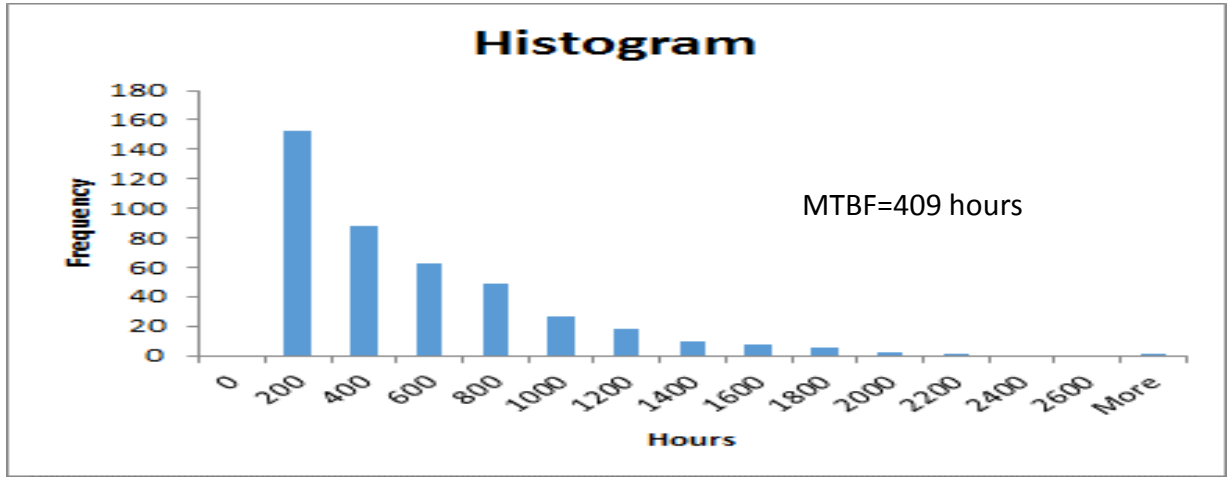
- Only analyzing non-repairable components
- Modeling only a series system for the configuration of the A-10 systems/units/components

Analysis

The A-10 Avionic Systems & Weapons Delivery Systems selected with failure data, to Illustrate mission critical systems/units that all most functions in conjunction with each other as designed for reliability and mission success.

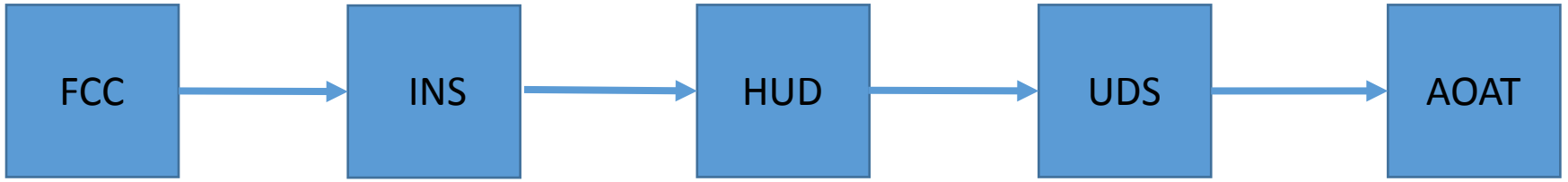
A-10	Avionic Systems				Weapons Delivery Systems					
System / Unit	Fire Control Computer		Inertial Navigation System		Heads-Up Display Unit		Umbilical Display Unit		Angle of Attack Transmitter	
Year	Total Failures	Op. Hours (E6)	Total Failures	Op. Hours (E6)	Total Failures	Op. Hours (E6)	Total Failures	Op. Hours (E6)	Total Failures	Op. Hours (E6)
2004	150	0.2413	87	0.1608	182	0.1608	43	0.1608	64	0.3217
2005	39	0.2309	73	0.1539	104	0.1539	47	0.1539	38	0.3079
2006	30	0.2276	37	0.1517	87	0.1517	36	0.1517	15	0.3035
2007	34	0.2294	22	0.1529	69	0.1529	15	0.1529	14	0.3058
2008	16	0.1672	21	0.1115	42	0.1115	11	0.1115	8	0.2292

- Analyzing the data to verify that the systems/units selected do have a Exponential Distribution.



This graph is the modeling of the Monte Carlo Simulation of the data

Analysis (Cont.)



$$\lambda_{FCC} + \lambda_{INS} + \lambda_{HUD} + \lambda_{UDS} + \lambda_{AOAT} = \lambda_{System}$$

$$MTBF = \frac{1}{\lambda_{System}}$$

System Reliability Analysis was performed using the actual A-10 failure data; failure counts, operating hours and failure rates, over the five (5) year period and as a hardware serial configuration model.

Analysis (Cont.)

Using the actual A-10 systems/units data, I performed a Monte Carlo simulation taking the minimum reliability count that was across all five (5) systems/units on each iteration of the simulation. To calculate the reliability life, the mean time to failure (MTTF) of the serial model I used : (Partial results shown below)

	Fire Control Lambdas		Nav Lambdas		AoA TRANS Lambdas		HUD Lambdas		Umb Display Lambdas	Over-all System
	0.0002453		0.0003409		0.0009508		0.00068757		0.0002159	409.0433489
0.60421	2053.950419	0.379521	2842.025548	0.44679891	847.3355545	0.48325275	1057.660268	0.26688738	6118.242295	847.3355545
0.680796	1567.439251	0.697736	1055.778126	0.40469397	951.4347084	0.83613138	260.2928066	0.50745826	3141.9213	260.2928066

Above is sample out put of the Monte Carlo Simulations of the subsystems series configuration. The five subsystems are simulated in the Blue columns. The first row represents individual Lambdas. The white columns represent the uniform (0,1) random variables that where generated to produce the Monte Carlo outputs for the blue columns. The Orange is the total system simulated mean-life of the rows minimum.

Initial Results

Reliability Block Diagram (RBD) calculation of MTBF of 403 hour

Monte Carlo simulation mean *approximately* (MTBF of 409) matching up with the values calculated from the actual data

Concern:

The data on the operational flight hours for the Inertial Navigation System, Heads-up & Umbilical Displays was exactly the same? This could mean that they are a subsystem(s) of the same system between Avionic & Weapons delivery system?

Next Steps In My Research

- Continue researching into the A-10 present preventative maintenance schedule(s)
- Gather A-10 subsystem engineering documentation to provide descriptions, and schematics to improve reliability block diagram (RBD) analysis configurations
- Include maintenance optimization policy correlation with the reliability analysis findings

For Additional Information

QUESTIONS?

Please feel free to contact me at:

joebrady@gwmail.gwu.edu