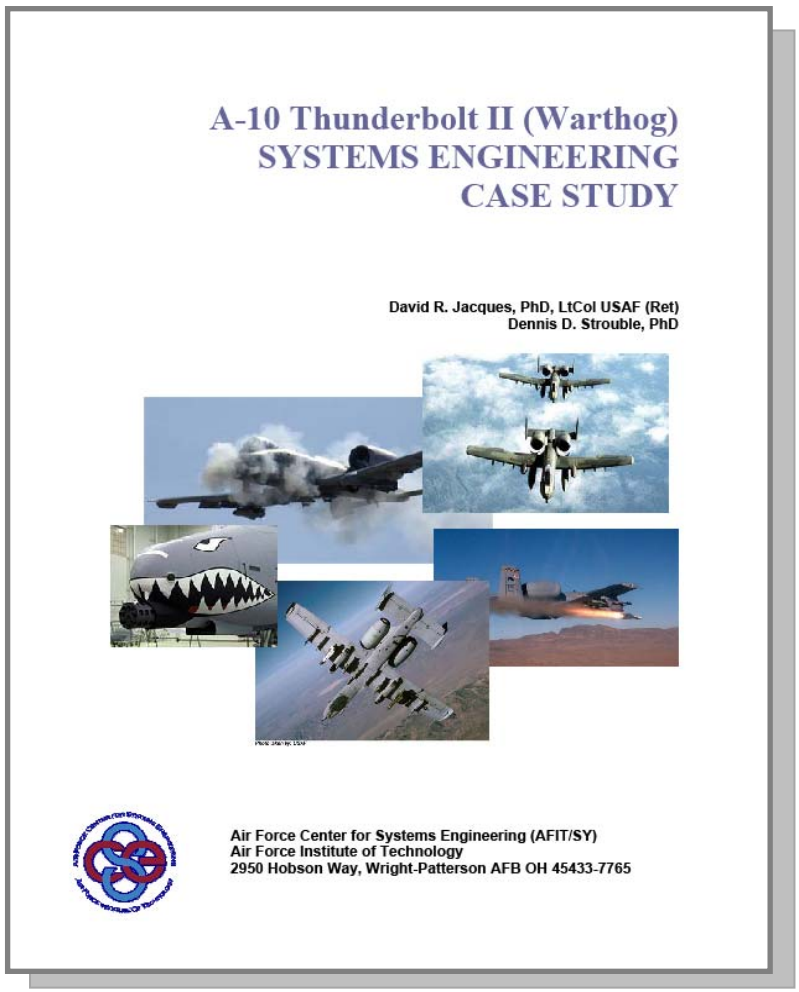

Sustaining Systems Engineering:

The A-10 Example

(Based on A-10 Systems Engineering Case Study)

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Overview

- Systems Engineering in Sustainment Phase
- A-10 Development and Operational Service
- Aircraft Structural Integrity Program
- Structural Problems on the A-10
- HOG-UP/Service Life Extension
- Re-winging Decision and the A-10C
- Summary

SE Sustainment Activities

A Partial List:

- Execution of strategies for operations, sustainment and, when necessary, disposal
  - Maintain baselines, data, and supply chain
- Maintain Operational Suitability, Safety and Effectiveness
  - Monitoring and comparing performance and condition to design and prediction models
- Re-engineering of legacy system performance requirements and designs
- Decision analysis support for upgrades/mods and life extension decisions
  - May include modifications to maintenance concepts

Aircraft Structural Integrity Program (ASIP)

- ASIP Initiated in 1958
  - Monitor and evaluate structural health of AF aircraft
  - AFI-63-1001 requires plan, MIL-HDBK 1530 provides guidelines and details
- During 1970's and 80's
  - Damage Tolerance Assessments (DTA)
  - Inspection and modification programs
  - Fatigue tests on wing, fuselage, and full aircraft
  - Used to develop individual aircraft tracking program, and tech orders for inspection, maintenance and repair actions

A-10: Early Struggles

- Within the Air Force
  - Close Air Support (CAS) was considered less important than strategic bombing, air superiority, and interdiction
  - Tactical force mix required less expensive aircraft, but AF still favored fast multi-role fighters
  - F-5, A-7D were early choices for the CAS role
  - Reluctantly agreed to pursue specialized CAS aircraft

A-10: Early Struggles (ctd.)

Within the Army

- Unsatisfied with level of CAS provided by Air Force
- Doctrine evolving towards air mobile tactics
- Increased reliance on armed helicopters
- Initiated development of AH-56 Cheyenne
- Competed with AF for CAS development $

Johnson-McConnell Agreement (1966)

- AF retained CAS mission, but recognized role of Army helicopters for fire support
- Army gave up large fixed-wing transports

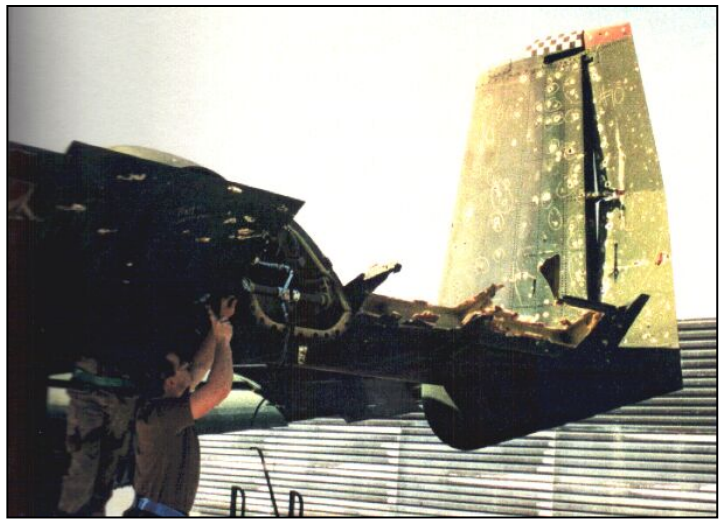
A-10: The aircraft that almost wasn't!

- Key sustainment features:
  - Survivability – redundancy, shielded systems, engine placement
  - Maintainability – interchangeable left/right side parts, simple skin panels, engine placement
  - Cost Considerations – lean avionics (no night/adverse weather systems), ammunition cost reduction efforts

A-10 Deployment, and Debate

- Final production aircraft delivered in 1984
  - No service support for continued production (F-16 factor)
- Army Air-Land Battle doctrine
  - Greater reliance on Battlefield Air Interdiction (BAI)
  - Survivability concerns associated with greater SAM threat
  - By 1985, studies emerged suggesting an A-16 as a replacement for the A-10
- Defense Authorization Act for FY88-89
  - Directed completion of CAS/BAI Master Plan
  - Directed yet another CAS fly-off (A-10, F-16, A-7, AV-8, F/A-18)

Desert Storm



- Performance vindication
  - High effectiveness, and demonstrated survivability
  - High sortie rate, low maintenance man hours/flight hour
  - CAS F-16's performed poorly, reverted back to standard
- Post war decisions
  - Serious proposal floated by CSAF to give CAS and A-10 to Army in exchange for ATACMS, space mission, et.al.
  - AF decided to keep A-10, but in reduced numbers

A-10 Structural Configurations

Retrofit WOP Configuration	Intended for Aircraft 7-441 (not completed on all aircraft)	Thin wing center panel, cold worked at WS 0, Retrofit thick wing outer panel. Qualified to 6,000 hours Spectrum 3.
Production WOP	Aircraft 442-581	Thin wing center panel, cold worked at WS 0, Production thick wing outer panel. Qualified to 6,000 hours Spectrum 3.
Thick Skin Configuration	Aircraft 582 and subsequent	Production increased wing center panel and outer panel thickness. Configuration qualified to 8,000 hour service life.

Notes:

- Original design life was 6,000 flight hours
- Design load spectrum changed in 1977 based on measured fleet usage
- Fatigue test failed at less than 60% of new spectrum service life
- Resulting production and retrofit changes indicated above

ASIP Implementation

- Fairchild sold A-10 rights to Grumman in 1987
  - Fairchild ceases to exist shortly after
- Grumman delivers updated DTA and associated Force Structural Maintenance Plan (FSMP)
  - Never fully incorporated into tech orders, not accomplished
  - Difficulty with field inspections, budget constraints cited
- Analytical Condition Inspection (ACI)
  - Addressed some inspection locations, but on few aircraft
  - Cracks found in several locations in 1995, 96
  - Cracks classified as minor

And then, the wheels started to come off!

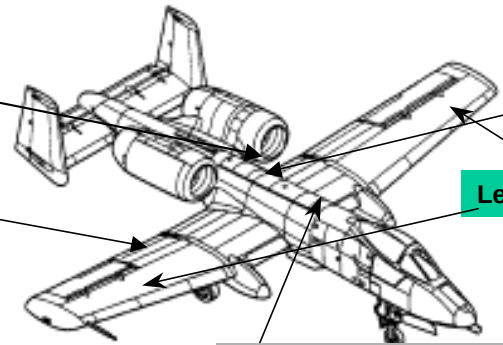
- 1994 – Northrop merges with Grumman
  - Although NG still the prime, most mods competed or done organically by government
  - “Fallout funds used to task NG to incorporate design changes into configuration baseline drawings…”
- 1995 Base Realignment and Closure (BRAC)
  - Closes McClellan AFB
  - Maintenance and repair operations moved to Hill AFB
  - Results in loss of 80% of experienced workforce by 2000
- 1997 – SPO competes prime sustainment contract
  - Lockheed Martin Systems Integration wins
  - NG expected to be part of team due to proposed LM-NG merger
- 1998 – LM-NG merger called off
  - NG reduced to supporting role

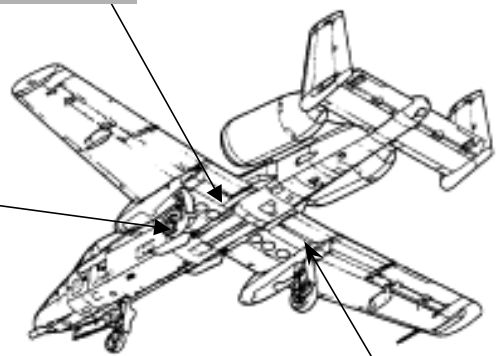
HOG UP

- 1998: Northrop Grumman delivers “A-10A Aircraft Wing Center Panel Rework-Fatigue Life Improvement” report
  - Detailed changes required to support 16,000 hour service life
  - Based on assumption that 1993 FSMP implemented
- 1999: SPO initiates HOG UP
  - Repair program vice modification
  - Allowed use of maintenance funding
  - Did not require acquisition approval
  - Configuration Control Board action not required
- HOG UP expands to catch other necessary changes
  - No composite assessment of structural risk
  - Cost growth from $140M to $600M, not including unprogrammed cost for WS-23 inspection and repair
  - No full-scale fatigue test to validate HOG UP

HOG UP Evolution

Hog Up 1999 and 2003





Forward/Aft Fuel Tank Cavity Corrosion control/inspections

Wing Outer Panel (WOP) Mid-Spar Web Rework

Wing Center Panel (WCP) Rework N/A for USAFE

Center Fuselage Fuel Cell Floor & Boost Pump Flange Repair

Wing Station 90 Repair

Center Fuselage Inspection Area

Leading Edges

Fuselage Station 365 Bulkhead Repair

Paint

Flight Control Rework

ACI Inspections

Additional ACI Inspections

1999 – Original Hog Up

2003 – Current Hog Up

Sometimes, things have to get worse before they can get better!

- HOG UP delays due to WS-23 inspection and repair
  - Number of unusable wings higher than expected
  - Predictions that serviceable wings would run out by 2011
  - Back-up of aircraft in depot due to longer than expected repair times
- Catastrophic failure of HOG UP wing in fatigue test (2003)
  - Well short of 16,000 hour life expectancy
- 2005: AF completes business case analysis
  - Option 1: Organic sustainment of thin skinned wings, increase SLEP for all wings ($4.6B)
  - Option 2: Buy 135 wings, increase SLEP for remaining wings ($3.16B)
  - Option 3: Buy 242 wings and avoid cost of SLEP ($1.72B)
- 2006: AF competes contract for new wings! (Option 3)
  - Boeing wins contract to build wings, to be installed on a Fairchild Republic aircraft, being maintained by Lockheed Martin!

Learning Principle 5*

Successful design, development and production is not enough to sustain a system throughout its life cycle.

- A-10 sustainment efforts were severely impacted by a number of factors
  - On-again, off-again retirement decisions
  - Vanishing prime contractor
  - BRAC, and general turnover of government personnel
- Loss of condition baseline led to initially poor decisions regarding life extension efforts
- A-10 sustainment has recovered, but after significant cost associated with the original HOG-UP program

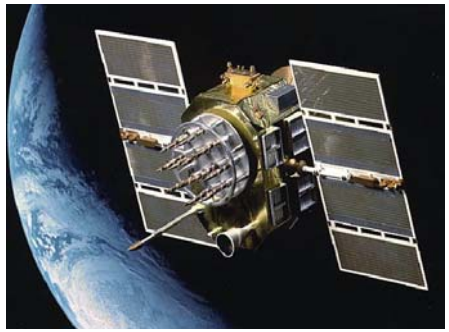
* 6 Learning Principles are contained in the A-10 Case Study

A Second Life for a Modern Day Hog

- Low Altitude Safety and Targeting Enhancements (1990's)
- Embedded GPS/INS system added (1999)
- Precision Engagement (2005)
  - Results in A-10C Designation
- Replacement of TF-34 Engines (Proposed)

Air Force Center for Systems Engineering Case Studies

Hubble Space Telescope



GPS (Global Positioning System)

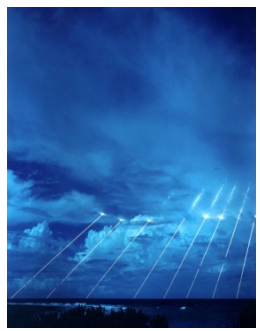
F-111 Aardvark

C-5 Galaxy

B-2

TBMCS (Theater Battle Management Core Systems)

A-10



Peacekeeper Intercontinental Ballistic Missile

Website:
http://www.afit.edu/cse/

Ongoing & Future Case Studies

International Space Station

Underway

MH-53J/M Helicopter

FY09 Option

E-10

FY10 Option

Global Hawk

Underway

KC-135 Simulators

FY09 Start

T-6A Texan II

FY10 Start

Questions?