Headquarters U.S. Air Force

Integrity - Service - Excellence

F-22 HSI Case Study

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The HSI Challenges

- Technology integration - facilitate operations and sustainment
  - Maintenance access vs. low observable
  - Engine advances vs. maintainability
  - New sensors / displays vs. information overload
- Rivet Workforce and other sustainment initiatives
  - Manpower reductions prior to verification / test
  - AFSC compression vs. training burden
  - Ability to find and train the right people / skills / clearances
  - Overload vs. “Maytag Repairman” syndrome
- Programmatic issues
  - Acquisition / procurement vs. ownership costs
  - First Integrated Product Team (IPT) approach

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The Setting

- Receptive PM
  - Tailored work breakdown structure
  - Actively sought human factors / HSI expertise
  - Engineering, Human Factors, Manpower / Personnel, Training, Logistics all integrated
- Knowledgeable Deputy for Logistics
  - Proactive in addressing maintenance / sustainment up front
  - Blue Two Visit (BTV) – government and industry
- Acquisition logistics team available at ASC
- AF HSI IMPACTS program / process established
- Air Force manpower reduction goals / requirements

Manpower / Personnel / Training Analyses

MPT Analyses
Constraints / Challenges

- Big AF goal to implement “Rivet Workforce” AFSC Compression
  - 5 AFSCs vs. predecessor 15
- Meet “R&M 2000” objectives
- All on-equipment AFSCs must perform APG tasks
- Support future growth for hardware / software
- Reduced / simplified support equipment
- Reduced logistics footprint
- All weather - Day / Night – All locations
- Rapid reaction taxi / takeoff

MPT Analyses
Approach

- Independent IPT from acquisition logistics team
  - Reported to PM and DPML
- Evaluate predecessor option and 3 alternatives
- Integrated treatment of Manpower, Personnel and Training
  - LCOM data
  - Saint / Micro-Saint analyses
  - Logistics support analyses
  - Repair level analyses
  - Instructional systems development
- Determine optimal ownership cost with best utilization rates

Human Systems Integration: F-22 HSI Analysis (MPT-Analyses)

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AFSC STRUCTURE	15 AFSC RIVET WORKFORCE ii		10 & 7 AFSC MIN-COMPRESSION & MID-COMPRESSION		5 AFSC MAX-COMPRESSION	
PAA (SQD/WING)	24	72	24	72	24	72
MANPOWER						
ON-EQUIP	107	312	126	369	114	333
OFF-EQUIP	105	271	67	169	61	169
TOTAL*	212	583	193	538	175	502
SPA - DIRECT Mx	8.8	8.1	8.0	7.5	7.3	7.0
SPA - TOTAL Mx		9.4		8.5		8.0
AVERAGE MANPOWER ON-EQUIPMENT UTILIZATION	45%		52%		53%	

AFSC Options / Utilization Rates

NOTE: Manpower figures are based on 1993 analyses and not reflective of current requirements.

Human Systems Integration: F-22 HSI Analysis (MPT-Analyses)

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MAINTENANCE MANPOWER SAVINGS VS 15 AFSC STRUCTURE

MANPOWER	10 & 7 AFSC MIN-COMPRESSION & MID-COMPRESSION	5 AFSC MAX-COMPRESSION
REDUCTION PER SQUADRON	20	20
REDUCTION PER WING	45	80
REDUCTION FOR F-22 AIR FORCE	567	882

Based on:
- Direct Maintenance Only
- 8.6 Wings - Peak

Is this the right answer?

Manpower Savings Options

NOTE: Manpower figures are based on 1993 analyses and not reflective of current requirements.

Human Systems Integration: F-22 HSI Analysis (MPT-Analyses)

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LIFE CYCLE COST COMPARISON - 8.6 WINGS (PEAK)

AFSC	SPA	AVE CRS LENGTH	AVE WK IN TNG	TOT INIT TNG $	20 YR REC TRNG $	20 YR WAGES	LCC $B
15	9.4	14	15	.1	.2	3.2	3.5
10	8.5	19	17	.1	.2	2.9	3.2
7	8.5	29	30	.1	.4	2.9	3.4
5	8.0	37	41	.2	.4	2.8	3.4

BASED ON:

AVE ANNUAL Mx ENLISTED O & S - $27,870.00
AVE WEEKLY TRAINING COST - $853.85
AVE ANNUAL Mx TURNOVER RATE- 13%
NO. WINGS - 8.6 (630 PAA PEAK)
NO OVERHEAD INCLUDED IN SPA

Less is not always best for LCC

NOTE: Manpower figures are based on 1993 analyses and not reflective of current requirements.

Human Systems Integration: MPT Impacts to Ownership Costs

- **F-22 Raptor**
  - **Conducted Maintenance AFSC structure studies**
    - **LCC Savings: $335M**
  - **Proposed ACC maintenance organization restructure**
    - **LCC Savings: $442M**
  - **HSI analyses offered four options for specialties:**
    - **15, 10, 7, or 5**
    - **Max cost savings: 10**
    - **LLC Savings Ratio 400:1**

Source: AF submission to 2007 HASC Report

NOTE: Manpower figures are based on 1993 analyses and not reflective of current requirements.

Early HSI analyses for total manpower / personnel requirements

Engineering the F-119 Engine

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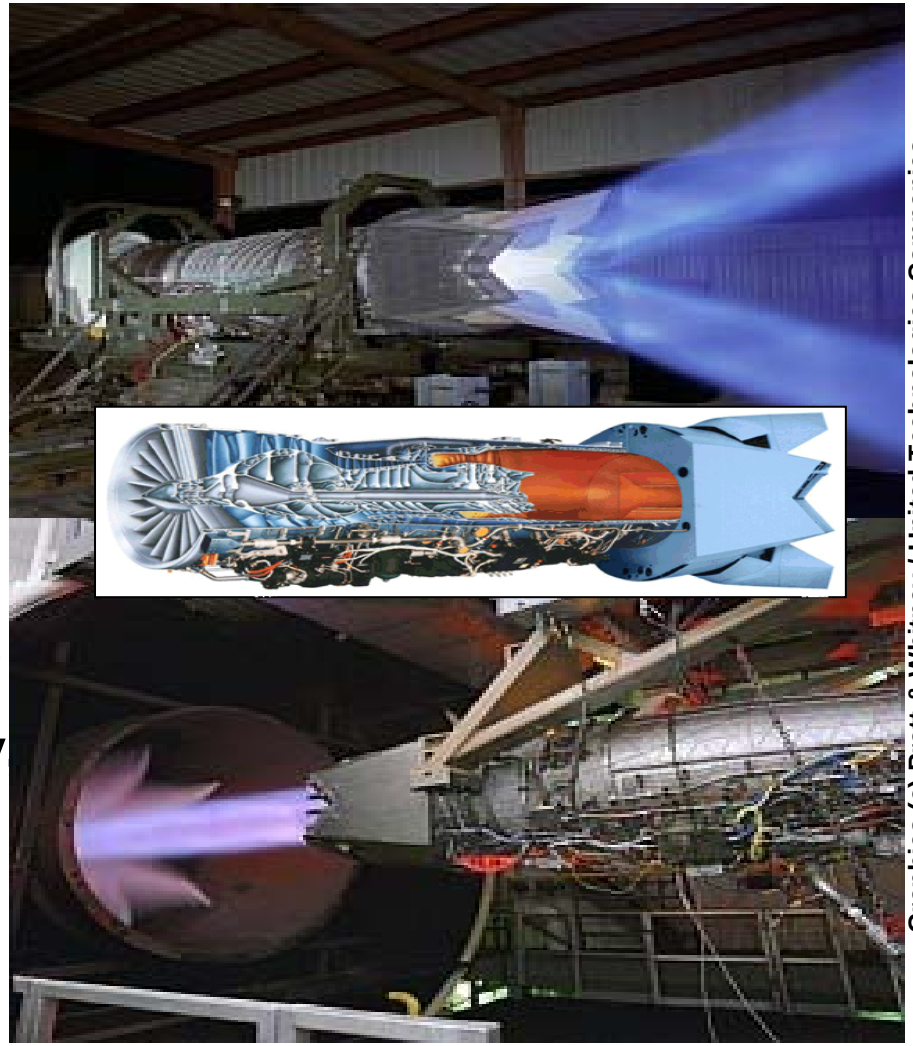
F-119 Engine

- Most powerful fighter engine of its time
- Supersonic (non-afterburning) cruise capability
- Evolved from advanced engine initiatives
- Development team focused on total integration
  - Simplicity
  - Accessibility
  - Maintainability
  - Commonality
  - Sustainability (Logistics footprint)
- Increased emphasis on external engine components

Human Systems Integration
F-119 Engine Design

- **F119-PW-100 Engine**
  - **Design incorporated reduced manpower requirements**
    - **Maintenance tool kit - 6 tools**
    - **Reduced number of parts**
    - **Ease of inspection / servicing**
    - **No safety wire**
    - **8 total connection points**
    - **All LRUs / LRCs accessible**
    - **Engine change-out: ~2 hours**
  - **Results: Increased availability maintainability, safety, and occupational health**

Direct results from HSI in initial design and construction



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F119 Key Features

Supportability, Maintainability, Safety & FOD Prevention

Removable Spraybars

Axially Split Cases

Accessible Mounts Adaptable to Right or Left Side Installation

Modular Engine Construction

Fan Trim Balance

Fast Removal Gearbox

Centrally Located Consumables / Interfaces

Easily Inspectable

- Borescope Ports
- Split Cases

Easily Maintainable

- Accessible LRU's-one Deep
- 20 minute LRU R&R
- 90 minute Engine R&R
- Interchangeable Components
- Color Coded Harnesses
- Quick Disconnects
- No Trim Required
- No Oil Tank
- No Component Rigging
- "Expert" Diagnostic System
- Captured Fasteners
- No Safety Wire
- 1/1000 UER/EFH rate
- MTBM of 200/EFH

Reduced Support Equipment

- 194 "O and I" Tools
- 6 LRU Tools
- SE Footprint Reduction
  - 65% Volume
  - 60% Weight

Engine Supportability & Maintainability

- No Component Rigging, Oil Tank, or Safety Wire
- Fast-Removable Gearbox
- Removable Spray Bars

- Ground Level Access – All LRUs on Bottom of Engine
- 40% Fewer Parts than Current Fielded Engines
- Interchangeable Engine Mounts (left to right)
- Self Trimming
- Only 6 LRU R&I Tools Req'd

Other F-22 HSI Applications

F-22 HSI
Other Applications

- Cockpit / Crew Systems
  - Extensive design simulations
  - Control / display integration & Information fusion
  - Active noise reduction
  - “G” protection / Life Support
- Maintenance & Sustainment
  - 80+ specific HSI relevant requirements impacting maintainability
  - Persistent, focused attention on logistics / maintenance footprint
  - Integrated approach

HSI
Key Relevant Requirements

- Maintenance, logistics, training analyses – reduce AFSCs
- On aircraft access / replacement
  - Avionics backplane
  - Quick disconnects
  - Software loading
  - Engine, accessories, throttles, and LRUs
- Common parts / tools / support equipment
  - Commonality with JIAWG, SE, NATO, training devices
  - No on equipment safety wire, cotter pins, bent tab washers
  - Spare parts provided with interface connections installed
  - Use JP-4, JP-5 or JP-8
  - Common, durable fasteners - minimal calibrated torque

HSI
Other Relevant Requirements

- Maintainable by 5th% female – 95th% male population
  - Ease of inspection in / around ejection seats

- Protection from toxins, radiation, thermal hazards
  - Installed & uninstalled environmental protection
  - Compatible with chem / bio / arctic gear

- Single point weapons station safing w/ visual verification
- Countermeasures safing with single accessible device
- Load without interference from other loaded stations

- Guides to preclude misalignment / improper installation
- Greater FOD tolerance / protection
- External fuel tank isolation during fuel / defuel

HSI
Other Relevant Requirements

- **Minimize support equipment – design for ease of use**
  - **100% fault detection / isolation**
  - **90 Minute engine change time (crew of 4)**
  - **Single scope size for all bore-scope**
  - **Maintainer access to all bore scope ports within 30 minutes**
  - **Gravity fill oil tanks to preclude over servicing**
  - **No special tools for intake and exhaust inspections**
  - **Fuel system interfaces for ease of service / inspection**
  - **Interchangeable external fuel tank (F-15 common)**
  - **Armament load crews limited to 3 people**
  - **No mirrors required for inspections**

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Designed-in Supportability & Maintainability Features

Access / Maintainability

- Ground Level Access:
  - Avionics - Engines
  - AMADS - Weapons
  - Inspection - Servicing
- Modular Avionics
- Fuel Pumps External of Tanks

Concurrent Servicing Operations

- Simultaneous Ammo/ Weapon Loading and Servicing
- Single Point Refueling
- Single Point Consumables Status Check
- Ext/ Ret Launchers using PMA from ground

Self Sufficient

- APU
- OBOGS
- OBIGGS
- Engine Start

Fault Detect / Isolate

- Built in Test / Test Sensors
- Signal Insertion and Signal Wrap Around
- Fault Filtering
- Failure Data Recording

Reduced Support Equipment

- 75% Less SE than Legacy Systems
- Only 6 Significant Items
  - IMIS - 270 Volt Cart
  - PAO Cart - Compressor Cart
  - COLT Tester - Engine Trailer

Reliability

- Fault Tolerant Avionics
- Liquid Cooled Avionics
- Composite Structure
- F119 Engine
- Flt Control Electronic Function w/ ECS Loss
- Design and Test to Actual Usage and Environment

Systems Engineering Lessons

- Tailor the WBS
  - Include the human with the hardware and software
- Right IPTs with right team members
  - Develop trust / confidence in government / industry relationship
  - Fight for longevity / consistency in membership
  - Know users / maintainers
  - Understand CONOPs and operational issues / missions
- Dare to set tough objectives
  - Conduct sound analyses to see what's possible
  - Decide what's optimal for all concerned
- Focus on usability, suitability and effectiveness
  - Operators, maintainers and supporters

Systems Engineering Lessons

- Challenge team members to get the interfaces right
  - Before hardware and production software are cut
  - With normal procedures and worst case (chem / bio, etc.)
  - Resolve challenges or go back to advanced development
- Do not underestimate the value of design simulation
  - Work the human interfaces early and often
  - Make certain you get consistent / timely support from users
- Be able to address HSI from a risk assessment basis

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Just Do it!!!

Make it REAL

***R*elationships – integrate competency**

***E*ngagement - be proactive and work it**

***A*ssessment - measure it and improve**

***L*essons Learned – capture and use**

Policy & Guidance

HSI Policy & Guidance

Policy / Instructions

- DoDD 5000.01
- DoDI 5000.02
- CJCSI 3170.1
- AFPD 63-1 / 20-1
- AFI 10-601
- AFI 36-2251
- AFI 48-101
- AFI 63-101
- AFI 63-1201
- AFI 99-103

Guidance

- DAG Chapter 6
- A&S Toolkit (multiple checklists)
- Requirements Pocket Guide
- HSI in Acquisition (3 Volume Set)
- AFHSIO & 711th HPW Web Sites
- AF HSI Handbook
- Handbook of HSI (Booher 2003)
- Mil Std 1472 & Mil Std 46855A
- INCOSE Systems Engineering HDBK