Air Force Materiel Command

Product Support Analysis - Maintenance Planning

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Purpose

Discuss select maintenance planning activities during Product Support Analysis and their impact on sustainment

Agenda

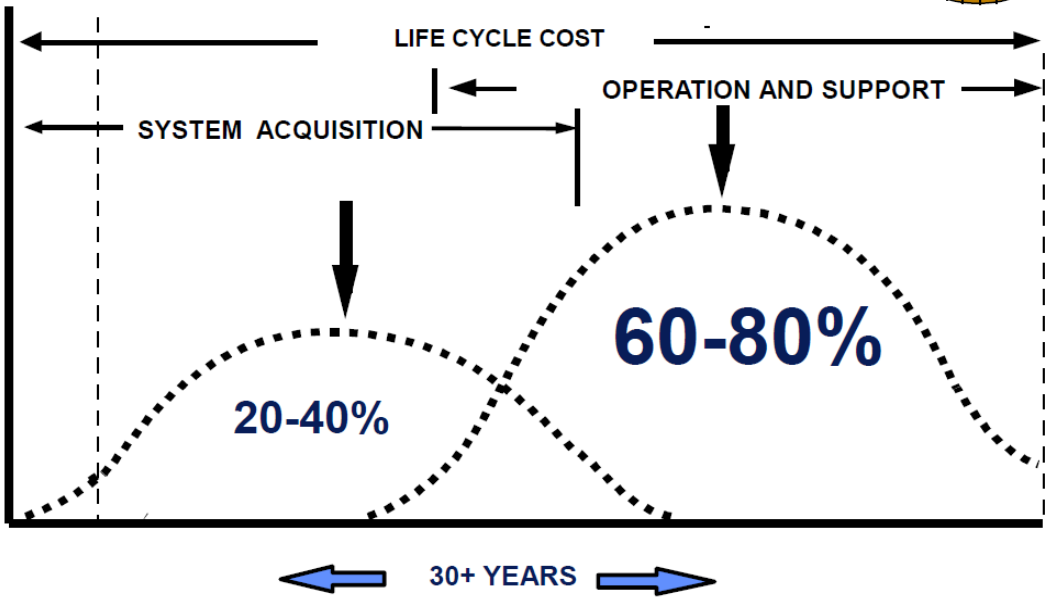
- Importance of Maintenance Planning
- Sustainment KPP, KSAs, Outcome Metrics
- Interactions of RAM Metrics
- Types of Maintenance Analyses
- Example A9A Projects
- Summary
- Discussion

Life Cycle Cost

Why is Life Cycle Management so Critical?

Defense Acquisition University

Typical DoD Acquisition Program with a Service Life of 30+ Years



Nominal Life Cycle Cost Distribution

Sustainment KPP & KSAs

Mandatory Sustainment KPP & KSAs

- **A Sustainment KPP (Availability) & two mandatory supporting KSAs (Materiel Reliability and Ownership Cost) will be developed for all JROC Interest programs involving materiel solutions**
  - **In the case of mandated Sustainment KPP (Materiel Availability), the supporting Materiel Reliability and Ownership Cost KSAs require changes to be documented in the subsequent update to the APB.**
- **Definitions:**
  - **KPPs are those system attributes considered most critical or essential for an effective military capability"**
    - Failure to meet a KPP threshold may result in reevaluation or reassessment of the program or a modification of the production increments
  - **KSAs are system attributes considered most critical or essential for an effective military capability but not selected as a KPP.**
    - KSAs provide an additional level of capability prioritization below the KPP but with senior sponsor leadership control (generally 4-star level, Defense agency commander, or Principal Staff Assistant)

Additional Information: 31 Jul 09 JCIDS Operation Manual
https://www.intelink.gov/wiki/JCIDS_Manual

Sustainment Metrics

Four DoD Life Cycle Sustainment Outcome Metrics

Defense Acquisition University

Goals Determined By Warfighter Needs

- **Availability (Materiel & Operational Availability) (KPP*)**
  - A Key Data Element Used In Maintenance & Logistics Planning
- **Materiel Reliability (KSA*)**
  - Provides A Measure Of How Often The System Fails/Requires Maintenance
  - Another Key Data Element In Forecasting Maintenance/Logistics Needs
- **Ownership Cost (KSA*)**
  - Focused On The Sustainment Aspects Of The System
  - An Essential Metric For Sustainment Planning And Execution
  - Useful For Trend Analyses – Supports Design Improvements/Modifications
- **Plus Mean Downtime**
  - A Measure Of How Long A System Will Be Unavailable After A Failure
  - Another Key Piece Used In The Maintenance/Logistics Planning Process
- **Other Sustainment Outcome Metrics May Be Critical To Specific Systems, And Should Be Added As Appropriate**
- **Established in 10 Mar 07 DUSD (L&MR) Policy Memo**
  - https://acc.dau.mil/CommunityBrowser.aspx?id=141309

** Sustainment KPP & KSAs Included in CJCSM 3170*

These 4 Life Cycle Sustainment Outcome Metrics Are Universal Across All Programs And Are Essential To Effective Sustainment Planning

Sustainment Metrics (cont.)

- **Material Availability**
  - **Am = TAI – (Depot Possessed + UPNR + NMCS + NMCM + NMCB)****
  - **Should be realistic, achievable**
  - **Ripple effect through sustainment planning/execution**
- **Material Reliability**
  - **Directly affects availability**
  - **How much should be invested (time, $) up front?**
- **Ownership Cost**
  - **Locked in by early decisions**
    - Will BCA frequency mitigate?
  - **Driven by material availability/reliability goals**
- **Mean Down Time**
  - **Directly affects availability**
  - **Determined in part by reliability and maintainability**

** Total Active Inventory (TAI), Unit Possessed Not Reported (UPNR), Not Mission Capable Supply (NMCS), Not Mission Capable Maintenance (NMCM), Not Mission Capable Both (NMCB)

Effects of Reliability and Maintainability on Availability

Reliability	Maintainability	Availability
Constant	Decreases	Decreases
Constant	Increases	Increases
Increases	Constant	Increases
Decreases	Constant	Decreases

Types of Maintenance Planning Activities

- Level of Repair Analysis (LORA)
- Depot Source of Repair (DSOR)
- Depot Activation
- Repair Network Integration (RNI)

Example Projects

- **LORA Study**
- **DSOR RIE**
- **KC-46 PDM Capacity Simulation**
- **F100-229 Repair Network Simulation**

LORA

- **Objective: Determine the state of LORA in the Air Force and make recommendations**
- **Sustainment Impacts:**
  - **50/50**
  - **Ownership Cost (KSA)**

Background

- **Air Force Logistics Readiness Board (AFLRB) meeting 29 – 30 Nov 2010**
  - **Process for developing item Expendability Reparability Recoverability Codes (ERRCs) vary by program office; often driven by contractor processes/models.**
  - **Board established new action items to work toward standardization of the ERRC assignment process. These action items are:**
    - Review the need for and current state of the existing Air Force LORA model.
    - If warranted, develop an Air Force LORA model for initially assigning item ERRCs.
    - Conduct analysis to determine when an LORA reassessment should be conducted to update item ERRCs.
- **A9A agreed to provide analysis support to review candidate models and policy to make a model recommendation and identify policy gaps directing LORA over the life cycle.**

LORA—From Integrated Product Support (IPS) Element Guidebook

- ***Level-of -Repair Analysis (LORA) is the most important physical supportability analysis business decision made during acquisition of a system.*** LORA produces the final answer as to how a system will be supported. LORA is performed in two steps: (1) using non-economic decision criteria to make the initial support decisions and (2) using an economic model to determine the most cost effective alternative to provide support for the system.
- The LORA process produces the final support solution for the system. It determines where each required maintenance action will be performed, the physical resources that must be available to support performance of maintenance, and what the support infrastructure must be capable of sustaining throughout the operational life of the system. The results of LORA are documented and used as the basis for development of the physical resources for support of the system.
- The LORA process starts by identification of the options where maintenance can be performed. It is common for systems to use 2 or 3 levels of maintenance. LORA produces a decision for each item within the system, indicating where each maintenance action for the item will be performed.
- Non-economic LORA decision criteria are a list of rules or guidelines that are used to determine if there is an overriding reason why maintenance should be performed. Some organizations have policies that any item costing less than a predetermined price level will be discarded and replaced rather than be repaired.

Identified Gaps

- **No standard tools/methods to conduct/assess LORAs in acquisition**
- **No AF guidance on updating LORAs after Milestone C**
  - **Frequency**
  - **Tools**
  - **Methods**

Recommendations

- **Require AF assessment of contractor-conducted LORAs**
- **Require LORAs at specific points in sustainment**
- **Follow Army's example of requiring a standard tool for LORA analyses throughout the life cycle**
  - **Adopt Army's COMPASS tool**
    - HQ AFMC/A9A and AFLMA have evaluated
    - Navy has already adopted
    - Available at no cost, fully supported
- **Supplement/change AF Guidance/Policy as required**
- **Coordinate with SAF/AQ**

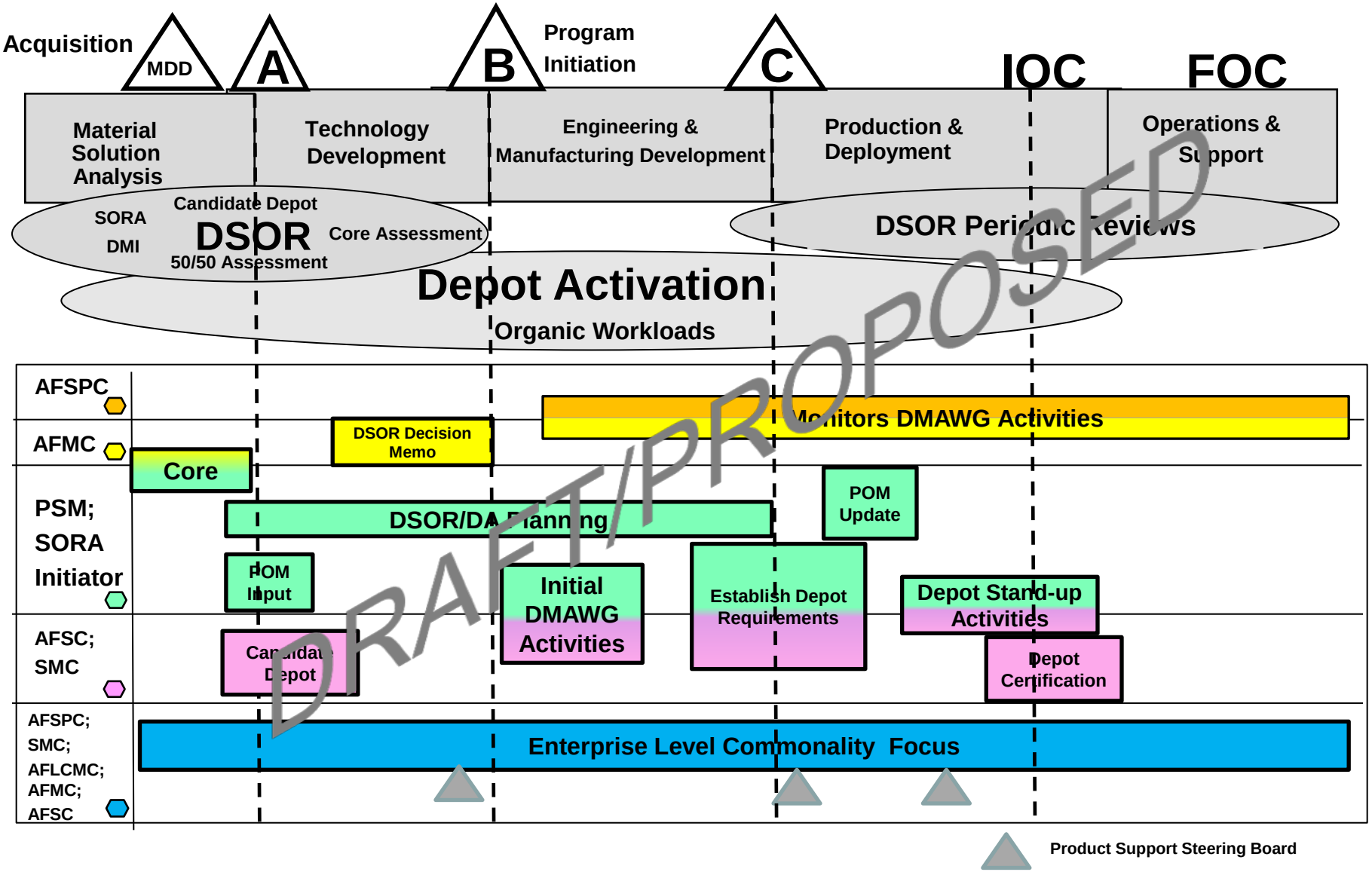
Depot Source of Repair (DSOR)

- **Objective: RIE to redefine the DSOR/Depot Activation Process**
- **Sustainment Impacts:**
  - **50/50**
  - **Ownership Cost (KSA)**

RIE Charter Problem Statement

- **Recent changes to laws, policies and reorganization to the 5 Center construct have adversely affected the DSOR process**
  - **Centers have minimal engagement responsibility in the Core/Candidate depot determination; key AFSPC and AFMC Center organizations must be engaged.**

Redefined End to End Process



Improvements

- **End to End Process Enables:**
  - **Realigned Core/Candidate Depot processes**
  - **Integrated DSOR and DA processes**
  - **Established minimum requirements to support DSOR**
  - **Refined DA planning prior to MS-A**
  - **Focused process on acquisition events and scheduled need dates**
  - **Addresses commonality across enterprise and life cycle**
  - **Expands governance structure to include PSSB**
  - **Established framework for metrics**

KC-46 PDM Capacity

- **Objective: Identify issues (if any) with the proposed Programmed Depot Maintenance (PDM) strategy**
- **Sustainment Impacts:**
  - **Am (KPP)**
  - **Ownership Cost (KSA)**

Proposed KC-46 PDM Strategy

- **Utilize the aircraft industry Maintenance Steering Group 3 (MSG 3) process to plan and execute scheduled maintenance**
- **Unlike most Air Force's PDM programs, will run a series of C-checks, one every 2 years, focusing on inspection of specific subsystems of the aircraft**
- **First KC-46 scheduled maintenance is slated for 2018**

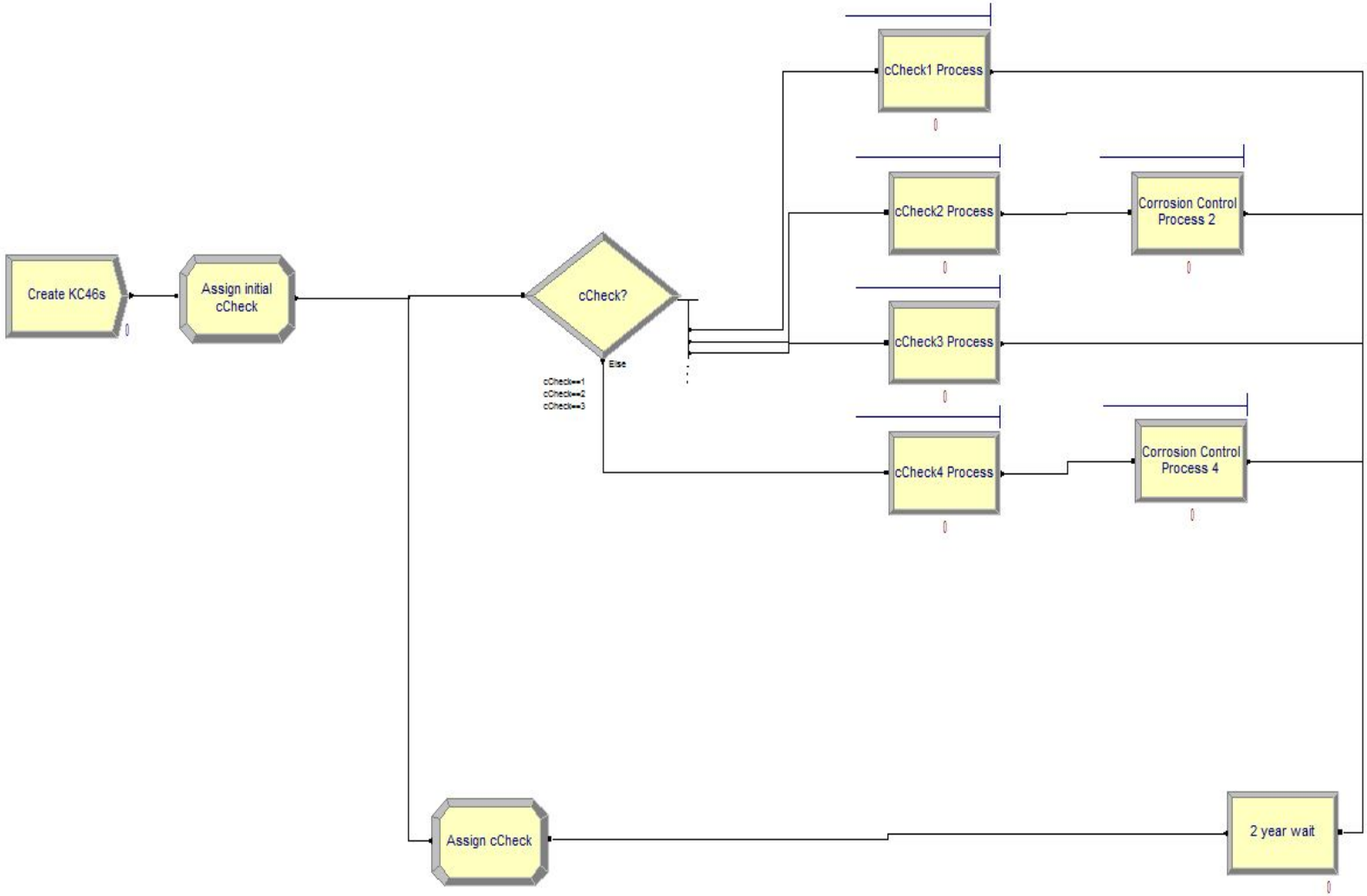
KC-46 PDM Strategy Study Approach

- **Use discrete-event simulation modeling to study the proposed PDM strategy**
- **Primary parameters of interest**
  - **Number of aircraft awaiting maintenance (in queue)**
  - **Number of aircraft at depot (queued, in maintenance)**
    - Depot Possessed segment of Am

KS-46 PDM Simulation Model Overview

- **Eight C-check docks: for maintenance of aircraft purged of fuel**
- **Two fuel maintenance docks: for maintenance of fueled aircraft**
- **Two corrosion control docks: for paint (after maintenance)**
- **Two corrosion control and fuel maintenance docks (multi-purpose docks): for maintenance and paint of fueled aircraft**
- **Model ran as follows:**
  - **Warm up of 15 years—allowed for delivery of all 179 aircraft**
  - **Additional run time 20 years of steady state**
  - **Five replications**

Model Layout (in ARENA)



Model Parameters

- **Used Triangular Distribution based on average flow days for each C-check**

	Maintenance Process			Corrosion Control Process		
cCheck	Low	Mid	High	Low	Mid	High
1	16	18	32	-	-	-
2	21	23	37	15	17	24
3	27	29	43	-	-	-
4	43	45	59	16	18	25

Results

- **No major delays**
- **Goal was to keep queue time under 90 days**
  - **To prevent over-fly**
- **Only area that appeared to challenge the system was the corrosion control process**
  - **Under 90 days but more than other C-checks**

	C-check 1	C-check 2	C-check 3	C-check 4	Corrosion (C-check 2)	Corrosion (C-check 4)
Average Queue Time	0.03	0.04	0.04	0.05	1.92	2.02
Max Queue Time	7.00	9.08	7.96	8.80	23.07	24.13

- **Utilization rates slightly higher for corrosion control docks**
  - **Could be an issue if corrosion control has higher flow days than modeled**
  - **Could drive longer wait times indicating more corrosion control docks needed**

Dock Type	Average Utilization (%)
C-check	0.75
Fuel Maintenance	0.27
Corrosion Control	0.79
Fuel Maintenance and Corrosion Control	0.89

Conclusions

- On average, between 10 and 11 aircraft at the depot
- Seems to align with the program plan to purchase 11 backup aircraft
  - Am goal is 89%
  - Ao: CDD objective requirement is 89%; threshold is 80%
- What are the implications to Am and Ao?
  - Am = TAI – (Depot Possessed + UPNR + NMCS + NMCM + NMCB)
  - Depot Possessed of 6% (11 aircraft) leaves 5% for all other statuses—may be difficult to achieve Am and Ao of 89% (KC-135 has averaged 21%)
- Informs planners that more backup aircraft may be needed

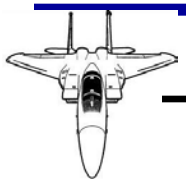
F100-229 RNI Simulation

- **Objective: Identify improvements to the F100-229 repair network that enable meeting serviceable engine levels more efficiently**
- **Sustainment Impacts:**
  - **Am (KPP)**
  - **Ownership Cost (KSA)**

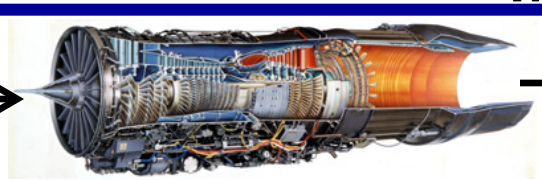
Approach

- Use discrete-event simulation to model F-100229 A/B repair network
- Use Design of Experiments (DOE) and the simulation model to build meta models (equations) for managers to use in exploring what ifs
  - In essence, “run” the model without running the model
- Use optimization techniques to identify best settings for all significant factors
- Update/embellish simulation model and DOE as appropriate

Enhanced Engine Velocity via Integrated Logistics (EEVIL) Model Overview



Engine unserviceable, removed, sent to JEIM

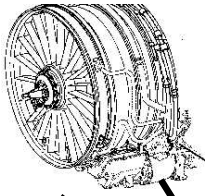


Base Supply: Serviceable Engine

JEIM

Module routed to base maintenance for module repair

Base Module Repair



Serviceable module routed to JEIM

Determined Beyond Base Repair (NRTS)

Depot Module Repair

Base Supply: Serviceable Module

JEIM Perspective

Enhanced Engine Velocity via Integrated Logistics (EEVIL)

JEIM Perspective

Engine unserviceable, removed, sent to JEIM

Base Supply: Serviceable Engine

JEIM Pipeline

AWM	ENMCS	In-Work

Model Factors Impacting ENMCS

- Base Module Spares
- Base Module Repair
- NRTS
- Depot Module Spares
- Depot Module Repair
- Order and Ship Time
- Retrograde

Magnitude of Experimental Design

- **23 factors at each base, 10 at depot**
  - **Engine Flow days (excluding ENMCS), Base Module TATs, Order & Ship Time, Retrograde Time, Depot Module TATs, NRTS Rates, Serviceable Modules at Depot**
- **Full factorial design would require 2^{33} or 8,589,934,592 model runs!**
- **Consulted with AFIT/ENS**
  - **Developed definitive screening design which allowed us to check for all main effects, all 2-way interactions, and for curvature of all main effects**
  - **Reduced number of runs required to 77**
    - Replicated 5 times
- **Response of interest:**
  - **Number of serviceable engines**
  - **ENMCS**
  - **Probability engine level is greater than or equal to WRE**

Meta Model Spreadsheet

INFOCON: 3 — UNCLASSIFIED — FPCON: Alpha

EEVIL 2_1.xlsm - Microsoft Excel

Enhanced Engine Velocity via Integrated Logistics vers2.0 (EEVIL 2.0)

Predicted # of Engines		95% Prediction Interval		
Lakenheath =	121	(109	, 130	)
Mt. Home =	61	(55	, 66	)
McEntire =	29	(25	, 31	)
Nellis =	55	(50	, 60	)
Toledo =	23	(20	, 26	)
Tulsa =	27	(24	, 30	)
TOTAL:	316			

# Serviceable Spares	
Lakenheath =	15
Mt. Home =	11
McEntire =	4
Nellis =	2
Toledo =	4
Tulsa =	5
TOTAL:	41

# Serv Spares are:	
Equal to WRE Req of	15
Exceeds WRE Req of	10
Equal to WRE Req of	4
Exceeds WRE Req of	1
Equal to WRE Req of	4
Equal to WRE Req of	5
Exceeds WRE Req of	39

Questions? Comments? Contact:
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Depot	
Core TAT Days	16
Gearbox TAT Days	29
Inlet Fan TAT Days	25
LPT TAT Days	12
Core OH Balance	24
Gearbox OH Balance	14
Inlet Fan OH Balance	27

Reset to Baseline

Set to Optimal

Optimal Option	
Nellis	
Eng AWM Days	7
Augmenter TAT Days	294
Augmenter RemRt	0.62
Eng In-Work Days	10
AUG Spares	5
Core RemRt	0.13
Core Spares	5
LPT RemRt	0.10
Inlet Fan Spares	6
Retrograde Days	3
GBX RemRt	0.03
HPT Spares	5
Inlet FanRemRt	0.41
LPT TAT Days	2
GBX Spares	1
LPT Spares	5
Core TAT Days	11
LPT NRTS Rate	0.50

Optimal Option	
Mt. Home	
Eng In-Work Days	48
Augmenter RemRt	0.10
Augmenter TAT Days	168
Eng AWM Days	3
Core RemRt	0.12
Core Spares	6
Eng Process Days	2
AUG Spares	5
OST Days	1
LPT RemRt	0.07
Retrograde Days	4
Inlet FanRemRt	0.09
LPT Spares	6
GBX Spares	6
GBX RemRt	0.06
Inlet Fan Spares	5
HPT Spares	6
Core TAT Days	7
HPT RemRt	0.02
Core NRTS Rate	0.50
LPT TAT Days	2

Optimal Option	7
Lakenheath	
Eng AWM Days	25
Eng In-Work Days	12
Eng Process Days	8
Augmenter RemRt	0.07
Augmenter TAT Days	78
Core RemRt	0.08
OST Days	20
LPT RemRt	0.07
GBX RemRt	0.06
Core Spares	6
Inlet Fan Spares	6
Retrograde Days	27
LPT Spares	6
Core NRTS Rate	0.50
Core TAT Days	40
GBX Spares	6
LPT NRTS Rate	0.50
AUG Spares	6
Inlet FanRemRt	0.07
Inlet Fan TAT Days	25

Optimal Option	
Toledo	
Eng In-Work Days	120
Augmenter TAT Days	250
Augmenter RemRt	0.53
Eng AWM Days	11
Core RemRt	0.76
Eng Process Days	48
Core Spares	5
AUG Spares	1
Inlet Fan Spares	5
Inlet FanRemRt	0.90
LPT RemRt	0.72
GBX Spares	2
LPT Spares	3
GBX RemRt	0.04
Retrograde Days	12
Core NRTS Rate	0.80
OST Days	1
HPT Spares	6

Optimal Option	
McEntire	
Eng In-Work Days	13
Eng Process Days	65
Augmenter TAT Days	10
Augmenter RemRt	0.20
Core Spares	4
AUG Spares	6
Core RemRt	0.06
GBX Spares	6
Eng AWM Days	1
Inlet FanRemRt	0.20
Inlet Fan Spares	6
LPT RemRt	0.45
LPT Spares	5
Retrograde Days	6
GBX RemRt	0.05
OST Days	2
Core NRTS Rate	0.50
HPT RemRt	0.04

Optimal Option	
Tulsa	
Eng In-Work Days	86
Eng Process Days	41
Eng AWM Days	57
Core RemRt	0.05
Augmenter TAT Days	120
Core Spares	6
Inlet Fan Spares	6
Augmenter RemRt	0.02
GBX Spares	5
LPT RemRt	0.04
LPT Spares	5
AUG Spares	6
Inlet FanRemRt	0.04
GBX RemRt	0.02
Retrograde Days	10
Core NRTS Rate	0.60
HPT RemRt	0.01
HPT Spares	6

Factor Inputs Legend	
	Large Impact (>2 Engines)
	Medium Impact (1 - 2 Engines)
	Small Impact (<1 Engine)
	Data Entry Cell

NOTES | Summary

Ready

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Results

- **Identified significant factors in repair network for improvement**
- **Identified optimal settings for each base as well as for entire network**
- **Provides engine managers a desktop tool that helps make repair network more effective and efficient**

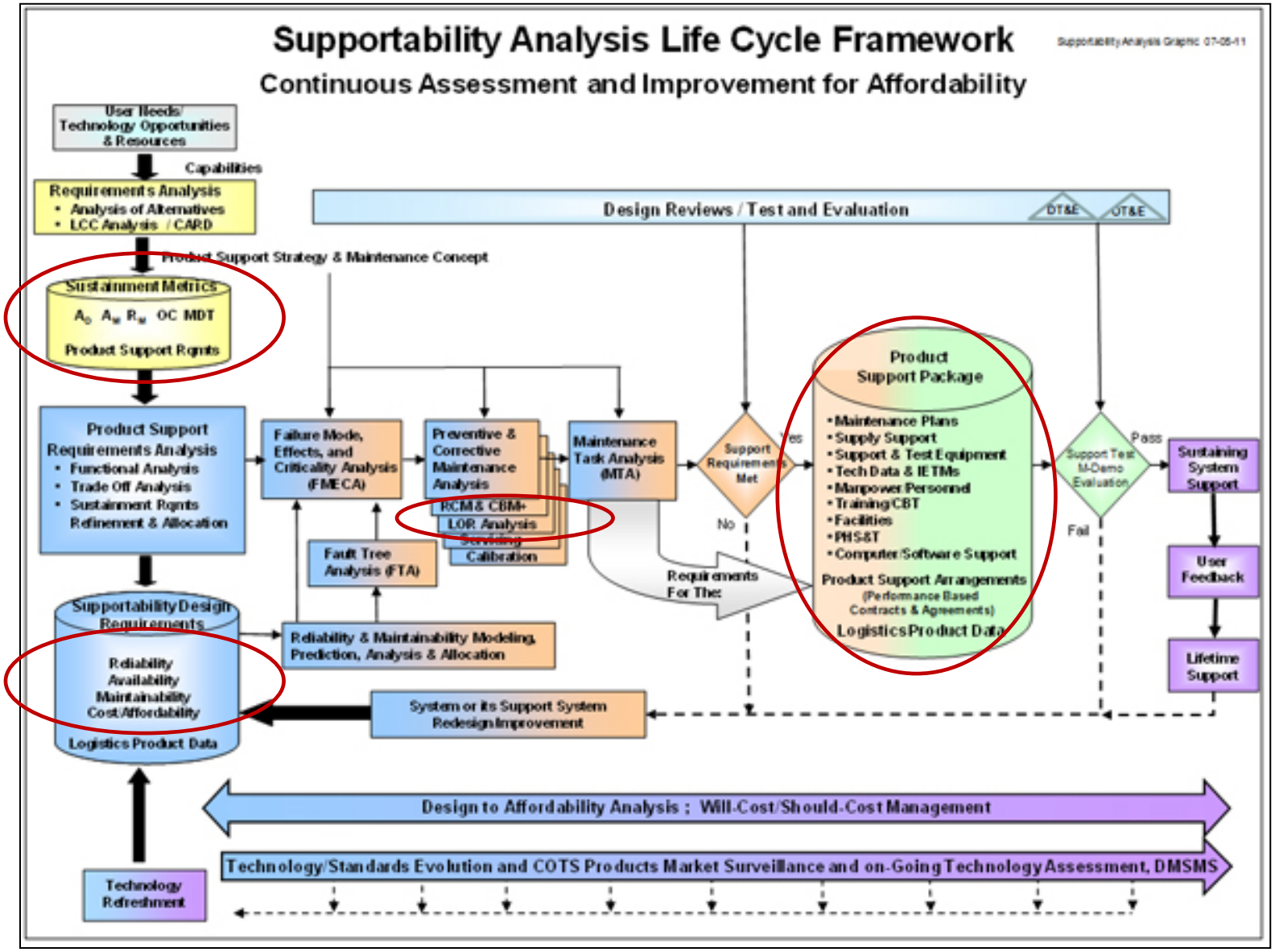
Summary

- **Maintenance planning has significant sustainment impacts**
- **Early, rigorous attention to KPPs and KSAs should guide maintenance planning thus improving product support**
- **Analysis tools like Simulation Modeling, Design of Experiments, and Linear/Nonlinear programming can inform maintenance planning**

AIR FORCE MATERIEL COMMAND

LEADING EDGE TECHNOLOGY • WORLD CLASS SUSTAINMENT • WAR-WINNING SYSTEMS

Focus Areas for Today



Sustainment Metrics

- **Availability**
  - **Material Availability (KPP)**
    - Am = (# operational end items) / (Total # ends items)
    - Am = TAI – (Depot Possessed + UPNR + NMCS + NMCM + NMCB)
  - **Operational Availability**
    - Ao = PAA – (NMCS + NMCM + NMCB)
- **Reliability (KSA)**
  - **Mean Time Between Failure (MTBF)**
  - **Must support both availability metrics**
- **Ownership Cost (KSA)**
  - **CAIG**

* Total Active Inventory (TAI), Primary Aircraft Authorization (PAA), Unit Possessed Not Reported (UPNR), Not Mission Capable Supply (NMCS), Not Mission Capable Maintenance (NMCM), Not Mission Capable Both (NMCB)

Ownership Cost (cont.)

- **As a minimum, the KSA is to include the following elements, as defined in the Cost Analysis Improvement Group (CAIG) Operating and Support Cost-Estimating Guide (October 2007):2.0 Unit Operations Element 2.1.1 only:**
  - 2.1.1 (only) Energy (fuel, petroleum, oil, lubricants (POL), electricity)
  - 3.0 Maintenance (all elements)
  - 4.0 Sustaining Support (all elements except 4.1 System Specific Training)
  - 5.0 Continuing System Improvements (all elements).

Tools Evaluation

	NRLA	COMPASS	LCOM
COST FACTORS INCLUDED			
Initial acquisition costs			
Replacement spares costs			
Support/Test Equipment (acq & Mx) costs			
Support/Test Equipment software costs			
Transportation costs			
Personnel training costs			
Repair labor costs			
Inventory management/admin costs			
Technical data acquisition costs			
Facility/overhead costs			
Disposal costs			
Repair materials			
INPUT FACTORS			
MTBF/break rate			
End-item Life Expectancy			
Condemnation rate			
Order & shipping time			
Repair time			
Safety spares levels			
Non-economic decision factors			
End item utilization			
Support/Test Equipment & supplies required			
Diagnostic time			
"False" removals			
Indenture levels			
REPAIR OPTIONS CONSIDERED			
Base-level Mx			
Depot Mx			
Discard			
Contractor Mx			
TECHNICAL CRITERIA			
Computer-based			
Automated			
ADMINISTRATIVE CRITERIA			
Helpdesk			
Training			
Documentation			
OUTPUTS			
Optimum maintenance policy(ies)			
Costs for optimum solution			
End item availability			
Sensitivity analysis			
Location/quantities of resources			

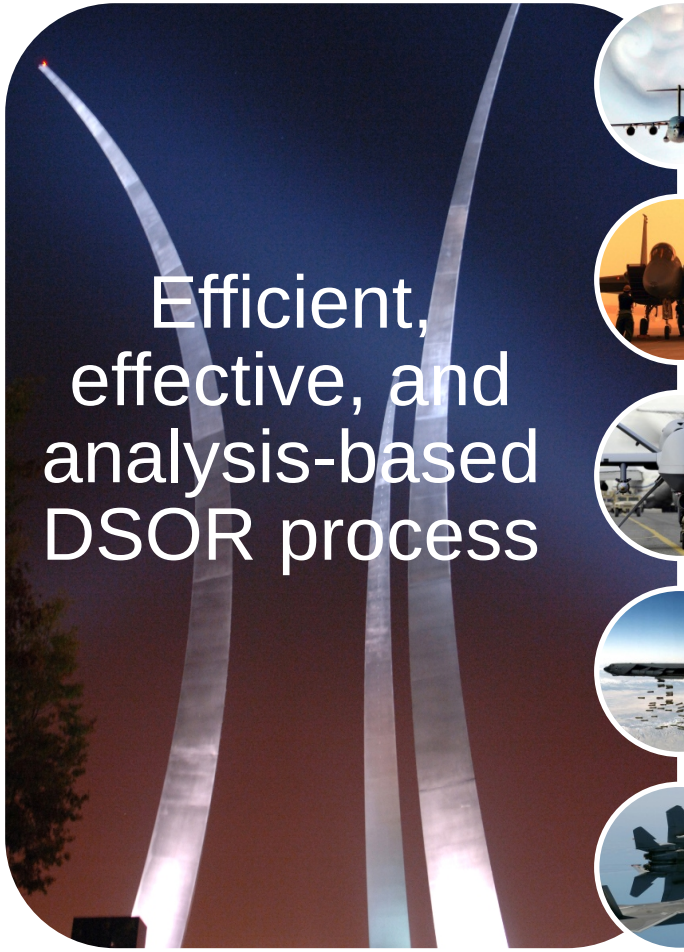
Legend

	= Does not support
	= Partially Supports
	= Supports

DSOR Analysis Recommendations

- **Form DSOR Team (e.g., Program Office, ALC/OB (Candidate Depot), AFSPC/A4U, AFLCMC/LG, AFSC/LG, AFNWC, planners/schedulers, SMEs, etc.)**
- **Leverage available data (cost, data rights, commonality, *Product Support BCA*, FEMECA, LORA, MTA, etc…) per AFI 63-101**
- **Team performs internal system/program-level analysis**
- **Team performs Enterprise commonality analysis (program and SOR)**
- **Align with strategic objectives (program and SOR)**
- **Pursue organic/contract?**
- **Document CD capability and capacity (if organic)**
- **Complete template with appropriate justification**

Resulting DSOR Process Improvements



Standardizes AFSPC, AFLCMC, AFSC, and AFNWC involvement in Phase II DSOR Team

Ensures alignment with Air Force Strategic Objectives

Provides Enterprise Commonality Analysis

Enables information exchange to/from Product Support BCA

Incorporates specific data (cost, data rights, PS BCA, FEMECA, LORA, etc…)

Process Realignment

- **Initial Core Assessment (10 USC 2464, 10 USC 2366a) transfers from HQ AFMC/A4DC to SORA submitter**
- **Candidate Depot Determination transfers from HQ AFMC/A4DC to AFSC**
  - **Continues to be based on the Technology Repair Center (TRC) construct**
- **Training and modifications to DSORII in progress**
- **Changes in responsibilities scheduled to coincide with next major release of DSORII (~May 2014)**
- **Benefits of transfers include:**
  - **Built-in process in DSOR II for immediate core assessment if program is close to milestone A**
  - **AFSC well-suited to improve coordination of candidate depot determinations**