Exploring Materiel Availability (A_m) Operational Availability (A_o) and Supply Product Support Analysis

Acquisition Insight Days
WPAFB
Mar 2014

Rob Blakey,
HQ AFMC/A9

Overview

Product Support Analysis - Supply Support Focusing on supply support, forum would address: structuring product support analysis (PSA); defining the questions; identifying programmatic requirements; exploring sustainment KPP and KSA; and identifying analysis capabilities (data, tools, skill sets, supporting organizations). Components of the discussion would include: supply support planning considerations; supply requirements tools (specifically Readiness-Based Sparing (RBS)); and supply support analysis applications (sparing strategies, spares requirements computations, and spares assessment applications).

Briefer: Rob Blakey, AFMC/A9A
Day/Session: 2/3
Room: 643-118
Capacity: 50

MATERIEL (A_M) AND OPERATIONAL AVAILABILITY (A_O) ANALYSIS

Applying analytical methods to sustainment KPPs to gain insight into the required sustainment infrastructure and exploring the logistics trade space.

Why is A_m and A_o Analysis Important?

- Because 63-101 says so?
  - "3.13.4. The PM shall collect, report, and **analyze sustainment metrics** to measure program life cycle sustainment outcomes that satisfy the sustainment KPP/ Key System Attributes (KSAs) defined by the user in accordance with the JCIDS Manual. This will include as a minimum, materiel availability, materiel reliability, total ownership cost (TOC) and mean down time (MDT). Additional sustainment metric calculation information can be found in AFPAM 63-128. – AFI 63-101."

- Or maybe because gaining a thorough understanding of availability measures will help build a better logistics strategy…

"(a) Materiel Availability. Materiel Availability is the measure of the percentage of the total inventory of a system operationally capable, based on materiel condition, of performing an assigned mission. This can be expressed mathematically as the number of operationally available end items/total population. The total population of operational end items includes those in training, attrition reserve, pre-positioned, and temporarily in a non-operational materiel condition, such as for depot-level maintenance, shipyard repair, etc. Materiel Availability covers the total life-cycle timeframe, from placement into operational service through the planned end of service life." ***– JCIDS Manual***

Some Recent Guidance

- **AIR FORCE LIFE CYCLE LOGISTICS (LCL) WORKFORCE GUIDEBOOK - 23 OCTOBER 2013**
  Two additional (PSM) responsibilities were added by PL 112-239 (FY13 NDAA):
  - **"Use appropriate predictive analysis and modeling tools that can improve material availability and reliability, increase operational availability rates, and reduce operation and sustainment costs**
  - Ensure that the product support strategy maximizes small business participation at the appropriate tiers. "

- **AFI 10-601 - 6 NOVEMBER 2013**
  "2.3.20. Implementing Command (Air Force Materiel Command (AFMC), Air Force Space Command (AFSPC), or Air Force Civil Engineering Center (AFCEC)):"
  "**2.3.20.9. Provides analytic expertise, assistance and guidance to ensure Sustainment KPPs and enterprise level considerations are properly addressed in operational capability requirements documents."**
- **DOD MANUAL 4140.01 10 FEBRUARY 2014 VOLUMES 2, 3, 7**
  - E.g. **"Materiel managers will use tools that implement RBS methodologies for provisioning new weapon systems to determine the optimum range and quantity of items required at all stockage and user locations to meet approved weapon system readiness goals"**

- **Peters PBL memo – 22 NOVEMBER 2013**

A PBL arrangement does not incentivize the consumption of maintenance labor hours, consumption of parts, or other transactional measurement in a way that is unaligned with the program's (system, subsystem, component) sustainment requirements. The appropriate course of action regarding PBL arrangements is determined through the product support strategy process and appropriate analyses.

How does it work?

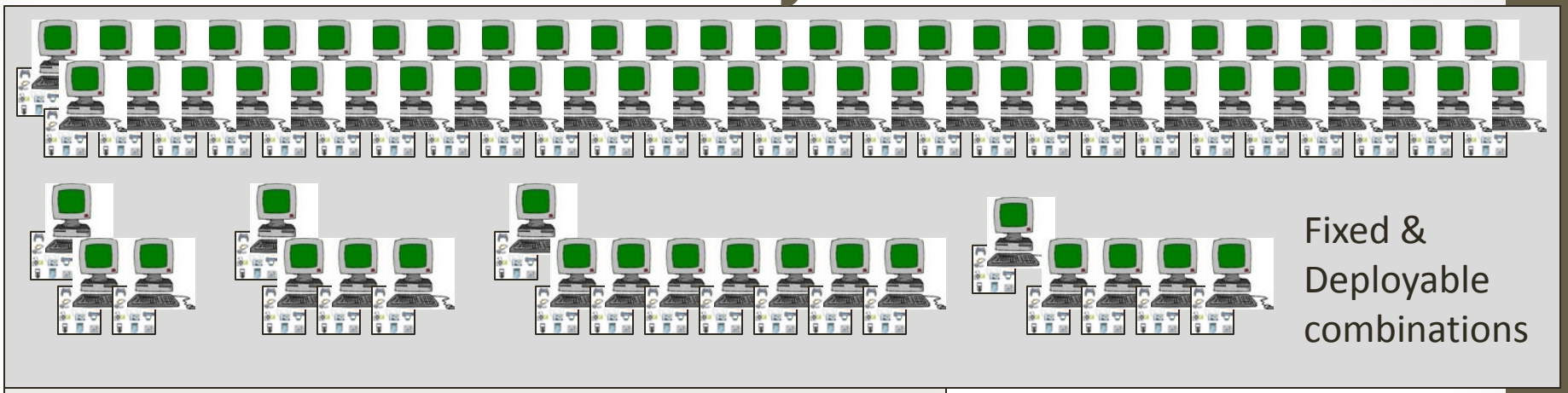
- The user requirement
  - Operationally available / operationally capable systems
- Requirement decomposition and assumptions
  - Mission capable (ready)
  - Not Mission Capable
    - Depot
    - Supply
    - Maintenance
    - Unit Possessed Not Reported
    - Others – training, test, pre-positioned, redundancy
- The physics of the problem
  - Can we get there from here?

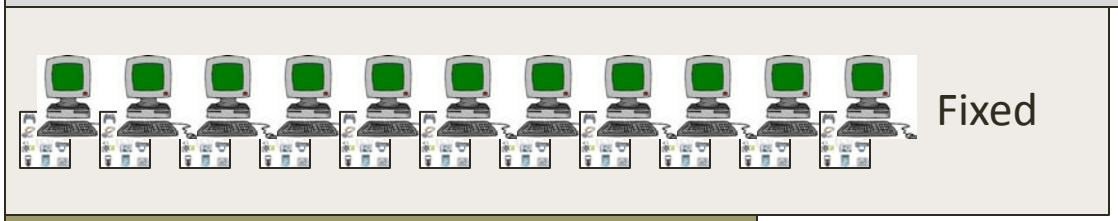
EXAMPLE 1 - NO KNOWN A_M

System Assumptions

- The program plans to acquire 42 fixed site terminals and 48 deployable terminals of identical configuration
- Fixed terminals operate 24 x 7 during “normal” operations
- Deployable terminals are maintained in ready to operate status (serviceable / available) but are only utilized if called upon during a contingency
- If deployable terminal(s) is activated, the fixed site terminal (if co-located) is non-operational
- Current force structure planning shows the following:
  - 27 locations with 1 fixed and 1 deployable terminal (1 additional fixed terminal identified separately)
  - 1 location with 1 fixed and 2 deployable terminals
  - 1 location with 1 fixed and 3 deployable terminals (1 additional fixed terminal identified separately)
  - 1 location with 1 fixed and 4 deployable terminals
  - 1 location with 1 fixed and 7 deployable terminals
  - 1 training location with deployable terminal only
  - 1 depot location with fixed terminal only
  - 8 locations with 1 fixed terminal
  - 4 deployable terminals with locations to-be-determined

Materiel Availability





Deployable: 48
Fixed : 42
Total Population: 90

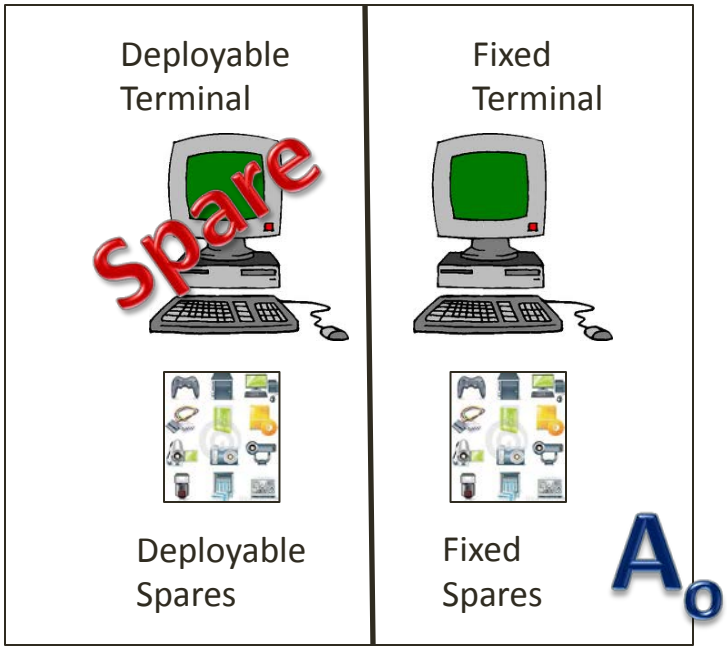
Materiel Availability

- "Typical" field site:
  - 1 Fixed Terminal
  - 1 Deployable Terminal

"(a) Materiel Availability. Materiel Availability is the measure of the percentage of the total inventory of a system operationally capable, based on materiel condition, of performing an assigned mission. This can be expressed mathematically as the number of operationally available end items/total population. *The total population of operational end items includes those in training, attrition reserve, pre-positioned, and temporarily in a non-operational materiel condition, such as for depot-level maintenance, shipyard repair, etc*. Materiel Availability covers the total life-cycle timeframe, from placement into operational service through the planned end of service life." – JCIDS Manual

A_m

"(b) Operational Availability. Operational Availability is the measure of the percentage of time that a *system or group of systems within a unit are operationally capable of performing an assigned mission and can be expressed as (uptime/(uptime + downtime)).* Determining the optimum value for Operational Availability requires a comprehensive analysis of the system and its planned CONOPS, including the planned operating environment, operating tempo, reliability and maintenance concepts, and supply chain solutions. Operational Availability may be equivalent to Materiel Availability if the total number of a system or group of systems within a unit is the same as the total inventory." – JCIDS Manual

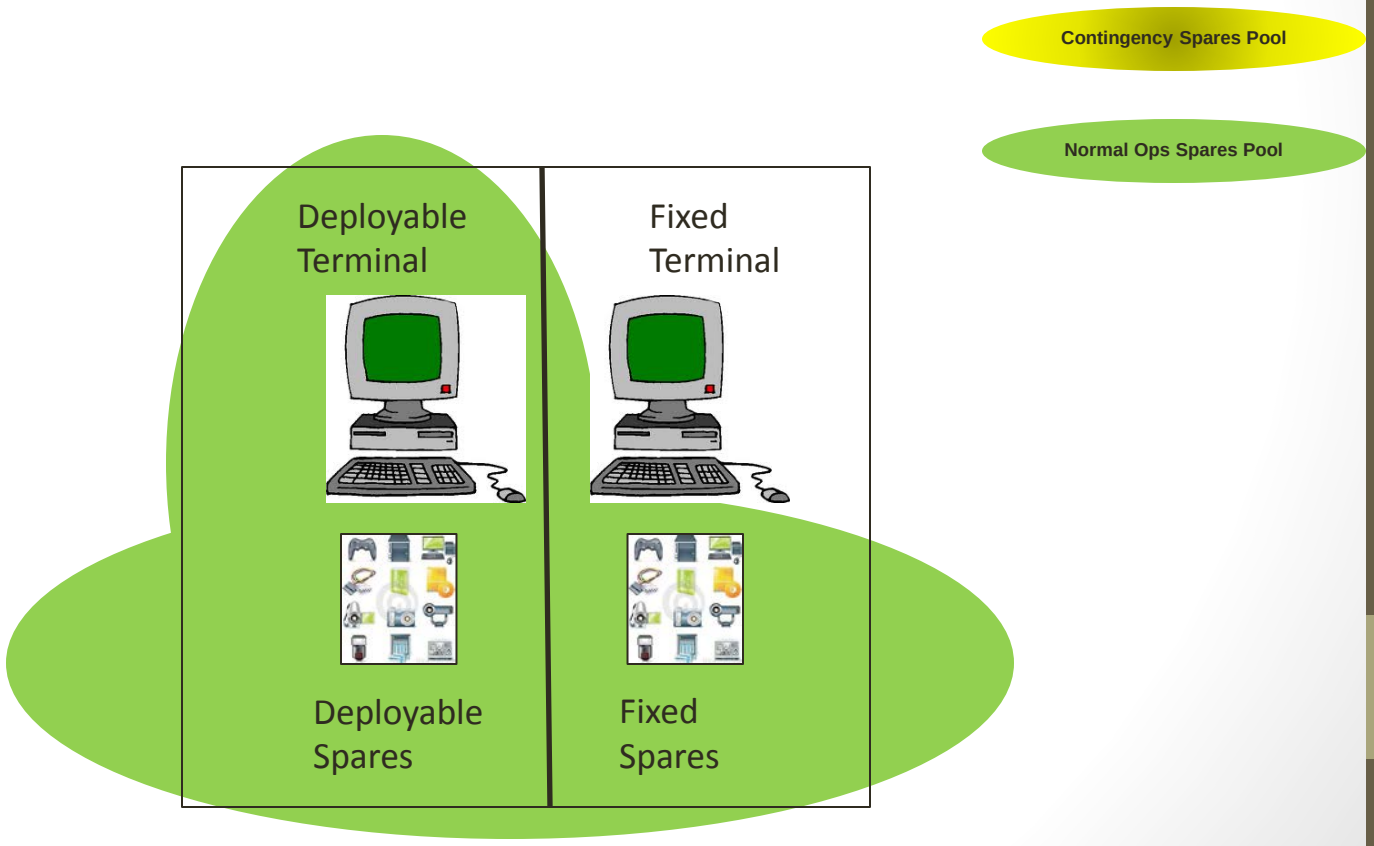


If there was only 1 site with 1 fixed and 1 deployable terminal, the A_m would be:

½ = 50%

Materiel Availability

- "Typical" field site:
  - 1 Fixed Terminal
  - 1 Deployable Terminal



Materiel Availability

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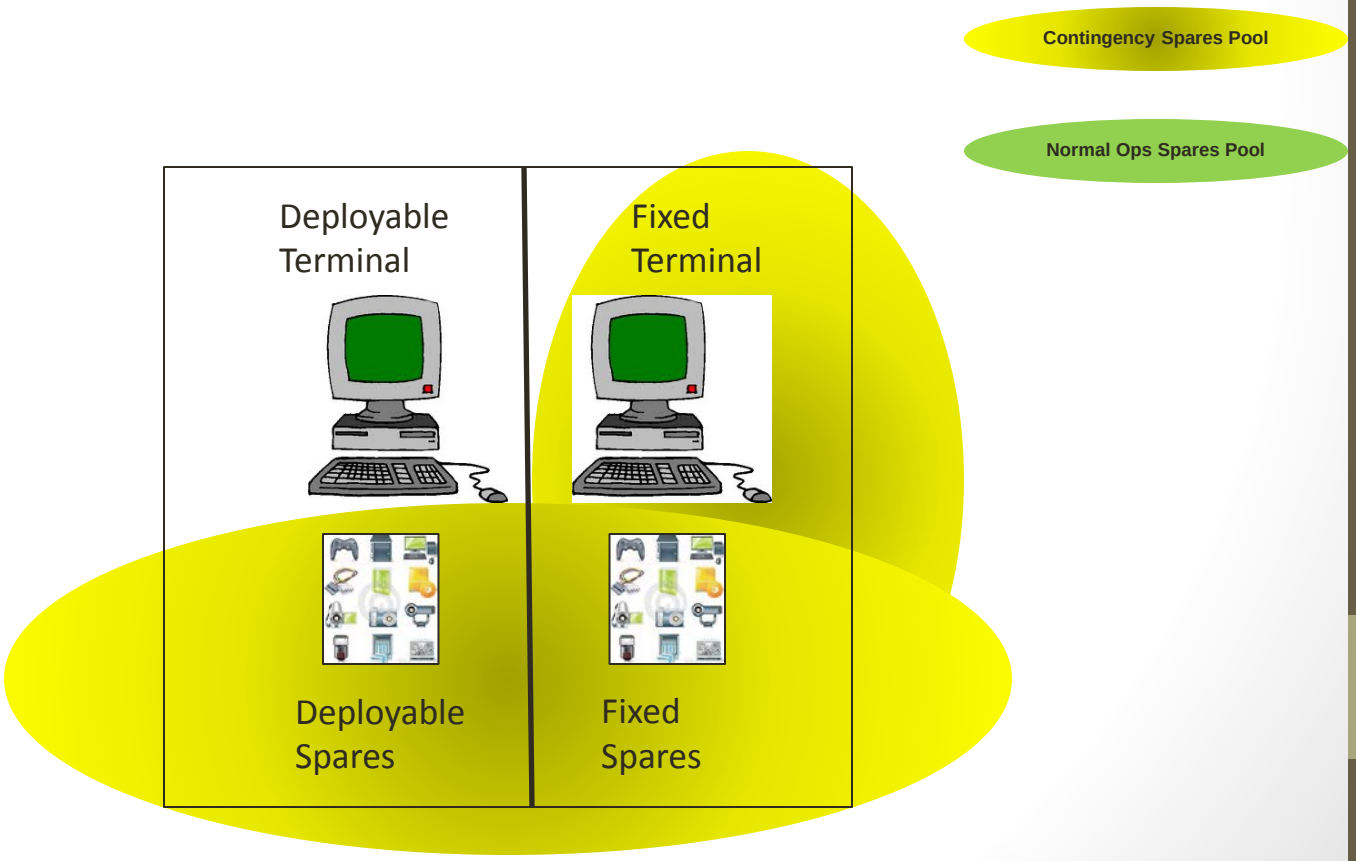
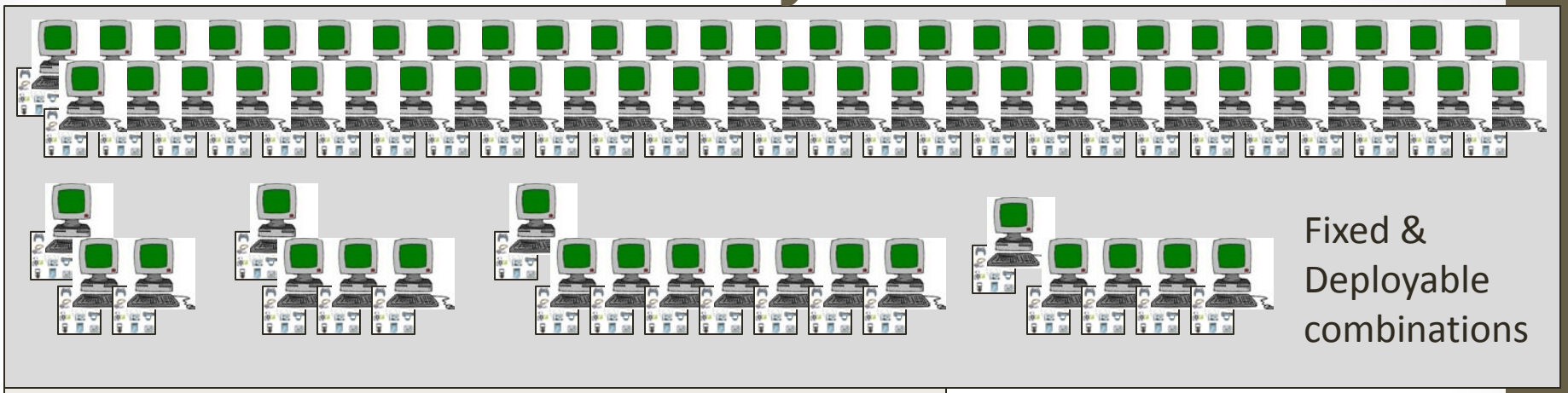
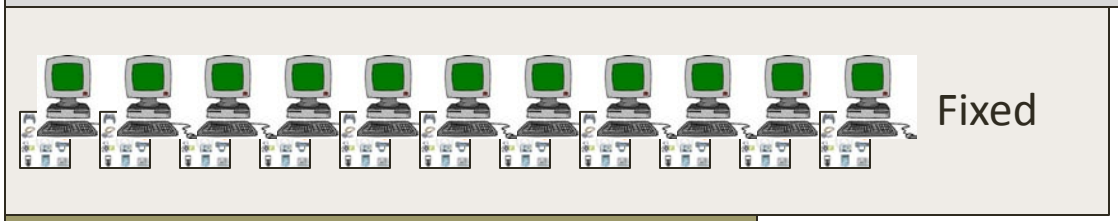


Materiel Availability





Deployable: 48
Fixed : 42
Total Population: 90

Possible Calculations

Materiel Availability Alternative 1: $\frac{90}{90} = 1$

Both fixed and deployable terminals are operationally capable, based on materiel condition, of performing an assigned mission. This alternative would drive a 100% A_m value. Therefore, it seems implausible given 48 of the 90 terminals are not operating at any given time.

Materiel Availability Alternative 2: $\frac{42}{90} = .46$

Fixed terminals are operationally available. Deployable terminals are considered prepositioned and not considered operationally available but are operationally capable and part of the total population. This computation seems to most closely fit the text of the JCIDS manual. A computation of A_m using uptime and downtime would likely produce a similar fraction.

Materiel Availability Alternative 3: $\frac{48}{90} = .53$

Deployed terminals are operationally capable, based on materiel condition, of performing an assigned mission. Fixed terminals are treated as redundant peacetime only operationally available terminals and evaluations should be made sole based on contingency requirements. This alternative presumes that the primary user requirement is for the deployable terminals in support of contingency operations. The fixed terminal requirements are treated as peacetime only assets akin to a training platform; vice a combat platform. This seems to obscure the fixed terminal requirements for normal operations. While more stringent than alternative 2, logistics solutions that favor non-operational end items may add risk to fixed terminal operations.

Materiel Availability Alternative 4: $\frac{48 \rightarrow 59}{90} = .53 \rightarrow .65$

A variable value between 48 and 59 divided by 90 assuming a mix of normal and contingency operations. Fixed terminals are operationally available, based on materiel condition, of performing an assigned mission; deployable terminals are considered to be partially prepositioned and partially operationally available and are part of the total population.

Views of Others

- Randy Wood, J-8/Joint Capabilities Division
  - Deferred to J4/Maintenance Division - LCDR Ryan Lawrenz
- J4 - LCDR Ryan Lawrenz – A9A interpretation of A_o definition is correct…"operationally available" and "operationally capable" are not synonymous
  - "From my point of view (keeping in mind I represent requirements for the warfighter), you need to be able to hit the 46.6% A_o. I would think that a high A_m based on this situation of ready spares but the actual need for only ~42 units at any one time would support that."
  - Requested detailed interpretation / validation from OSD LM&R

Views of Others

- Unnamed OSD “SME”
  - "I think the answer is somewhere between 1 and 4. I don't think its 3 and 2 discounts what terminals might be up. For a critical nuclear system like this I would think you would want the logistics infrastructure to sustain a high value system the same whether it was fixed or deployable. If there are periodic inspections of the deployable systems and they are considered ready for deployment at a given time's notice, that sounds like an available asset. I don't think it needs to equal 100% availability given that at some point there will be systems that are down for maintenance or training. You'd still have a high availability, but the value would not be 100%."

EXAMPLE 2 –A CONTRACTED A_0 VALUE

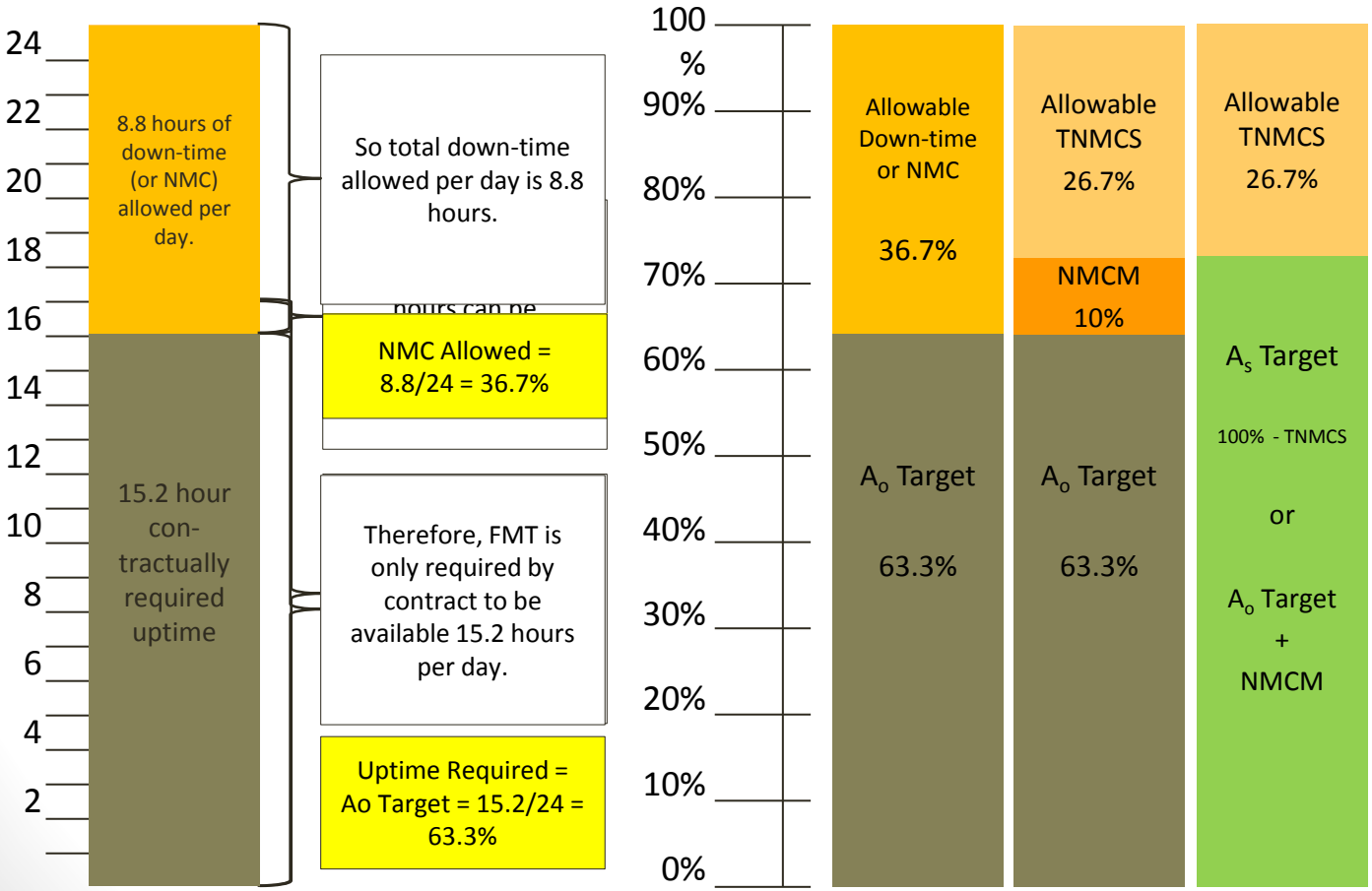
Contractual Operational Availability Requirement

- 95% A_o required within specified operating window
- Contractor only held responsible for simulator downtime when scheduled training is impacted
- Customer does not attempt to schedule simulator when it is known to be down
- Historical performance shows A_o always well over 95%

Calculating Operational Availability and Supply Availability target for FMTs

Operational Availability (A_o): the percent of time that a system is available for a mission; or the percent of time that a system is not down due to maintenance (Mx) actions and/or supply shortage; 100% - % Not Mission Capable (NMC)*

Supply Availability (A_s): the percent of time that a system is not down due to supply shortage; 100% – % Total Not Mission Capable Supply (TNMCS)



Since NMCM is unknown, we can provide a range of As targets by performing sensitivities on NMCM.

If NMCM is…

10%

Allowable TNMCS is…

36.7% - 10% =

26.7%

And A_s Target is…

100% – TNMCS =
100% - 26.7% =

73.3%

NMCM	A_s Target
0%	63.3%
10%	73.3%
15%	78.3%
20%	83.3%

SUPPLY PRODUCT SUPPORT ANALYSIS - INSIGHTS AND OPPORTUNITIES

Supply Product Support Analysis - Insights and Opportunities

- *All* of the programs we recently studied (in the sustainment phase) had surplus* spares inventory
  - Common threads:
    - CLS sustainment
      - Tendency is to assume inventory management is the solely KTRs responsibility
    - Total Asset Visibility problems
      - Programs struggled with knowing, or finding out, how much materiel they have purchased, have on hand and how much more they need to procure (if any)
    - A factor (E.g. % of end item cost) is often used to estimate early lifecycle spares requirements. This is rarely appropriate.
      - Pre-MS B estimates can be developed using legacy data, analogy, market research, etc.
      - Spares requirements can be objectively modeled as soon as a design is set (CDR) ***if*** the necessary data is available

* "Surplus" is defined here by comparing on-hand inventories with inventory requirements computed using standard AFMC models and business rules

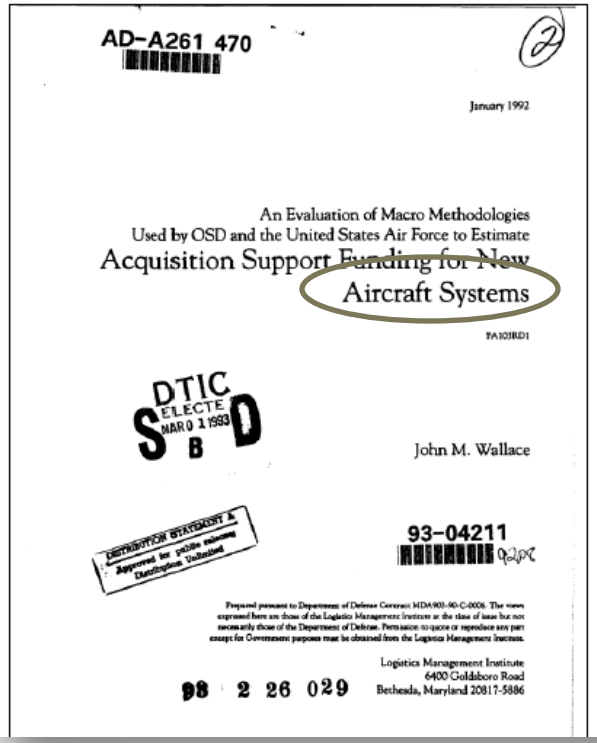
Supply Product Support Analysis - Insights and Opportunities

- The CLS sustainment concept leads to eroding USG insight to sparing decisions
  - Performance based arrangements (PBLs) can foster a "fire & forget" perspective
    - "It's the contractors job to meet the metric"
  - Given the oligopolistic economic environment, lack of visibility can drive cost risk
- Deliberate identification of sustainment KPP (A_m), or "Sponsor defined sustainment metrics," is lacking
  - User specified A_o is often assumed to be a spares target; which it is not…
- Logisticians struggle with the JCIDS requirement for the A_m KPP

A little about "factored" spares costing

ref: Initial Spares, Heuristics and Institutional Cognitive Bias – Jackson & Waters 2012

Plausible background for the 10% initial spares factor



AD-A261 470

January 1992

An Evaluation of Macro Methodologies Used by OSD and the United States Air Force to Estimate Acquisition Support Funding for New Aircraft Systems

PA101RD1

DTIC ELECTE MAR 0 1 1993 S B D

John M. Wallace

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TABLE 4-1

INITIAL SPARES FACTORS

(Applied to cost of end items delivered during a fiscal year)

Equipment category	First 3 years	Next 3 years	Factor base
Whole engines/engine modules	N/A	N/A	Calculations done IAW AFR 400-1
Aircraft components			
Engine	10%	7%	Total recurring flyaway cost
Avionics	10%	7%	Total recurring flyaway cost
Other	10%	7%	Total recurring flyaway cost
Peculiar support equipment/automatic test equipment (PSE/ATE)	7%	5%	Recurring PSE/ATE cost

Note: N/A = not applicable; IAW = in accordance with.

- Wallace (1992) cited Headquarters Air Force Logistics Command (AFLC) as the OPR for publishing initial spares factors (see above)
- Understandable that an institutional expectation for a 10% initial spares factor developed

A little about "factored" spares costing

ref: Initial Spares, Heuristics and Institutional Cognitive Bias – Jackson & Waters 2012

Analysis of historical data (1 of 2)

- Historical data obtained from Wallace (1992)
- Conducted Mann-Whitney-Wilcoxon (MMW) test:
  - Does not assume normal distribution
  - Does not assume symmetrical distribution
- Looks at Fighter vs. Non-fighter aircraft:

Aircraft	Initial Spares Factor	Type	Ranking
C-5B	3.5%	NF	1
F-15A/B	4.9%	F	2
C-5A	5.2%	NF	3
F-15C/D	5.8%	F	4
B-1B	6.2%	NF	5
C-141B	7.0%	NF	6
F-16A/B	8.3%	F	7
F-15E	9.4%	F	8
F-16C/D	10.7%	F	9

Mann-Whitney-Wilcoxon Test:
Wilcoxon convention is to designate the smaller of the two populations as population 1

Population 1: NF	n_1	4
Population 2: F	n_2	5
Sum or Ranks:		45
Sum of Ranks (T_{NF}):		15
Sum of Ranks (T_F):		30
T_L		12
T_U		28

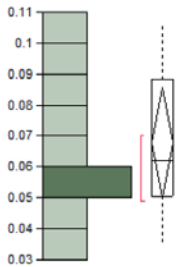
(see backup)

Null hypotheses:	Critical Values	Reject Ho When
Ho: $T_{NF} = T_F$	T_L and T_U	$T_{NF} \leq T_L$ or $T_{NF} \geq T_U$

Result:
Since T_{NF} (15) is between T_L (12) and T_U (28) we fail to reject the null hypothesis

MMW results suggest one can treat Fighters and Non-fighters as one population

Analysis of historical data (2 of 2)



Percentage:	Value:
100.0%	10.7%
75.0%	8.85% (quartile)
	6.80% (mean)
50.0%	6.20% (median)
25.0%	5.05% (quartile)
0.0%	3.50% (minimum)

- Aggregate data: 6.2% (median) to 6.8% (mean)
- Fighter data: 7.8% (mean)
- Sherbrooke and Mattern (1987) fighter range: 6.1%-7.8%

Several sources point to an initial spares factor as low as 2.2% up to ~8% with a median at ~6%

shows that part of the reason is that new systems have more negotiated and insurance items. The transports – the C-5, C-130, C-141, and C-135 – are in a cluster that ranges from 5.0 percent for the C-5 to 2.2 percent for the C-135. Despite

Summary

- There is an understandable (but not defendable) basis for the institutional expectation that initial spares should be ~10% of flyaway costs
- Once formed, this expectation becomes a detrimental institutional cognitive bias which unduly influences how various groups interpret detailed estimates
- Historical data suggest an initial spares factor of between 6% and 8%

What to do instead?

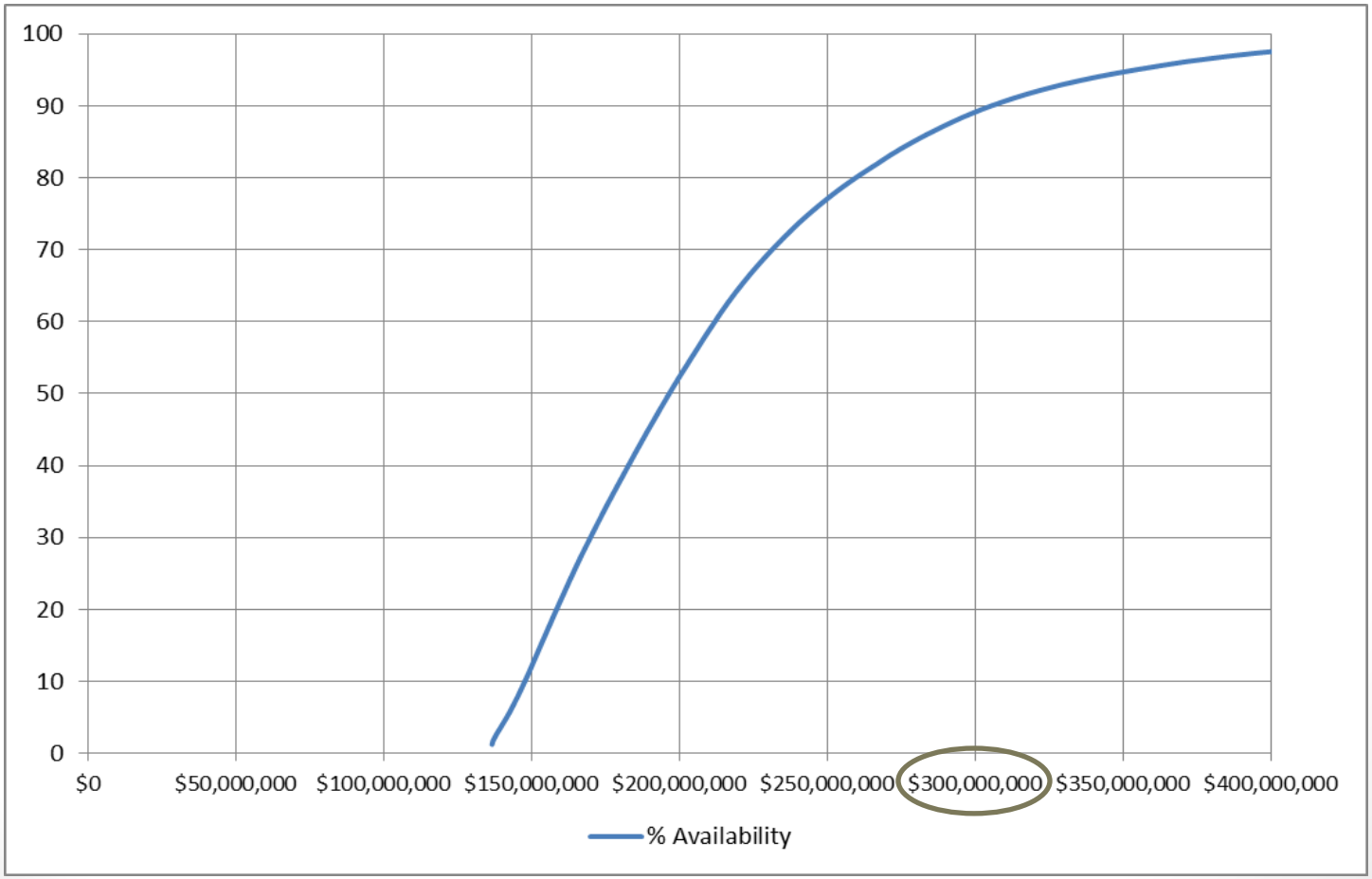
- Analogy
  - What does the system resemble?
  - Is there a legacy instance of the system?
  - Is there another DOD service or commercial variant?
- Compute using estimated rates…
  - Engineering estimates from OEM
  - Like subsystems (vendors, other systems)
  - Commercial data
- Toolset
  - Simple pipeline calculation
  - RBS model
  - Monte Carlo simulation

Analogy Example – Aircraft

- What if we calculated requirements for KC-135R parts…
  - Using KC-46 “mature” flying hours and assumptions:
    - 11 Users
    - 168 Aircraft (total delivered aircraft)
    - 87,711 Flying Hours/Year (peak hours)
    - 90% Supply Availability target
    - 686 LRUs
    - Zero Assets
    - 100% OIM Factor (no depot demands)
    - 100% Application (installed on all aircraft)
    - Unique Items (KC-135 only)

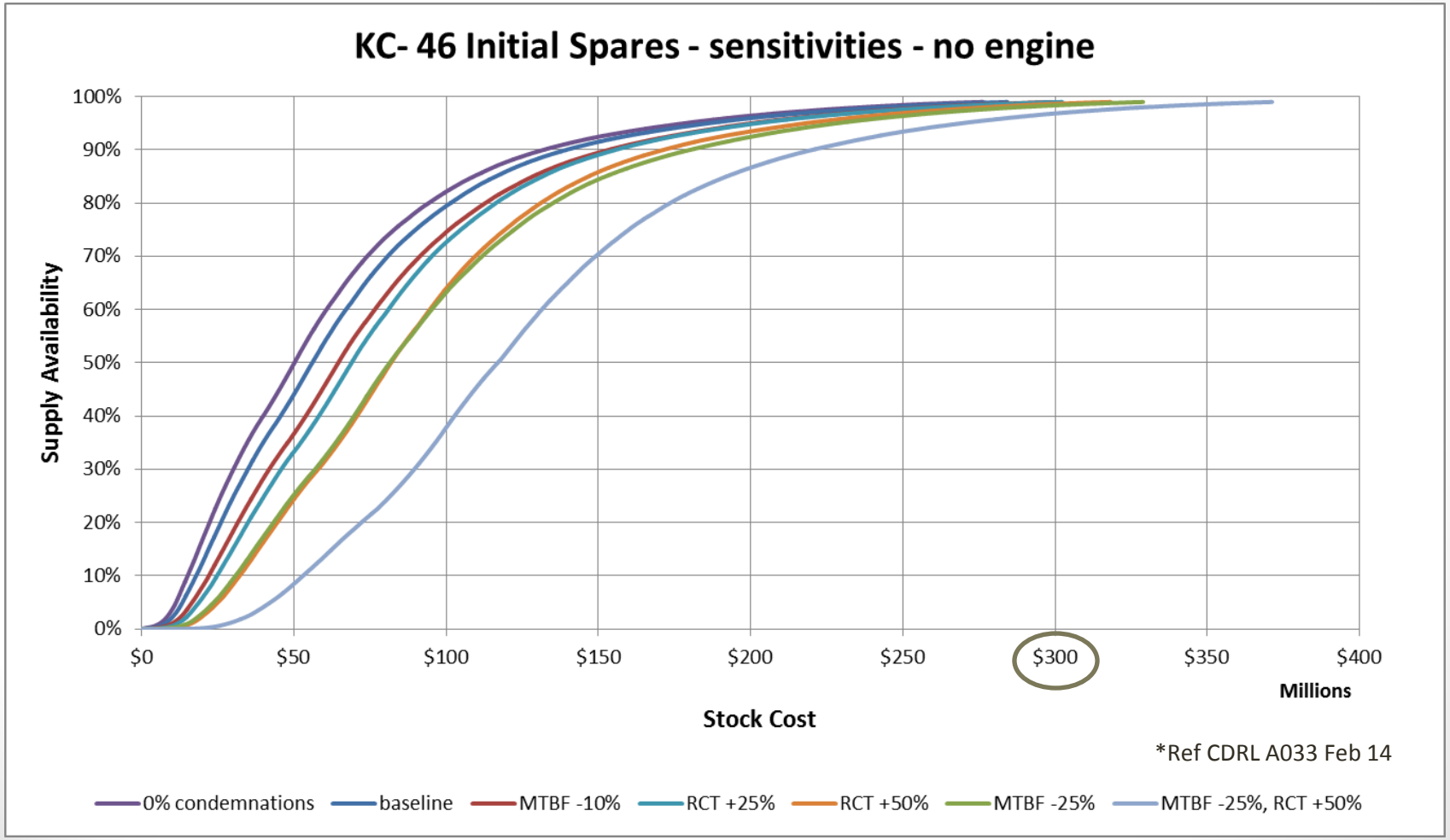
Analogy Example – Aircraft

- Results (KC-135R "actuals")
  - **$305M Cost,** @ 90% Target



Compute using estimates - Aircraft

- Results using Boeing Supplied Data*



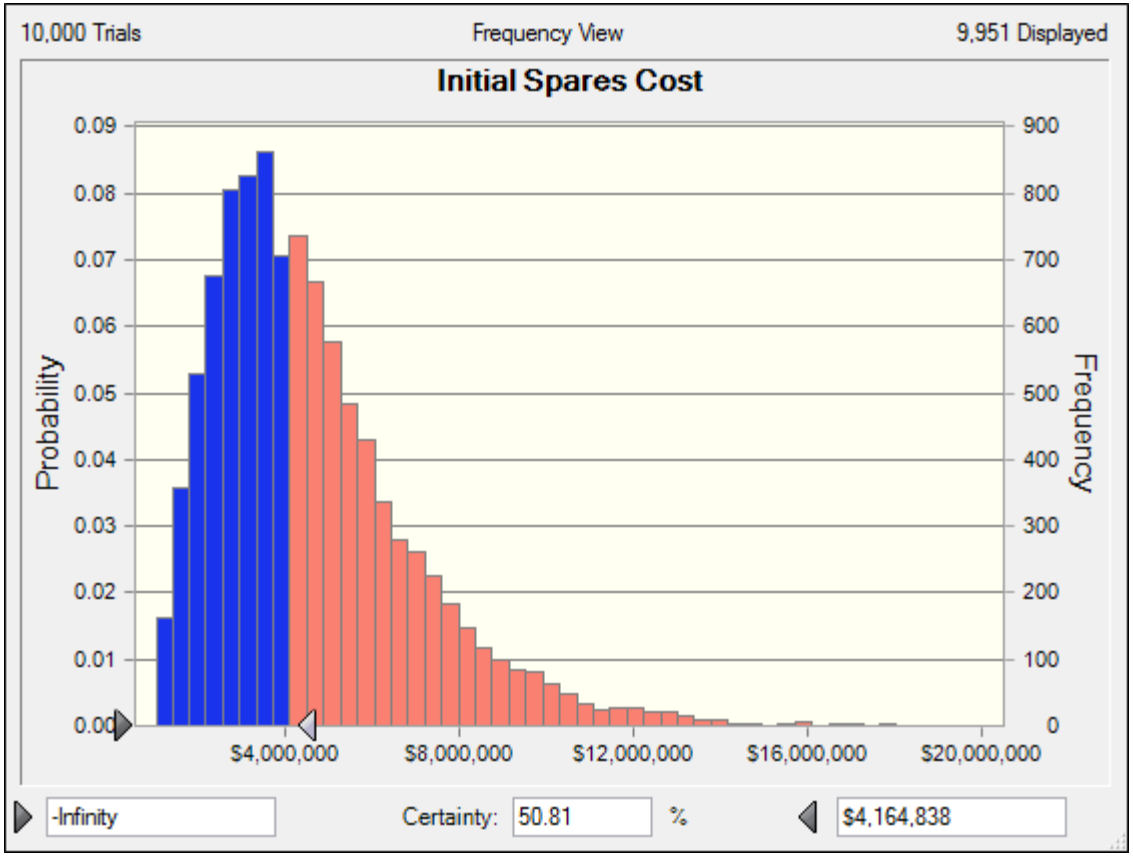
Compute using estimates in Monte Carlo Simulation – Sub-system

- Assumptions
  - Order and Ship Time modeled as Triangular Distribution with Min = 1, Likeliest = 14, Max = 27
  - Depot Repair Cycle Days modeled as Triangular Distribution with Min = 14, Likeliest = 74, Max = 134
  - Repair Cost modeled as Triangular Distribution with (Min = 20%, Likeliest = 25%, Max = 30%) of Unit Cost

- *Initial Spares cost does not include safety level, Monte Carlo Simulation is not run to supply target*

Compute using estimates in Monte Carlo Simulation – Sub-system

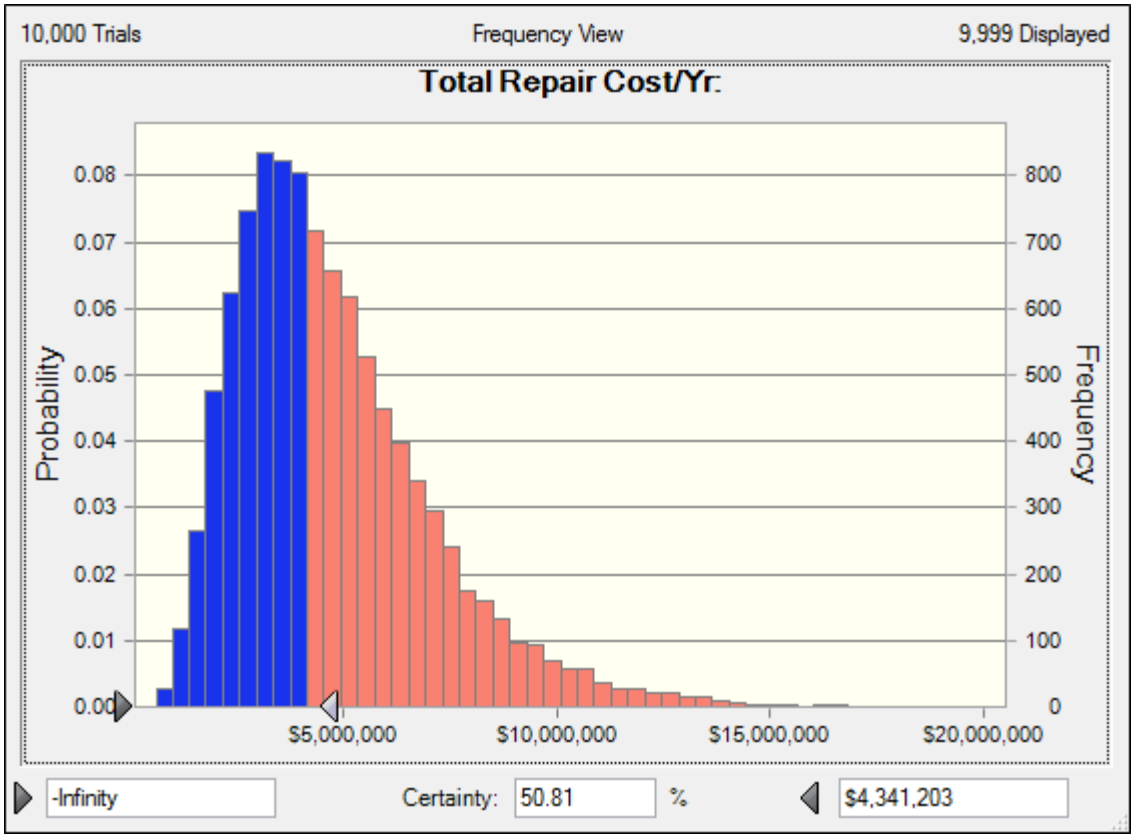
- Initial spares pipeline



50% probability that initial spares cost will be less than or equal to $4,164,838

Compute using estimates in Monte Carlo Simulation – Sub-system

- Annual Repair Cost



50% probability that yearly repair cost will be less than or equal to $4,341,203

Compute using estimates in an analytic RBS model– Sub-system

- Assumptions
  - 52 total units, 42 operational
  - 1 MOB, 3 FOBs, 1 Depot
  - Order and Ship Time = 14 days
  - Depot Repair Cycle Time = 74 days
  - 100% NRTS
  - Repair requirement calculated as follows:
    - (Operating Hours*QPA)/MTBF

Compute using estimates in an analytic RBS model– Sub-system

	78% As Spares Req't	90% As Spares Req't	Annual Repairs
1553 Bus. Coupler	$ 3,000	$ 3,750	$ 37
AB-2000	$ 25,000	$ 25,000	$ 7,465
B0 Antennas	$ 152,920	$ 152,920	$ 52,129
B1 Antennas	$ 16,625	$ 16,625	$ 2,586
B1-3 Horn Antenna	$ -	$ 7,000	$ 118
B2-3 Omni Antenna	$ -	$ 7,000	$ 119
Cabling	$ -	$ -	$ 1,220
Dampers	$ 15,000	$ 15,000	$ 1,746
Encryption Chassis	$ 832,215	$ 1,109,620	$ 1,229,469
FDTR	$ 225,000	$ 525,000	$ 195,680
GCS Kit	$ -	$ 122,000	$ 50,391
LN-251	$ -	$ 200,000	$ 95,635
PECU	$ 112,980	$ 131,810	$ 24,840
PFR-S	$ 27,220	$ 68,050	$ 5,304
POD	$ -	$ -	$ 3,345
Power Distributor Unit (PDU)	$ -	$ 75,000	$ 12,775
Power Supply	$ -	$ 92,000	$ 23,945
RFD-2C	$ 750,000	$ 1,500,000	$ 1,225,494
Temp Sensors	$ 10,000	$ 12,500	$ 295
VGPP	$ 400,000	$ 700,000	$ 345,531
VGPP-FE	$ 800,000	$ 900,000	$ 453,260
VGPP-PE	$ 200,000	$ 300,000	$ 151,617
VQIFD2	$ 5,400,000	$ 6,600,000	$ 5,488,772
Total:	$ 8,969,960	$ 12,563,275	$ 9,371,771

Baseline MTBFs

	78% As Spares Req't	90% As Spares Req't	Annual Repairs
1553 Bus. Coupler	$ 3,000	$ 3,750	$ 46
AB-2000	$ 25,000	$ 50,000	$ 9,331
B0 Antennas	$ 152,920	$ 172,035	$ 65,161
B1 Antennas	$ 16,625	$ 19,000	$ 3,233
B1-3 Horn Antenna	$ 7,000	$ 7,000	$ 148
B2-3 Omni Antenna	$ 7,000	$ 7,000	$ 149
Cabling	$ -	$ -	$ 1,525
Dampers	$ 15,000	$ 17,500	$ 2,182
Encryption Chassis	$ 1,109,620	$ 1,941,835	$ 1,536,836
FDTR	$ 525,000	$ 600,000	$ 244,600
GCS Kit	$ 122,000	$ 122,000	$ 62,989
LN-251	$ -	$ 200,000	$ 119,544
PECU	$ 131,810	$ 131,810	$ 31,050
PFR-S	$ 27,220	$ 68,050	$ 6,630
POD	$ -	$ -	$ 4,181
Power Distributor Unit (PDU)	$ -	$ 75,000	$ 15,969
Power Supply	$ 92,000	$ 92,000	$ 29,932
RFD-2C	$ 1,250,000	$ 2,250,000	$ 1,531,867
Temp Sensors	$ 10,000	$ 12,500	$ 368
VGPP	$ 600,000	$ 900,000	$ 431,914
VGPP-FE	$ 800,000	$ 1,000,000	$ 566,575
VGPP-PE	$ 200,000	$ 300,000	$ 189,521
VQIFD2	$ 6,600,000	$ 7,600,000	$ 6,860,974
Total:	$ 11,694,195	$ 15,569,480	$ 11,714,722

MTBFs minus 20%

Results for TNMCS targets include safety level

So what is RBS anyway?

- Readiness-Based Sparing (RBS): recommend parts that provide the greatest contribution to a system's availability for an investment
  - Optimizes either cost or availability
    - Math can minimize the spares dollars needed to meet a weapon system availability target
    - Math can maximize weapon system availability for a given spares budget
    - RBS math translates item stock levels to weapon system performance
  - Can model multi-indenture and multi-echelon (MIME)
  - Can consider common items
  - Can apply existing assets but doesn't have to
- Contrast is a demand-based (fill rate) approach
  - What % of demands are filled immediately?
  - Each item is treated equally

RBS vs. Demand-Based Sparing

- RBS models recommend parts on a system basis, according to which items provide the greatest contribution to a system's availability for use
  - The system approach
    - Links item to system performance
    - Presents a range of possible solutions
    - Optimizes spares mix giving the most efficient performance per dollar
- Demand-based sparing/ fill rate models
  - Recommend parts on an item by item basis according to historical demand
    - High MTBF → Low Demand → Item stocked less
    - Low MTBF → High Demand → Item stocked more
  - No explicit linkage to the system or cost
  - Equipment readiness and investment are *uncontrolled* outputs

RBS Models and Applications

- Aircraft Sustainability Model (ASM) aka “D087”
  - Standard AF RSP model
  - Initial provisioning; replenishment spares
  - Assessments
- Aircraft Availability Model (AAM) aka “D200”
  - Replenishment Spares
- VMETRIC /EDCAS / TEMPO
  - Replenishment Spares
  - Life Cycle Cost
  - LORA
- COMPASS
  - Standard Army and Navy LORA model
- OPUS10
  - Replenishment Spares
  - Life Cycle Cost
  - LORA

Note: Not an exhaustive list

In Summary

- Evolving policies continue to grow requirements for objective analysis in the sustainment space
  - What is the plan going forward?
- Understanding A_m and A_o, and the relationship between the two, opens the door for sustainment planning and trade-space
- A comprehensive spares analysis uncovers not only potential sparing missteps, but a variety of other sustainment questions
  - Level of program insight
  - Data availability
  - Maintenance implications
  - User requirements
- Resources
  - More information on RBS is available at: https://eis.af.mil/cs/rbs/default.aspx (you will need to request access)