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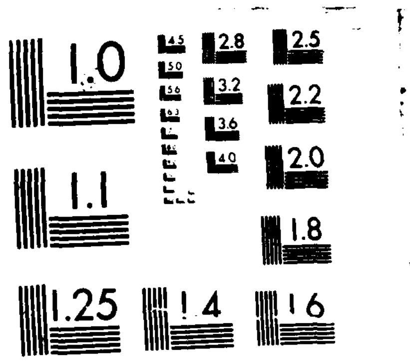

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COMPARISON OF AIRCRAFT AVAILABILITY WITH VARIABLE SAFETY LEVEL METHODS FOR BUDGET PROGRAM 1500 ALLOCATION

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W. B. Fisher
C. H. Hanks
M. A. Lueck
F. M. Slay

LOGISTICS MANAGEMENT INSTITUTE
4701 Sangamore Road
P. O. Box 9489
Washington, D. C. 20016

EXECUTIVE SUMMARY

This report contains the results of a comparison of the Aircraft Availability Model (AAM) with the Variable Safety Level (VSL) model. Both models compute spares safety levels in relation to funding levels. The AAM was developed by LMI for the Air Staff and has been used in recent years to evaluate Air Force spares programs and budgets. The VSL model was used by the Air Force Logistics Command (AFLC) prior to FY83 to compute spares requirements within the Recoverable Consumption Item Requirements (D041) System.

The purpose of the comparison was:

- to determine if use of the AAM would result in significantly improved supply performance in the Aircraft Replenishment Spares Program (Budget Program 1500, BP-15); and

- to assess the changes in funding profiles that could occur if the AAM were used for BP-15 allocation.

The results indicate strongly that use of the AAM would lead to improved supply performance. For the March 1982 D041 data base, the AAM computes a buy list that achieves the same expected aircraft level backorders as a VSL solution costing $1.76 billion, but at a cost of $350 million less. Limiting funding to the levels (by aircraft type) of the VSL solution, the AAM produces a solution that reduces total aircraft level backorders from the VSL level of over 5,000 to less than 2,000. Altering funding by aircraft type to reflect aircraft availability targets in line with Air Force logistics support priorities, the AAM yields a third solution that costs approximately the same as the VSL solution but still results in 1,900 fewer backorders.

The results also show that improved supply performance is achievable without major disruption in current BP-15 funding profiles. Allocations to Federal Supply Classes and Air Logistics Centers do not undergo significant change as a result of shifting to aircraft availability objectives. Even when different aircraft availability targets are used, the AAM allows planners to observe, and therefore control, the shifts in funding profiles that do occur. Thus, conversion to AAM-based methods would lead to increased flexibility, visibility, and control in the BP-15 program without causing unacceptable funding migration.

AFLC has already taken initial steps towards using aircraft availability methods in BP-15 allocation. While the AAM per se was not used for the FY83 allocation, a version was and is being used by AFLC to evaluate and modify VSL-based solutions.

Based on an initial review of the revised D041 system at Oklahoma City, it appears feasible to integrate the AAM into that system and provide acceptable products to working levels at the Air Logistics Centers. If the AAM is to be used for the FY84 BP-15 allocation, joint coordination and planning among AFLC, LMI, and the Air Staff should be initiated soon.

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1. BACKGROUND

A meeting between Air Staff and Air Force Logistics Command (AFLC) personnel was held at AFLC Headquarters in May 1982 to discuss the feasibility and to determine a course of action for incorporating "aircraft availability" into future computations of Budget Program 1500 (BP-15) spares requirements. At the meeting it was agreed that:

a. "Allocation of BP-15 funds for FY83 must be targeted toward improved aircraft availability."

b. "In the future, we must imbed weapon system readiness (availability) in the requirements computation process as the key objective function."[1]

Recognizing that the shift to aircraft availability, away from existing fill-rate methods, could affect BP-15 funding profiles, the meeting participants also decided that such effects should be identified and analyzed in advance, prior to making final decisions on how to proceed.

LMI was asked by the Air Staff to investigate two aspects of the proposed shift to availability: (1) the improvement in supply performance that could be expected to result from allocation and buy guidance from the Aircraft Availability Model (AAM); and (2), the potential effects on BP-15 resource allocation (funding profiles) that use of the AAM would have.[2]

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[1]Meeting minutes, Air Staff/AFLC discussions on Application of Aircraft Availability Criteria for Future Computation of BP-15 Spares Requirements, May 11-12, 1982.

[2]A third aspect of LMI's task, to identify how AAM output could be made compatible with existing Air Force procedures and systems, has been delayed (except for an initial review) pending completion of the D041 system transition to the Oklahoma City Air Logistics Center.

2. GROUND RULES FOR THE COMPARISON

THREE GROUND RULES

While there are important differences between the models, up to a certain point they both use similar mathematical methods. In order to focus on the fundamental differences for the comparison, the AAM was modified to eliminate minor differences with the Variable Safety Level (VSL) model in those areas where the models are similar. Appendix A contains a description of these modifications. With the modifications in place, the comparison could focus on the key differences in the models, which was the first ground rule.

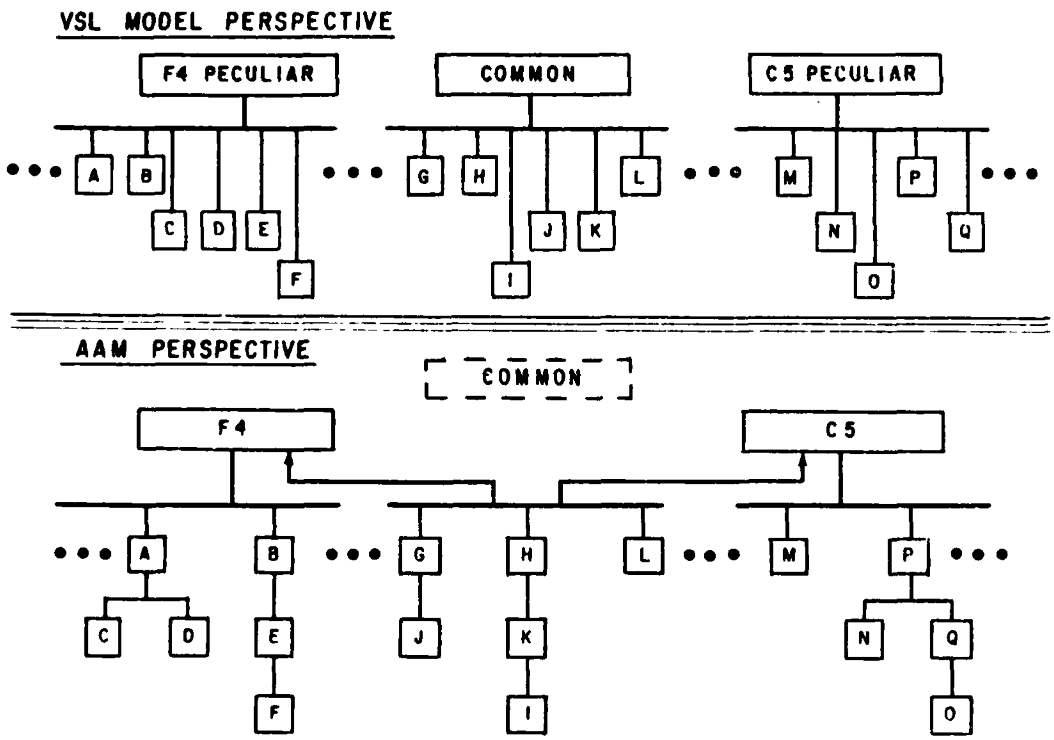
The first important difference is that the AAM uses aircraft availability rate by Mission/Design (MD) as its objective function, rather than item fill-rate (by System Management Code), as used in the VSL model. Second, the AAM handles item indenture relations and common components in fundamentally different ways than does the VSL model.

Figure 1 illustrates how the two models view indenture relations and common components. The small blocks with letters represent components.

In the VSL model, all components are treated as though they applied directly to the aircraft at the same level of indenture, level one. Budget Support Objectives (which determine the amount of safety level spares) are set for MD-peculiar components and for the several System Management Code (SMC) categories of common components. With the VSL model, it is not possible to discriminate among common components within the same common SMC, and levels-of-indenture relations are only simulated (by setting floors based on NRTS/cost combinations in the D041 data).

In contrast, the AAM explicitly models indenture relations using D041 application data, so that interactions between Line Replaceable Units (LRUs) and their constituent BP-15 subassemblies (e.g., Shop Replaceable Units or SRUs) are considered in computing safety levels. For common components, the AAM prorates costs and benefits to the appropriate MDs, and computes requirements accordingly. A single run of the AAM produces cost versus availability curves for each MD that cover the range of reasonable budgets, and from which item-specific shopping lists can be produced for any allocation plan.

FIGURE 1. MODEL PERSPECTIVES



A second ground rule was that the March 1982 D041 data base would be used as the common basis for comparing the models. Both models ran on the "unscrubbed" version of the data base, so the effects of data base errors and adjustments do not affect the comparative results.

Finally, the third ground rule was that the number of expected backorders (EBOs) per aircraft would be used as the measure of supply performance against which the models would be judged. It would have been unfair to the VSL model to use aircraft availability as the measure, because the AAM optimizes availability and, as a result, would outperform the VSL model, which does not use availability as its objective function. The number of EBOs at the aircraft level, as a measure of supply performance, has the dual advantage of being unbiased in favor of either model, but having the desired weapon system orientation. (See Appendix B for a further discussion of the relation between aircraft availability and EBOs per aircraft.)

METHOD OF COMPARISON

The basic method of the comparison was to compute the aircraft level EBOs (i.e., LRU EBOs) that resulted from a component "buy list" generated by the VSL model using the March 1982 D041 data base. This VSL "buy list" was generated at AFLC based on an 88 percent fill-rate objective, but with certain minimum floors for many components. The resulting total VSL funding equates to that for a 92 percent fill-rate objective. The levels-of-indenture version of the AAM (modified to eliminate non-fundamental differences with the VSL model) was then run, and AAM solutions of three different types were obtained. First, an AAM "buy list" corresponding to the VSL funding levels by MD was generated and EBOs per aircraft for each MD calculated. This made it possible to compare the supply performance of the models when they each spend the same amount on each MD. Second, an AAM result which produced the same EBO levels as the VSL solution was generated, to compare the cost differences that exist when both models reach the same level of EBO performance. Finally, based on a set of availability targets reflecting Air Force logistics support priorities for the various MDs, EBO levels for a "military essentiality" solution were computed and compared to the VSL results. The purpose of this third comparison was to investigate how MD funding allocations might change as AAM availability targets are modified.

3. RESULTS

SUPPLY PERFORMANCE RESULTS

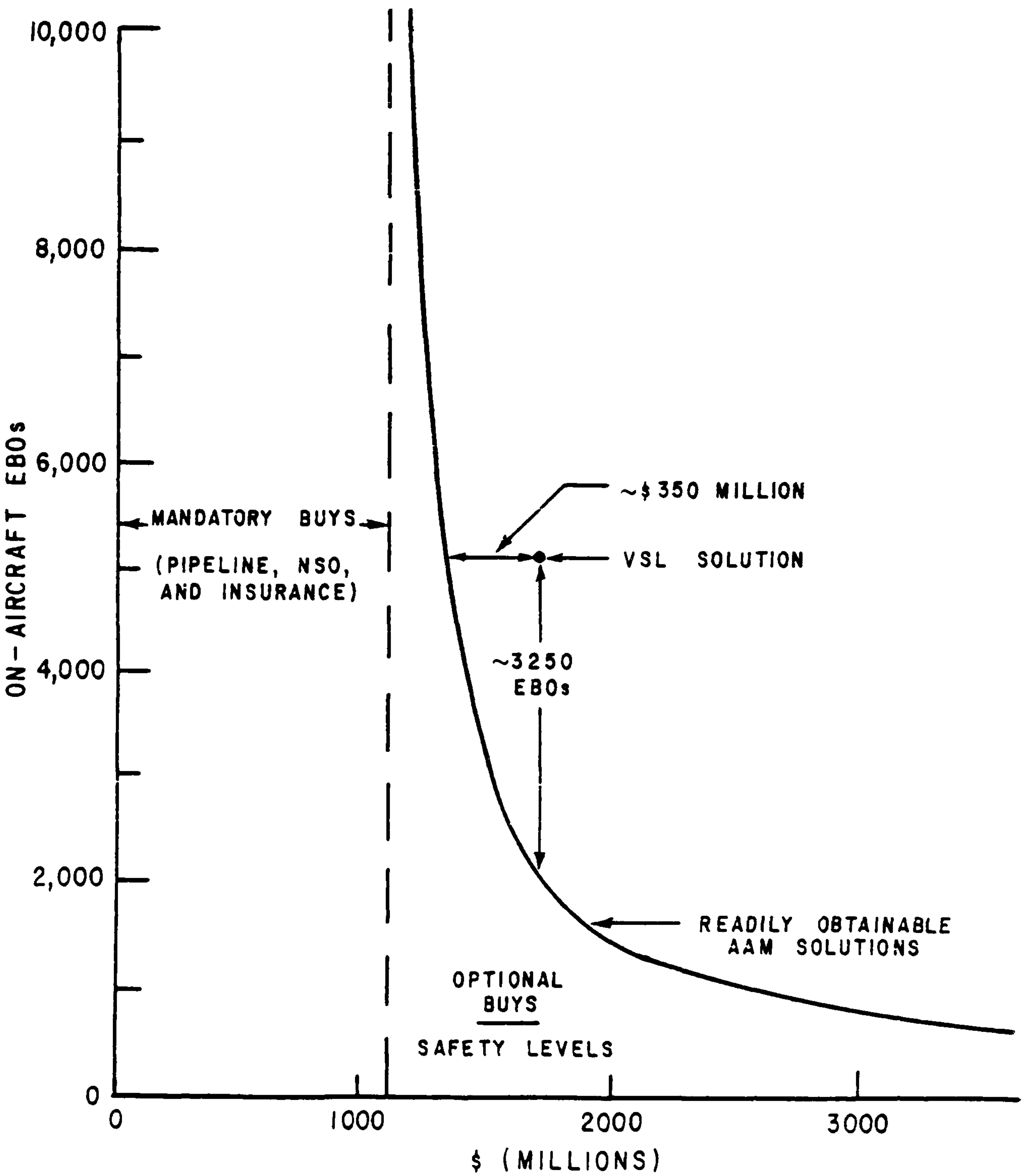
EBO Levels

When funding is the same for both models, the AAM achieves significantly lower EBO levels both Air Force-wide and by MD. Conversely, to achieve the same EBO level, the AAM spends substantially less than the VSL model. Figure 2 shows the Air Force-wide results. As indicated in the figure, both models were set to buy the same insurance and numeric stockage objective (NSO) components, as well as the same mandatory pipeline levels. Differences between the models show up in the safety levels, which are the only optional buys. The VSL model produces a set of "point" solutions, clustered around a single target solution. The AAM operates over a full range of EBO versus cost values, derived from the availability versus cost curves it produces. The VSL solution shown in Figure 2 is the VSL target solution for the March 1982 data base.

The figure shows that the AAM is able to achieve the VSL "solution" of over 5,000 on-aircraft expected backorders for approximately $350 million less than the $1.76 billion the VSL spends on its buy list. Conversely, the figure shows that for approximately the same amount, $1.76 billion, the AAM reduces Air Force-wide EBOs from the VSL level of over 5,000 to less than 2,000 on-aircraft backorders.

The curve in Figure 2 is not "optimal" in the sense of representing the lowest Air Force-wide EBO levels achievable for the dollars. By altering MD availability targets, AAM solutions can be obtained which fall below the curve in Figure 2. Conversely, if funds are applied to complex, expensive MDs to attain high availabilities and low EBOs, then Air Force-wide EBOs will be

FIGURE 2 **PROJECTED ON-AIRCRAFT EXPECTED BACKORDERS (EBOs) — AIR FORCE WIDE**



above the curve. The reason in both cases is that MD availabilities, not Air Force-wide EBOs, are being used as the objective functions. By using the AAM, such results at the MD level can be observed and controlled by Air Force decision makers.

Table 1 shows EBOs per MD and EBOs per aircraft for the VSL funding levels by MD. The totals at the bottom of the first and second columns correspond to the VSL solution and "same cost" AAM solution shown in Figure 2.[1] Categories I, II, and III refer to logistic support priority groups for the MDs shown. The third column shows the AAM results when funding by MD is changed to support availability targets that reflect the categories. The "other" category in Table 1 refers to less significant aircraft, which can be individually shown if desired (e.g., A-37 and T-33).

An important result reflected in Table 1 is that even when adjusted for "military essentiality" (M.E.) and operating under approximately the same overall funding level, the AAM still outperforms the VSL model in total EBOs.

Aircraft Availability Levels

Although EBOs per aircraft provided the basis for comparing the performance of the two models, aircraft availability levels were also computed in the course of the analysis. Table 2 shows the results when aircraft availability is used as the supply performance measure instead of EBOs, with VSL funding levels by MD. Table 3 is similar to Table 2 except the AAM solution reflecting logistics support priorities is shown. Tables 2 and 3 together illustrate the flexibility and visibility offered by the AAM, in terms of relating and controlling capability levels (availability) and resource levels.

[1] To get the results in Figure 2, the AAM "accepted" a VSL buy (costing approximately $88 million) of certain miscellaneous components which were not tied to MDs. The AAM could have obtained significantly better results for these components (approximately 73 EBOs as opposed to 342), but for purposes of the comparison, the VSL buys and associated EBO levels were used.

TABLE 1. EXPECTED BACKORDERS (EBOs) AT AIRCRAFT LEVEL

MD	VSL BUY EBO/MD	VSL BUY EBO/AC	VSL $ PER MD AAM BUY EBO/MD	VSL $ PER MD AAM BUY EBO/AC	AAM WEIGHTED FOR M.E. EBO/MD	AAM WEIGHTED FOR M.E. EBO/AC
			CATEGORY I			
B52	430.1	1.58	82.2	0.30	57.5	0.21
B111	106.7	1.81	24.4	0.41	12.9	0.22
C5	186.8	2.83	52.8	0.80	13.5	0.20
C141	400.9	1.58	224.5[2]	0.88	45.9	0.18
E3	125.9	4.50	16.7	0.60	5.7	0.20
			CATEGORY II			
C135	375.6	0.53	132.4	0.19	198.1	0.28
F4	451.8	0.31	160.7	0.11	471.3	0.32
F15	678.8	1.14	140.1	0.24	179.4	0.30
F16	387.7	0.66	45.6	0.08	163.6	0.28
F111	406.5	1.37	83.5	0.28	89.9	0.30
H3	36.3	0.48	10.9	0.14	23.3	0.31
H53	32.8	0.76	9.2	0.21	12.9	0.30
			CATEGORY III			
A7	107.5	0.33	45.2	0.14	148.1	0.46
A10	198.3	0.34	61.0	0.10	231.8	0.40
C130	313.5	0.46	151.1	0.22	324.3	0.47
F5	49.4	0.47	37.4	0.35	43.6	0.41
F106	46.0	0.29	21.6	0.14	66.4	0.42
H1	14.4	0.11	5.9	0.05	57.0	0.45
T37	59.2	0.09	20.0	0.03	195.2	0.31
T38	256.8	0.31	38.0	0.05	253.7	0.31
OTHER	122.7		144.6		291.5	
TOTAL EBO	4787.7		1507.8 (+ 342)		2885.6	
TOTAL DOLLARS ALLOCATED (MILLIONS)	1767.14		1761.71		1765.50	

[2] AAM allocation to C141 is $2.27 million more than VSL's. However, AAM overall is $5.43 million less.

TABLE 2. AVAILABILITY RATES WITH VSL FUNDING BY MD

MD	AVAILABILITY(%) WITH VSL BUY	AVAILABILITY(%) WITH AAM BUY	COST($MILLIONS) VSL BUY	COST($MILLIONS) AAM BUY
		CATEGORY I		
B52	20.7	73.9	266.24	266.06
B111	16.2	65.9	38.24	38.01
C5	5.4	44.6	237.43	237.18
C141[3]	20.8	41.1	57.02	59.29
E3	1.0	55.0	78.86	78.17
		CATEGORY II		
C135	58.8	82.9	87.55	86.13
F4	73.5	89.7	119.74	119.46
F15	31.8	79.0	263.21	262.82
F16	51.7	92.7	140.88	139.64
F111	25.5	75.5	133.94	133.64
H3	61.8	86.6	5.35	5.13
H53	46.1	80.6	5.34	5.19
		CATEGORY III		
A7	71.8	87.0	21.06	21.01
A10	71.1	90.1	51.78	51.52
C130	63.5	80.4	43.36	43.05
F5	62.7	70.2	24.98	24.37
F106	74.6	87.2	6.60	6.59
H1	89.2	95.5	6.05	5.98
T37	91.1	96.9	18.34	18.06
T38	73.3	95.5	58.05	57.50
SUBTOTAL			1664.02	1658.80
OTHER			103.12	102.93
TOTAL			1767.14	1761.71

[3]AAM allocation to C141 is $2.27 million more than VSL's due to forced buy of common. However, note that overall AAM allocation to major MDs is $5.22 (1664.02 - 1658.80) million less than VSL's.

TABLE 3. AVAILABILITY RATES WITH VSL FUNDING VS AAM FUNDING BY MILITARY ESSENTIALITY

MD	AVAILABILITY(%) WITH VSL BUY	AVAILABILITY(%) WITH AAM BUY	COST($MILLIONS) VSL	COST($MILLIONS) AAM
		CATEGORY I		
B52	20.7	81.0	266.24	285.05
B111	16.2	80.3	38.24	45.16
C5	5.4	81.5	237.43	311.36
C141	20.8	83.5	57.02	88.54
E3	1.0	81.6	78.86	91.77
		CATEGORY II		
C135	58.8	75.5	87.55	89.52
F4	73.5	72.6	119.74	82.62
F15	31.8	73.9	263.21	238.41
F16	51.7	75.7	140.88	108.46
F111	25.5	73.9	133.94	132.61
H3	61.8	73.4	5.35	3.84
H53	46.1	74.0	5.34	4.31
		CATEGORY III		
A7	71.8	63.2	21.06	12.01
A10	71.1	67.1	51.78	39.36
C130	63.5	62.7	43.36	34.96
F5	62.7	66.1	24.98	23.84
F106	74.6	65.5	6.60	4.05
H1	89.2	63.7	6.05	4.41
T37	91.1	73.6	18.34	13.26
T38	73.3	73.0	58.05	51.38
OTHER			103.12	100.58
TOTAL			1767.14	1765.50

FUNDING PROFILE RESULTS

Turning to the question of how use of the AAM would affect funding profiles, the comparison shows that improved supply performance is achievable with the AAM without major disruption in current BP-15 profiles. Table 4 illustrates this point using allocations to Air Logistics Centers (ALCs).

TABLE 4. ALLOCATION TO ALCs

	VSL BUY		VSL $ PER MD & AAM BUY		AAM-WEIGHTED BY MILITARY ESSENTIALITY	
	$MILLIONS	%	$MILLIONS	%	$MILLIONS	%
OKLAHOMA CITY	378.61	21.4	408.46	23.2	423.25	24.0
OGDEN	207.05	11.7	185.81	10.5	155.07	8.8
SAN ANTONIO	678.50	38.4	687.13	38.9	706.44	40.0
SACRAMENTO	87.30	4.9	81.66	4.6	88.40	5.0
WARNER ROBINS	415.67	23.5	398.75	23.6	392.34	22.2
TOTAL	1767.13		1761.81		1765.50	

Reading from left to right, the table shows that ALC allocations do not necessarily undergo significant change when aircraft availability replaces fill-rate as the objective. It is important to note that the funding profile for the "military essentiality" solution is based on a particular set of availability targets chosen for the comparison (see "AAM Buy" column in Table 3). Thus, for example, the drop in Ogden's share in the right-hand column of Table 4 reflects lower Peacetime Operating Stock funding for the F-4 and F-16, based on the lower logistic support priority those systems have (Category II) in comparison to Category I aircraft such as the C-5 and B-52. If different results are desired, or planners wish to examine other options, the AAM can accept any set of specified availability targets, and funding profiles can be observed and controlled accordingly.

Table 5 shows funding results for the twelve most costly Federal Supply Classes (FSCs). As was true for the ALC allocations, FSC allocations do not change significantly when aircraft availability is used, even when availability targets are modified to accommodate military essentiality considerations.

TABLE 5. TWELVE MOST COSTLY FEDERAL SUPPLY CLASSES ($MILLIONS)

FSC	CATEGORY	VSL BUY	VSL $ PER MD AAM BUY	AAM WITH M.E. WEIGHTING
2840	AIRCRAFT JET ENGINES	611.82	627.90	649.42
1560	STRUCTURAL COMPONENTS	142.54	136.71	144.70
5865	EW	107.59	105.57	97.33
1620	LANDING GEAR	107.46	98.66	98.06
2915	FUEL SYSTEMS	105.62	108.04	93.28
6605	NAVIGATIONAL INSTRUMENTS	98.20	72.60	83.48
1270	GUNNERY FIRE CONTROL	81.05	65.32	57.85
1280	BOMBING FIRE CONTROL	65.88	71.10	73.56
5841	RADAR	45.89	43.04	38.81
1650	HYDRAULIC	31.60	37.93	37.68
2835	NON-AIRCRAFT JET ENGINES	30.46	36.03	35.31
1660	AIR CONDITIONING & HEATING	25.30	28.50	27.92

The allocation to FSC 2840 (Engines) is about equal to the total for the next six classes. Both the AAM and the VSL model may exaggerate the importance of engine components because whole engines and engine modules are not included in the BP-15 data base. Even so, the AAM will achieve a better mix for engine components as a result of its level-of-indenture feature. Further, it is conceptually simple to add engines and modules to the AAM at appropriate indenture levels without considering them as potential "buys." This would reduce the direct impact on aircraft that some engine components now have in the model.

Table 6 shows the distribution of funds by levels of indenture for both models. The first column shows the pipeline, insurance, and NSO buys common to all solutions.

TABLE 6. BUYS BY LEVEL OF INDENTURE (MILLIONS)

LEVEL	BUY TO PIPELINE		VSL BUY		VSL $ PER MD AAM BUYS		AAM WITH M.E. WEIGHTING	
	$MILLIONS	%	$MILLIONS	%	$MILLIONS	%	$MILLIONS	%
1	778.82	70.1	1273.90	72.1	1327.61	75.4	1331.99	75.5
2	315.30	28.4	466.67	26.4	414.29	23.5	413.74	23.4
3	15.79	1.4	24.57	1.4	18.18	1.0	18.05	1.0
4	1.69	0.1	2.00	0.1	1.70	0.1	1.70	0.1
5	0.01	-	0.01	-	0.02	-	0.02	-
TOTAL	1111.61		1767.14		1761.80		1765.50	

Table 7 is similar to Table 6 except that it shows the levels-of-indenture distribution for safety levels only. The higher AAM buys for level 1 reflect the disproportionate importance given to lower level components by the single level-of-indenture VSL model.

TABLE 7. SAFETY LEVEL BUYS BY LEVEL OF INDENTURE

LEVEL	VSL BUY		VSL $ PER MD AAM BUYS		AAM WITH M.E. WEIGHTING	
	$MILLIONS	%	$MILLIONS	%	$MILLIONS	%
1	495.08	75.5	548.79	84.4	553.17	84.6
2	151.37	23.1	98.99	15.2	98.44	15.1
3	8.78	1.3	2.39	0.4	2.26	0.3
4	0.31	0.1	0.01	-	0.01	-
5	-	-	-	-	-	-
	655.54		650.18		653.88	

Levels-of-indenture interactions are affected by the asset position of components on different levels, as illustrated in Figure 3. These interactions are too complex to be satisfactorily handled by a set of rules for all the components of individual SMCs, as the VSL model attempts to do. Figure 3 illustrates how the AAM takes levels of indenture into consideration. Stock number 1270004715947 is an LRU for the F106 aircraft. Stock number 1270010704986 is a subassembly of that LRU. Both models recognize that the LRU, having a safety level almost four times its pipeline, is well protected. Neither model budgets for additional units of the LRU. The AAM, recognizing the healthy posture of the LRU, budgets only for a mandatory buy of 29 units to fill the pipeline of the subassembly. The VSL model, not recognizing the situation for the LRU, budgets for an unnecessary 34-unit safety level above the mandatory buy of 29 units. The unit cost of the subassembly is $8,939. Thus, for a given overall budget for the F106, the AAM has over $300 thousand to apply to better advantage. There are also examples where the AAM only buys to the pipeline for expensive LRUs, yet buys sizable safety levels for its inexpensive lower level subassemblies.

FIGURE 3. LEVELS-OF-INDENTURE EFFECTS

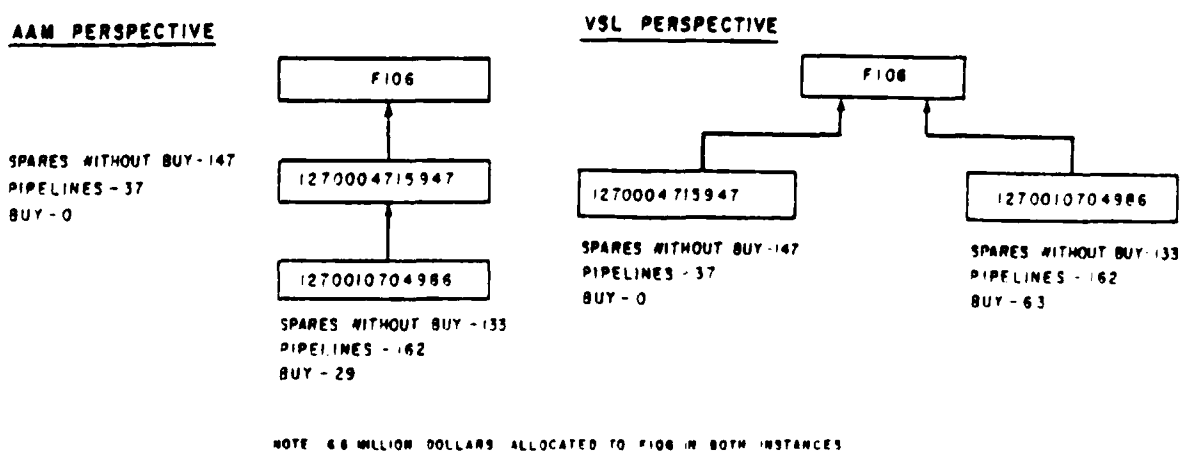


Table 8 shows funding profiles by unit cost categories, and finally, Table 9 shows allocations to the common component SMCs (9999, 999A, etc.) For common components, of course, the AAM and VSL buys will differ substantially for many individual items, even if aggregate common component funding levels are approximately the same.

TABLE 8. ALLOCATIONS BY UNIT COST CATEGORIES

	VSL BUY		VSL $ PER MD AAM BUY		AAM WITH M.E. WEIGHTING	
COST RANGE ($)	$MILLIONS	%	$MILLIONS	%	$MILLIONS	%
LE 1,000	135.45	7.7	149.31	8.5	146.49	8.3
GT 1,000 LE 7,500	385.91	21.8	448.98	25.5	429.22	24.3
GT 7,500 LE 40,000	645.01	36.5	663.30	37.6	628.67	35.6
GT 40,000	600.71	34.0	500.22	28.4	561.12	31.8
TOTAL	1767.08		1761.81		1765.50	

TABLE 9. ALLOCATIONS TO COMMON COMPONENT SMCs (9999, 999A, ETC.)

	VSL BUY	VSL $ PER MD AAM BUY	AAM WITH MILITARY ESSENTIALITY WEIGHTING
$MILLIONS	370.22	399.78	413.32
% OF REQUIREMENT	20.9	22.7	23.4

4. CONCLUSIONS

Use of aircraft availability methods for BP-15 allocations would result in improved supply performance and weapon system readiness. Further, this could be accomplished without major disruption in BP-15 funding profiles. These benefits, together with the improved visibility, flexibility, and control offered by the AAM, make a strong case for the use of the AAM in future BP-15 allocations.

The Air Staff and AFLC have already taken significant steps towards using aircraft availability methods. While the AAM *per se* was not used for the FY83 allocation, a version of the model is being used by AFLC to evaluate and modify VSL-based solutions.

An initial review of the revised D041 system at Oklahoma City indicates that it is feasible to interface the AAM with D041 and provide acceptable products to working levels at the ALCs. To interface with existing D041 systems and take full advantage of the AAM's capabilities, it appears that AAM output should be used to establish Budget Support Objectives at the component level. Further study is needed to verify these conclusions, and careful planning is required to determine the precise steps for implementation. Active participation of appropriate AFLC personnel will be crucial in this phase. If the AAM is to be used for the FY84 BP-15 allocation, it is necessary that joint coordination and planning between LMI and AFLC and the Air Staff be initiated at an early date.

APPENDIX A

AAM MODIFICATIONS

For purposes of the comparison, certain fundamental differences between the AAM and VSL models were left unchanged--namely, using aircraft availability rates as the objective function rather than fill rates, treatment of common components, and indenture relationships among components. The point of the comparison was to measure the effect of precisely these differences.

In those areas where the models are similar, the policies regarding modifications to the AAM to eliminate non-fundamental differences were as follows:

1. The two models use slightly different distributions in the case of large pipelines. Since the effect of these differences is small, no changes were made. Also, and again with no significant effect on results, depot pipelines are not separated in the AAM as they are in the VSL model.

2. Except for the way in which indenture relationships cause backorders to be "passed up" from a lower to a higher level assembly (an area of fundamental difference) and the handling of depot pipelines noted above, the AAM's treatment of depot level maintenance (DLM) pipelines is consistent with the VSL approach.

3. In the AAM, the variance-to-mean ratio parameter, which is a measure of the uncertainty associated with pipeline projections, was based on pipeline size, as in the VSL model.

4. The number of users (bases) used in the AAM calculations of the EBO levels associated with different depot/base distributions, was taken from the D041 data base to be consistent with the VSL model.

5. Maximum/minimum constraints in the VSL model on EBO levels and pipeline buys (100 percent of all pipelines were bought) were applied in the AAM for consistency. Floors and ceilings on buy levels, based on NRTS/cost combinations that were applied in separate VSL exercises at AFLC, were not incorporated into AAM runs.

6. For purposes of the comparison, both models used D041 unit costs, so that differences in handling cost escalation would not affect results.

7. During marginal analysis, the VSL model discounts unit cost by a factor of 1 minus the NRTS rate for each item, to simulate indenture effects. This was not done in the AAM since the AAM models indenture relationships explicitly.

8. To be consistent with the VSL model, war reserve materiel (WRM) assets were not considered available for use in the AAM runs made in the comparison. (The AAM allows the user to apply WRM assets or not, simply by setting a "yes" or "no" parameter at the beginning of a model run.)

The changes to the AAM outlined above were made so that the effects on weapon systems could be related to the fundamental differences between the AAM and the VSL model. If the AAM is eventually used to perform budget allocations, the advisability of incorporating these changes should be re-evaluated.

APPENDIX B

AVAILABILITY RATE AND EXPECTED BACKORDERS PER AIRCRAFT

An interesting by-product of the comparison results is an expression for the relationship between projected availability (A) and expected backorders per aircraft (EBO/AC). For each MD, it is approximately true that

$$EBO/AC = -\ln A.$$

Note that the relationship does not depend on fleet size or aircraft complexity.

To see the mathematical justification for this relationship, let EBO_i be the number of expected backorders for component i, let QPA_i be the quantity per application on the aircraft type, and let AC be the number of aircraft. Recall that the availability rate is given by:

$$A = \prod_i \left(1 - \frac{EBO_i}{AC \cdot QPA_i}\right)^{QPA_i}$$

where the product is taken over all first-indenture level items on the aircraft. We are assuming, for purposes of the demonstration, that all application percentages are 1.0 and that commonality considerations may be ignored.

Expanding the product out to first order terms, we have

$$A = 1 - \sum_i \frac{QPA_i \cdot EBO_i}{AC \cdot QPA_i} + R$$

$$= 1 - \frac{1}{AC} \sum_i EBO_i + R$$

$$= 1 - EBO/AC + R$$

The remainder term, R, consists of second and higher order terms. These all involve multiples of $EBO_i/(AC \cdot QPA_i)$ which are typically very small.

Since exp(-EBO/AC) can be expanded into the Maclaurin series:

$$\exp(-EBO/AC) = 1 - EBO/AC + (EBO/AC)^2/2! - \ldots,$$

we have, ignoring second and higher order terms,

$$A = \exp(-EBO/AC), \quad \text{(or equivalently)} \quad EBO/AC = -\ln A.$$

Strong empirical evidence for the relation appears in the test results. Figures B-1, B-2, and B-3 contain a graph of the function EBO/AC = - ln A, together with plots of data points from the test. The goodness of the fit provides the empirical evidence for the relation.

Figure B-1 shows data for optimal AAM stock levels when overall funds for each MD are set equal to the VSL computed requirement (EBO/AC from Table 1 and A from Table 2 in the report).

The relationship holds, as well, for non-optimal stock levels computed by the VSL model, as shown in Figures B-2 and B-3. Of course, a given MD has higher A value and lower EBO/AC value for the equal-cost AAM solution. This may be seen by comparing Figure B-1 with Figures B-2 and B-3. An extreme case is the E3 aircraft. The VSL computed stock level gives a one percent projected availability rate with a value of 4.50 for EBO/AC (see Figure B-3). The equal-cost AAM solution gives a 73.9 projected availability rate, with an EBO/AC value of 0.60 (see Figure B-1). Yet, in both instances, the relation still holds. In fact, it appears that the relation begins to fail only in the

FIGURE B-1 EBO/AC vs. "A" WITH AAM STOCK LEVELS AND COST PER AIRCRAFT TYPE TO VSL COMPUTED REQUIREMENTS

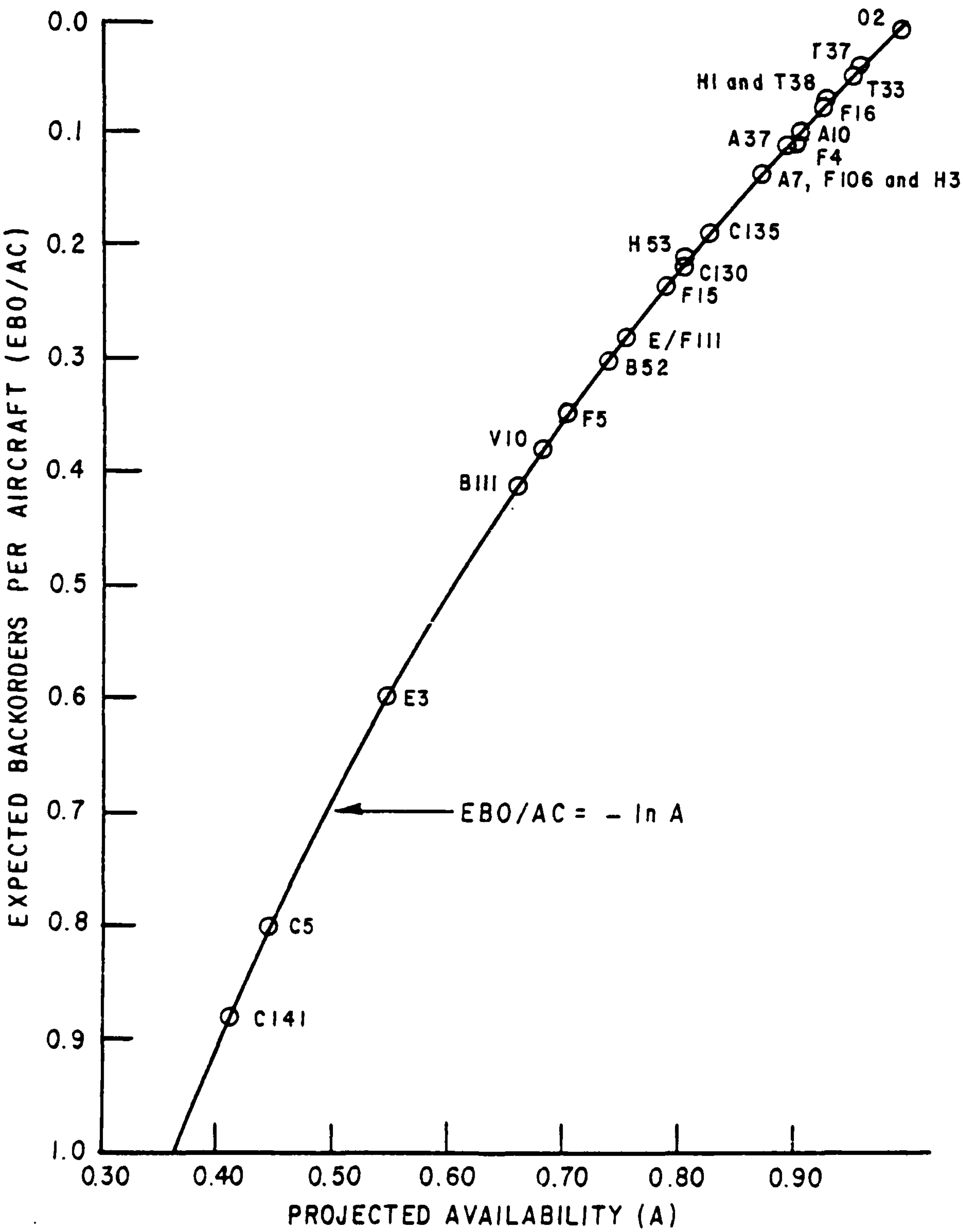


FIGURE B-2 EBO/AC vs."A" WITH VSL STOCK LEVELS (AIRCRAFT WITH "A" GREATER THAN 0.35)

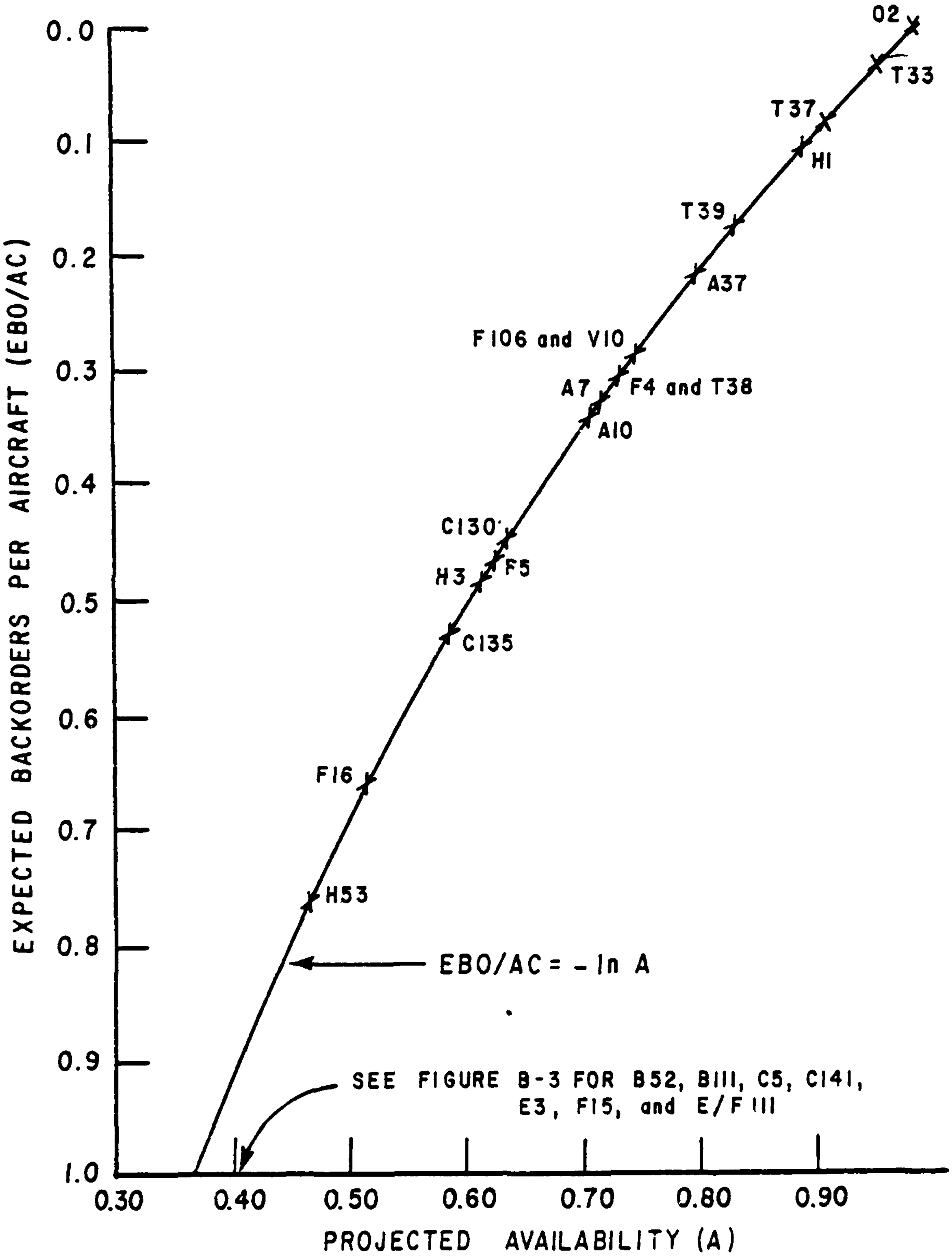
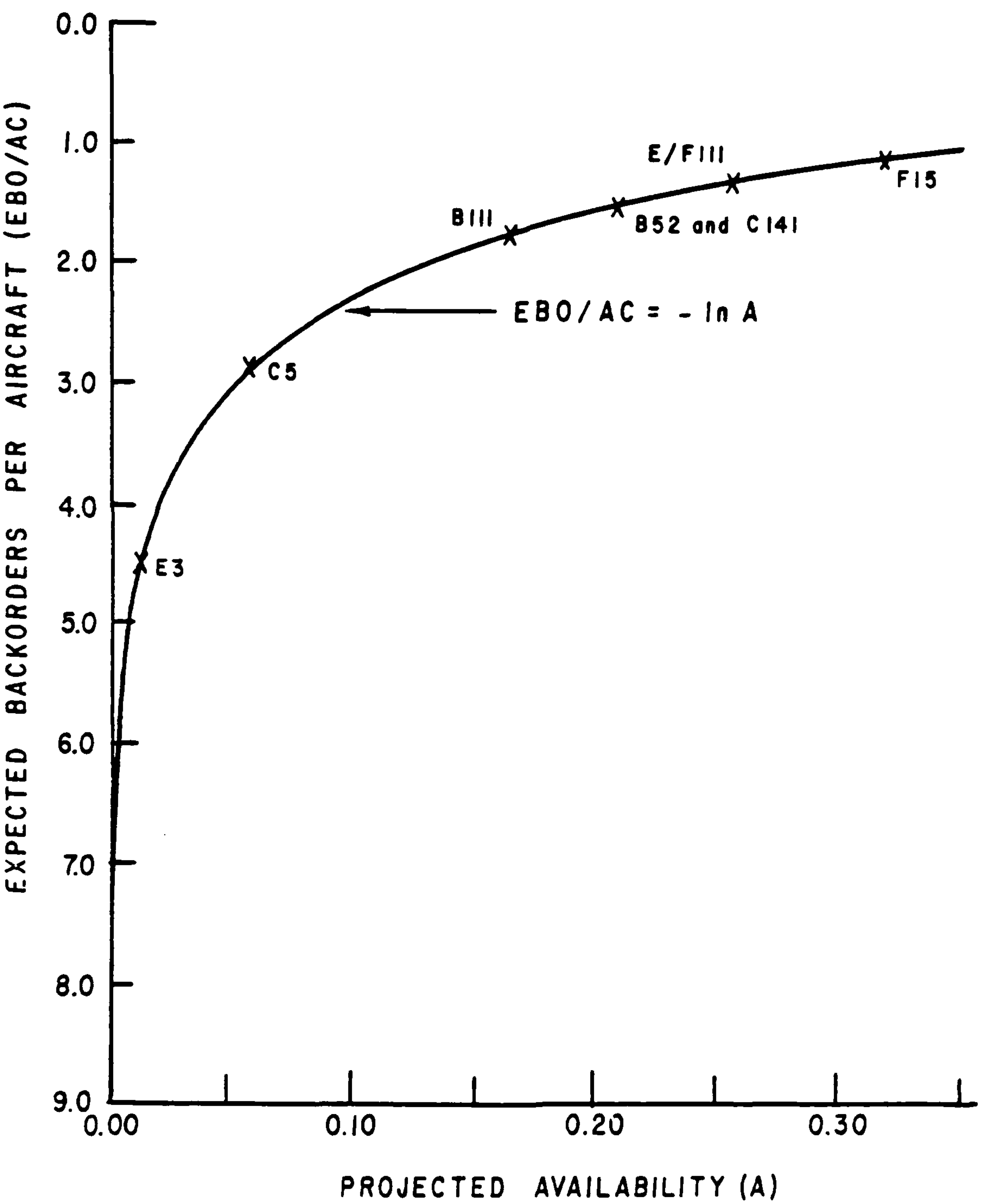


FIGURE B-3 EBO/AC vs. "A" WITH VSL STOCK LEVELS
(COMPLEX AIRCRAFT WITH "A" LESS THAN 0.35)



extreme (and unlikely) cases when many other model assumptions also fail to hold.

Figure B-3 illustrates the degree to which a fill-rate per stock number objective function penalizes complex aircraft, insofar as both availability and "holes" per aircraft are concerned.

This straightforward transformation from availability to EBOs per aircraft within an MD, and (therefore) EBOs per MD, may prove useful for setting availability targets; it may be useful in analyzing availability rates for non-optimal mixes of spares, e.g., "opening position" rates at the asset cutoff date; and it may facilitate translation of AAM outputs to interface with existing D041 systems. In any applications, however, it will be important to consider war reserve assets, repair effects, and cannibalization, all of which can affect the validity of the formula as a tool for approximations.

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W. B. Fisher, C. H. Hanks, M. A. Lueck, F. M. Slay

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Since the early 1970's, the Air Force Logistics Command has been setting worldwide Air Force spares levels for recoverable (depot-level-reparable) components using a Variable Safety Level (VSL) methodology within the D041 Recoverable Consumption Item Requirements system. Based on item cost, failure rate, and repair/resupply times, the VSL method computes safety level requirements (at both depot and bases) for each item to minimize *system-wide* backorders for given levels of investment in spares. The Aircraft Availability Model (AAM) developed by LMI for the Air Force extends and improves the VSL approach in several ways. Most importantly, AAM methods replace VSL system backorder and fill rate objectives with weapon-system-oriented supply objectives. AAM methods also take levels-of-indenture relationships between components into account and handle common components using weapon-system-oriented pro-rating techniques rather than treating common components as a separate system.

The combined effect is that with AAM methods, the same level of supply performance [expected backorders (EBOs) per aircraft type] can be achieved for less cost than with VSL methods; or, for the same cost, higher levels of performance can be achieved. The report presents an example quantifying how much better performance/cost is possible by comparing VSL and AAM costs and projected supply performance (EBOs per aircraft type) for the latter half of FY82, based on data from a March 1982 D041 data base and VSL computation.

The report also shows that a shift to weapon-system-availability methods need not cause a major disruption in AFLC's allocation of funding among the five Air Logistics Centers.

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19. ABSTRACT *(Continued)*

An appendix to the report discusses the equivalence between EBOs/aircraft and aircraft availability rates. Given this equivalence, and the fact that the AAM is designed to optimize aircraft availability, it is not surprising that AAM methods outperform VSL methods in terms of supply support to weapon systems. The main results of the report are intended to simply quantify the improvements that are possible.

END

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