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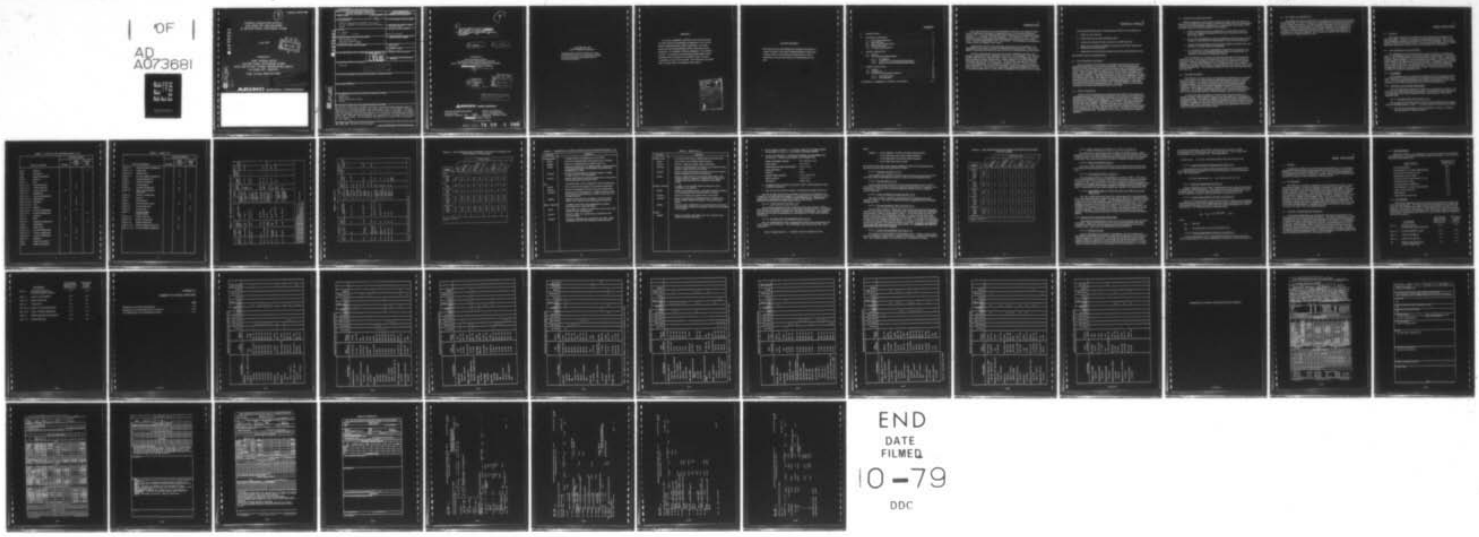

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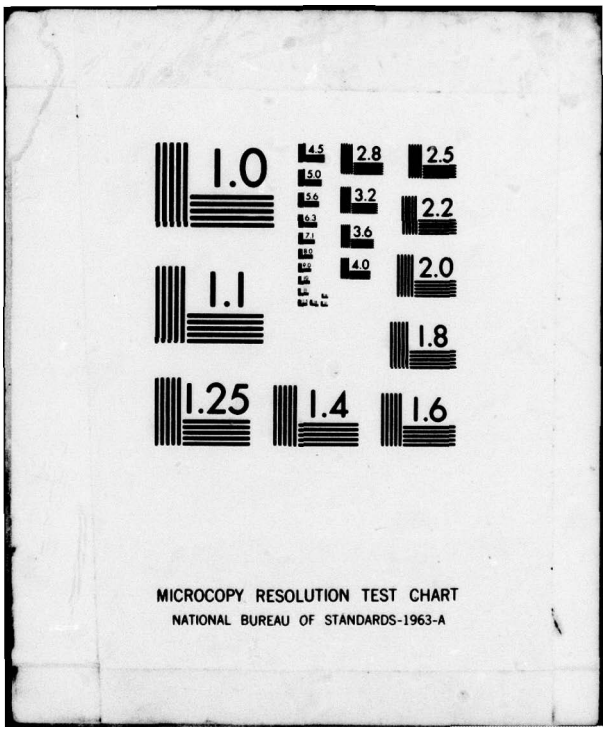
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AVIONICS INSTALLATION (AVSTALL) COST MODEL FOR USER EQUIPMENT OF NAVSTAR GLOBAL POSITIONING SYSTEM

June 1979

Prepared for

JOINT PROGRAM OFFICE
NAVSTAR GLOBAL POSITIONING SYSTEM
SPACE AND MISSILE SYSTEMS ORGANIZATION (SAMSO)
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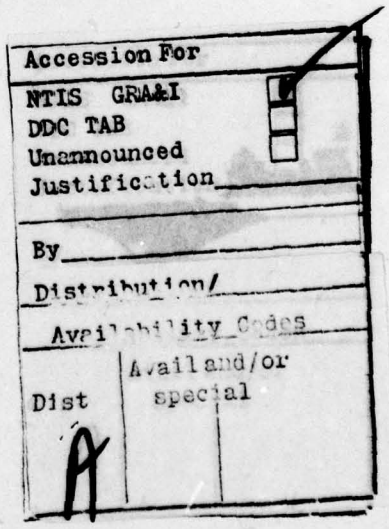
ABSTRACT

An avionics installation (AVSTALL) cost model developed by ARINC Research Corporation for application to the Navstar Global Positioning System (GPS) is described. The model determines the aircraft-peculiar costs of installing avionics equipment — for example, GPS user equipment — into military aircraft. It is based on cost estimating relationships (CERs) developed from an analysis of 51 previous Class V avionics modifications to Air Force aircraft. The development and application of these CERs are explained in this report.



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CONTENTS

1
INTRODUCTION

This report describes an avionics installation (AVSTALL) cost model developed by ARINC Research Corporation for application to the Navstar Global Positioning System (GPS). The model determines the aircraft-peculiar costs of installing avionics equipment – for example, GPS user equipment – into military aircraft. It is based on cost estimating relationships (CERs) developed from an analysis of 51 previous Class V avionics modifications to Air Force aircraft. The development and application of these CERs are explained in this report.

Although the AVSTALL cost model was developed for the GPS program, it is applicable to a wide range of aircraft modifications involving avionics. Some of the specific limitations that restrict the use of the CERs are discussed later in this report.

AVSTALL estimates the total cost of an aircraft modification through a combination of generalized CERs, specialized GPS CERs, and throughputs. Only aircraft-peculiar costs such as installation labor, Group A kits, Group A engineering, modification prototype, testing, documentation, support equipment, and initial spares are estimated using the basic AVSTALL CERs. Group B costs, including kits, RDT&E, and sustain engineering, are throughputs to the basic AVSTALL. For the GPS program, additional CERs involving aircraft-peculiar Group B development and documentation were derived. These Group B relationships specifically developed for GPS are not considered applicable to the same scope of application as the basic AVSTALL model.

2
TECHNICAL APPROACH

The technical approach taken in developing the AVSTALL cost model was to:

a. Define the cost elements

b. Collect historical aircraft modification data

c. Screen and normalize the data to produce a reliable data base

d. Apply one of a number of methods to isolate the CER inputs (regressors) and develop the CER equations

e. Determine how well the CER predicted cost fits the actual data base costs.

Each of these steps are discussed below.

2.1 COST ELEMENT DEFINITION

The cost elements for AVSTALL were identified by starting with the Cost Assessment Improvement Group (CAIG) cost format. This format was chosen because it met the immediate needs of the GPS program and, by expanding its format, cost elements could be included to support future cost and budget reporting requirements. Certain nonapplicable cost elements such as war reserve and facility construction were dropped. Then additional subtier elements were included to meet the most detailed of the future reporting requirements, which is the Modification Proposal and Analysis (MPA) form. The expansion of the CAIG format to meet MPA requirements was limited to those cost elements contributing significantly to cost, since the cost elements that historically contribute a very small percentage to modification costs did not warrant the development of CERs. The final AVSTALL cost elements developed are presented and discussed later in this report.

2.2 DATA COLLECTION

The key to the development of any CER-based cost model is the acquisition of an adequate data base. The AVSTALL data base is very extensive and includes technical and cost information concerning 51 previous Air Force Class V modifications. The data base is summarized in Appendix A. The technical data were collected primarily from Time Compliance Technical Orders (TCTOs), with supplemental data from the MPA documentation. Most of the cost data were collected from AFLC Forms 44, 44A, 44B, and 44C, and from the AFLC G079 computer products obtained at AFL Headquarters at Wright-Patterson AFB, Ohio. The data base includes both actual and forecasted costs. Examples of AFLC Form 44 and G079 are included in Appendix A.

2.3 SCREEN AND NORMALIZE DATA

Before the data base could be used to develop the CERs, each cost element of each aircraft modification was carefully reviewed to eliminate those not representative of the true cost of the particular modification, or which include extraordinary costs. Examples of the type of data eliminated are the following:

a. Group A engineering costs for modification, in which AFSC developed the Group A equipment during RDT&E and did not include the cost in the AFLC cost reports.

b. Group A kit and installation costs for installations involving major aircraft structural modifications not representative of most avionic installations.

c. Group A kit and installation costs for which insufficient technical data were available to reliably define the installations.

d. Cost elements in certain modifications in which the cost accounting rules are suspected to be substantially different from most modification cost estimates, and which are inadequately defined.

Once the data base was screened, the data that remained were normalized to express the cost in the same year's dollars and to adjust Group A average unit kit costs and average unit installation costs for learning curve effects due to different quantities. To reduce the probability of error in this procedure, the normalized quantity and base years were chosen to be representative of the majority of the modifications in the data base. The normalized quantity was 250 units and normalized base year was 1977.

2.4 CER DEVELOPMENT

The CERs for each cost element were developed by applying one or a combination of four methods; the ARINC Research Multiple Regression Analysis (REGAN) computer program, the company's Non-Linear Least Square Analysis (NLLSA) computer program, and standard statistical analysis and engineering analysis techniques. REGAN was used whenever possible to initially isolate the CER regressors with the highest correlation coefficient, and to detect interdependent regressors. The NLLSA computer program was used to find the coefficients of the CER for the best fit when the form of the CER equation selected was nonlinear.

As with most CER developments, the final results were derived from an iterative process, with the objective being to drive the coefficient of determination as high as possible. The choice of regressors was limited to those available for the GPS program, which is in the initial stages of installation concept and support concept definition. Emphasis was placed on the development of CERs for the Group A kit and installation labor costs, since these costs were the most significant of the cost elements to be included in the AVSTALL model.

2.5 FIT CHECK AND SENSITIVITY

The coefficient of determination (R^2) is a measure of how well the CER predictions fit the actual data. R^2 values computed for each coefficient are presented later in this report with the CER equations. In cases for which the sample size was too small to give the coefficient of determination any statistical significance, the coefficient was omitted. In these cases the samples were carefully selected to be representative of a "normal" aircraft modification involving avionics. In all cases the regressors in the CERs were varied for sensitivity, and to identify any behavior that could not be justified from an engineering point of view.

3
MODEL DESCRIPTION

3.1 GENERAL

This chapter introduces and explains the cost estimating relationships of the AVSTALL model. AVSTALL estimates the total investment cost for a Class V aircraft modification employing a combination of CERs and throughputs. Since the basic AVSTALL CERs do not estimate costs for Group B equipment, additional cost relationships were developed for certain Group B cost elements of the GPS program.

3.2 COST ESTIMATING RELATIONSHIPS

The expanded CAIG cost element structure used in AVSTALL is presented in Table 1. The additional subtier cost elements (fourth and fifth indenture) are used to break out the cost separately for aircraft modification, Class 1 trainer, mobile training sets, support equipment, Group B equipment, and software. Also noted in Table 1 is the method of cost estimation for each cost element – throughput, basic AVSTALL CER, or special GPS CER. Generally the basic AVSTALL CERs are designed to handle a wider range of aircraft installation types, whereas the special GPS CERs are applicable primarily to systems similar to GPS. These three sources of cost estimation are discussed separately below.

3.2.1 Throughputs

The throughput costs are estimated outside the AVSTALL cost model and used in the AVSTALL as CER regressors and to complete the aircraft modification estimate. The most prominent throughput is the Group B kit cost which, in case of GPS, accounts for more than 50 percent of the total aircraft modification cost.

3.2.2 AVSTALL Cost Estimating Relationships

The cost relationships employed by AVSTALL are summarized in Table 2. The CERs are valid within the range limits specified. All regressors and cost elements are expressed in 1978 dollars (thousands) unless otherwise noted. Each CER is discussed below.

3.2.2.1 Aircraft Group A Kit Cost (201.1.1.1)

The average unit cost of the Group A kit for aircraft modification can be found using the estimating values in Table 3. To estimate the kit cost, proceed as follows:

a. Describe the modification using the descriptors in column 1 of Table 3. The descriptors are defined in Table 4.

TABLE 1. AVSTALL COST ELEMENTS (Sheet 1 of 2)

CAIG Cost Element		Estimating Method		
		Thruput	Basic AVSTALL CER	Special GPS CER
100.	RDT&E			X
200.	Investment			
201.	System Investment			
201.1	Group A			
201.1.1	Kits			
201.1.1.1	Aircraft Mod Kit		X	
201.1.1.2	Trainer Mod Kit		X	
201.1.1.3	Group B Mod Kit	X		
201.1.2	Integration			
201.1.2.1	Aircraft Modification			
201.1.2.1.1	Engineering		X	
201.1.2.1.2	Prototype		X	
201.1.2.1.3	Test		X	
201.1.2.1.4	Software	X		
201.1.2.2	Trainer Modification		X	
201.1.2.3	Group B Modification			X
201.2	Group B			
201.2.1	Kits	X		
201.2.2	Sustained Engineering			X
201.3	Installation			
201.3.1	Labor Cost			
201.3.1.1	Aircraft Modification		X	
201.3.1.2	Trainer Modification		X	
201.3.1.3	Group B Modification	X		
201.3.2	Material		X	
202.	Support Investment			
202.1	Support Equipment			

TABLE 1. (Sheet 2 of 2)

CAIG Cost Element		Estimating Method		
		Thruput	Basic AVSTALL CER	Special GPS CER
202.1.1	Peculiar Support Equipment			
202.1.1.1	Single PSE		X	
202.1.1.2	Multiple PSE		X	
202.1.2	Common Support Equipment		X	
202.2	Training Equipment			
202.2.1	Mobile Training Set		X	
202.3	Documentation			
202.3.1	Aircraft Modification		X	
202.3.2	MTS/Trainer/Support Equipment		X	
202.3.3	Group B Modification			X
202.3.4	Group B			X
202.4	Initial Spares			
202.4.1	Aircraft Group A Kits		X	
202.4.2	Group B Mod Kits			X
202.4.3	Group B Kits			X
202.4.4	Training Equipt/ Support Equipt			
202.4.4.1	Trainer Mod Kit		X	
202,4.4.2	Mobile Training Set		X	
202.4.4.3	Support Equipment			
202.4.4.3.1	Peculiar Support Equipment		X	
202.4.4.3.2	Common Support Equipment		X	

TABLE 2. COST ESTIMATING RELATIONSHIPS (Sheet 1 of 2)

Cost Element				Regressor			Statistical Data		
Number	Name	Range Limit(1)	Estimating Equation	Name	Range Limit(1)	Development Method	Sample Size	R^2	Notes
201.1.1.1	A/C Mod Kits	0-10K Unit	See Table 3	Installation Descriptor Aircraft Type Average LRU weight	- - 0-50 lb.	Stat. Anal.	17	0.94896	(2) (3)
201.1.1.2	Trainer Mod Kit	0-100K Unit	$0.094\ Q_T\ D_T$	Q_T = Trainer Quantity D_T = Trainer Dev. Cost	1-50 100K-2000K	Stat. Anal.	8	0.96725	(4)
201.1.2.1.1	A/C Mod Eng	0-1000K	See Para 2.2.2.3	Avg. Unit Kit A Cost	0-10K	Eng. Anal.	11	-	
201.1.2.1.2	Prototype	None	$B_A + B_1' + A_1 + I_1$	B_A = Gp B Common Average Unit B_1' = Gp B Pec First Unit A_1 = Gp A First Unit I_1 = Installation First Unit	None	Eng. Anal.	-	-	
201.1.2.1.3	Test	0-150K	$4\ B_A^{0.4}\ A_A^{0.6}$	B_A = Gp B Avg. Unit A_A = Gp A Avg. Unit	0-100K 0-10K	Eng. Anal.	4	-	
201.1.2.2	Trainer Mod Eng	0-1000K	$13.25\ A_U^{0.39} A_E^{0.445}$	A_E = A/C Mod Eng A_U = Gp A Avg. Unit	0-1700K 0-50K	Stat. Anal.	6	0.9782	
201.3.1.1	A/C Installation	0-1000 Unit Hrs.	See Table 4	Installation Decriptor Aircraft Types Average LRU Weight	- - 0-50 lb.	Stat. Anal.	30	0.98621	(5) (6)
201.3.1.2	Trainer Mod Installations	0-25K Unit	$22\left(1 - e^{-D_T/272}\right)$	D_T = Trainer Dev Cost	0-1500K 0-50	Stat. Anal.	7	0.90834	
202.1.1.1	Single PSE	1-6000K	$0.5825\ B'^{0.8375}\ Q_A^{0.945}$	Q_A = Aircraft Quantity B' = Gp B Avg. Unit Cost Supported by PSE	0-600 0-250K	NLLSA	15	0.89898	(7)
202.1.1.2	Multiple PSE	1-6000K	Same as Single PSE	Q_A = Total Aircraft Quantity Supported B_1' = Gp B Avg. Unit Cost Supported by PSE	0-1800	-	-	-	

(1) All dollars unless otherwise noted are in FY78.
(2) The cost element range limit applies to the average unit cost for 250 units.
(3) Aircraft Kit A costs are computed in FY77 dollars.
(4) The cost element range limit applies to the average unit cost for any number of units less than 50.
(5) This CER computes hours. For dollars apply specific labor rate.
(6) The cost element range limit applies to the average unit hours for 250 units.
(7) REGAN = ARINC Research Multiple Progression Analysis Computer Program.

TABLE 2. (Sheet 2 of 2)

Cost Element				Regressor			Statistical Data		
Number	Name	Range Limit(1)	Estimating Equation	Name	Range Limit(1)	Development Method	Sample Size	R^2	Notes
202.1.2	Common SE	100-1700K	$10.43\ Q_A^{0.836}\ e^{-3.2/B'}$	Q_A = Aircraft Quantity	0-600	REGAN	6	0.99848	(8)
				B' = Gp B Avg. Unit Cost Supported by CSE	0-150K				
202.2.1	MTS	None	$Q_M\ (A_1 + B_A + B_1')$	Q_M = MTS Quantity	None	Eng. Anal.	6	-	
				A_1 = A/C Gp A First Unit Cost	0-20K				
				B_A = Gp B Common Avg. Unit Cost	0-100K				
				B_1 = Gp B Pec First Unit Cost	0-50K				
202.3.1	A/C Gp A Documentation	0-8000K	$1.74\ A_U^{0.2688}\ A_D^{0.8263}$	A_D = A/C Gp A Development (201.1.2.1)	10-7000K	NLLSA	13	0.95312	
				A_U = Gp A Avg. Unit Cost	0-40K				
202.3.2	MTS/Trainer/SE Documentation	0-700K	$E\left(0.477 - 1.694E \times 10^{-4}\right)$	E = Engineer Cost	0-2000K	Stat. Anal.	15	0.80103	
202.4.1	A/C Gp A Kits Spares	None	$A_A\left(0.074e^{12.3/(3.7 + Q_A)}\right)$	A_A = Gp A total kit cost per year	None	Trend	13	-	
				Q_A = Total Aircraft Quantity	None				
202.4.4.1	Trainer Mod Kit Spares	None	$T_A\left(0.15e^{0.5/(Q_T - 0.4)}\right)$	T_A = Trainer mod total kit cost	None	Trend	11	-	
				Q_T = Trainer Quantity	None				
202.4.4.2	MTS Spares	None	$0.15M_A$	M_A = MTS total acquisition cost	None	Trend	4	-	
202.4.4.3.1	PSE Spares	None	$0.15P_A$	P_A = PSE total acquisition cost	None	Trend	11		
202.4.3.2	CSE Spares	None	$0.042C_A$	C_A = CSE total acquisition cost	None	Policy (AFR 173-10)	-	-	

(8) NLLSA – ARINC Research Non-Linear Least Square Analysis Computer Program.

TABLE 3. COST ESTIMATING RELATIONSHIP FOR GROUP A AIRCRAFT KIT (1977 Dollars, 250 Unit Average)

Installation Descriptors, N	CER Equation Σ	Coefficient of CER, $K: Fighter and Fighter/Bomber	Heavy Attack	Light Attack and Observation/Attack	Light Observation	Bomber	Medium-Large Transport	Small Transport	Helicopter
Constant	C	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Mounting Shelf									
Install	$CN^{0.8}$	0.10	0.10	0.10	0.08	0.10	0.10	0.10	0.10
Replace	$CN^{0.8}$	0.10	0.10	0.10	0.05	0.10	0.10	0.10	0.10
Modify	CN	0.05	0.05	0.05	0.02	0.05	0.05	0.05	0.05
LRU									
Install	Eq. 1*	0.04	0.04	0.02	0.015	0.04	0.04	0.04	0.04
Relocate	$CN^{0.8}$	0.20	0.20	0.15	0.10	0.20	0.20	0.15	0.20
Major Cable Run									
Install	$CN^{0.5}$	0.15	0.15	0.10	0.08	0.20	0.30	0.10	0.15
Replace	$CN^{0.8}$	0.15	0.15	0.09	0.08	0.20	0.20	0.10	0.15
Cockpit Panel									
Install	CN	0.20	0.20	0.20	0.10	0.20	0.20	0.20	0.20
Remove	CN	0.10	0.10	0.08	0.04	0.10	0.10	0.10	0.10
Relocate	CN	0.20	0.20	0.15	0.08	0.20	0.20	0.15	0.20
Replace	CN	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Modify	CN	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Antenna Location									
Install	CN	0.60	0.60	0.30	0.20	0.40	0.40	0.40	0.50
Remove	CN	0.10	0.10	0.05	0.04	0.10	0.10	0.07	0.10
Relocate	CN	0.60	0.60	0.30	0.20	0.40	0.40	0.40	0.50
Modify	CN	0.40	0.40	0.40	0.15	0.30	0.30	0.27	0.30

*Equation 1: $CN^{0.6}$ (W/N)

TABLE 4. DEFINITION OF AVSTALL INSTALLATION DESCRIPTORS (Sheel 1 of 2)

Descriptor	Definition
Mounting Shelf	A single shelf for mounting one or more LRUs.
Install	Add a new mounting shelf to the avionics bay or interior.
Replace	Remove an existing shelf and install a new one.
Modify	Modify an existing shelf by adding brackets, making cutouts, or trimming any part of the shelf that may obstruct the installation of an LRU.
Relocate	Remove shelf and install in a different location, usually to make room for LRU installations.
Remove	Remove shelf from the aircraft, usually done in conjunction with the permanent removal of LRUs.
LRU	An avionics unit ($\geq$1 lb) considered a Group B equipment.
Install	Add a new LRU with mounts to an aircraft compartment.
Remove	Remove an existing LRU from an aircraft compartment.
Relocate	Remove an LRU and install it in a different location in the same vicinity or compartment, usually to make room for an additional LRU.
Replace	Remove an LRU from its mounting or rack and install another LRU using the same mounting and connectors.
Major Cable Run	A bundle of wires from one compartment to another, traversing two or more bulk heads.
Install	Add a cable run, usually to connect two or more new LRUs installed in two compartments.
Remove	Remove a cable run, usually done in conjunction with removing LRUs.
Replace	Remove an existing cable and install a new cable, taking advantage of the old cable clamps and bulk head holes.

TABLE 4. (Sheet 2 of 2)

Descriptor	Definition
Cockpit Panel	An avionic control and/or display panel in the crew area.
Install	Add a panel to an available cockpit location.
Remove	Remove a panel and replace with a blank panel.
Relocate	Remove an existing panel and install in an available location, usually to make room for a new panel.
Replace	Remove a panel and install a new panel in the same location, taking advantage of most of the old wiring.
Modify	Remove a panel that is to be modified (actual panel modification expense is separately estimated), and replace the modified panel with little or no change to the existing wiring.
Antenna Location	A location on the aircraft exterior prepared for quick installation of an antenna.
Install	Modify an aircraft skin panel, and install necessary doublers and mounting hardware to accommodate an antenna.
Remove	Remove an antenna and replace with a cover panel.
Relocate	Remove an antenna and mounting hardware, install cover panel, modify a different skin panel, and install antenna mount.
Modify	Perform minor modifications to an existing antenna location, such as adding a doubler or replacing a mount to accommodate a new antenna.
Antenna	
Replace	Remove an antenna and install a new one, using the same antenna mount and connectors.

b. Set the number of actions, N, in column 2 equal to the number of times the descriptor is used, i.e., the number of antennas installed.

c. Locate the coefficient, C, in columns 3 through 8 corresponding to the aircraft type. Typical aircraft types in each category are:

Fighter and fighter bomber:	F-4, FB-111, F-16
Heavy attack:	A-7, A-10
Light attack and observation/attack:	A-37, OV-10
Light observation:	O-2
Bomber:	B-52
Medium-large transport:	C-5, C-130, T-43
Small transport:	C-140, C-12
Helicopter:	HH-53, H-3

d. Compute the term in column 2 using the N and C values selected for each installation descriptor.

e. Sum the non-zero terms in column 2, yielding the average unit kit cost.

Once the average unit kit cost is computed, a learning curve adjustment can be applied to match the actual kit quantity. A learning curve of 90 percent is recommended based on guidelines in the NASA Technical Memorandum, Guidelines for Application of Learning/Cost Improvement Curves, TM X-64968.

3.2.2.2 Trainer Mod Kit Cost (201.1.1.2)

The estimating equation for Class 1 trainer mod kit cost is shown in Table 2, and is based on the quantity of trainers and the trainer development cost. The equation is for the total kit cost for all trainers for a particular aircraft type. The AVSTALL data base did not justify the application of a learning curve for the trainer quantities represented.

3.2.2.3 Aircraft Group A Kit Engineering (201.1.2.1.1)

The cost relationship for Group A engineering is based on the average unit cost of the Group A kit for 250 units. The relationship varies with aircraft type, and is expressed as:

Group A Engineering Cost = Constant x Group A Average Unit Cost

where

Constant = 100 for fighters, bombers, and heavy attack aircraft
= 80 for helicopters and medium/large transports
= 70 for light attack aircraft and small transports
= 50 for light observation aircraft

The AVSTALL data base cannot support application of the cost relationship beyond the narrow Group A first unit costs noted in Table 2.

3.2.2.4 Prototype Cost (201.1.2.1.2)

The prototype cost equals the average Group B common unit cost plus the first unit costs of the aircraft-peculiar Group B, Group A kit, and installation labor.

3.2.2.5 Test Cost (201.1.2.1.3)

Prototype test and kit proof cost is found using the equation given in Table 2. Test cost is a function of the Group B average unit cost and Group A average unit cost for 250 units. This cost does not include additional testing for new or modified Group B equipment.

3.2.2.6 Trainer Modification Engineering (201.1.2.2)

The Class 1 trainer modification engineering cost is determined from the equation in Table 2. This cost is a function of Group A engineering cost and Group A average unit cost.

3.2.2.7 Aircraft Installation Labor Cost (201.3.1.1)

The man-hours required to install the Group A and B kits are found in the same manner as the Group A kit cost. The terms of the estimating equation and coefficients are presented in Table 5 and described in Table 4. As for the Group A kit cost, the number of actions for each installation descriptor are entered into the term in the second column along with the appropriate aircraft coefficient, and then the terms are summed to find the average unit man-hours for 250 units. A learning curve adjustment is required for the particular quantity desired. A learning rate of 80% is recommended based on the guideline in the NASA Technical Memorandum, Guidelines for Application of Learning/Cost Improvement Curves, TM X-64968. For installation labor cost the appropriate depot labor rate is applied.

3.2.2.8 Trainer Mod Installation Cost (201.3.1.2)

The equation for estimating the unit installation cost of a Class 1 trainer modification is presented in Table 2 and is a function of the trainer modification development cost. The resulting estimate is for the labor cost of modifying one trainer.

TABLE 5. COST ESTIMATING RELATIONSHIP FOR INSTALLATION HOURS (250 Unit Average)

Installation Descriptors, N	CER Equation Σ	Coefficient of CER, Hours							
		Fighter and Fighter/Bomber	Heavy Attack	Light Attack and Observation/Attack	Light Observation	Bomber	Medium-Large Transport	Small Transport	Helicopter
Mounting Shelf									
Install	$CN^{0.9}$	8	8	6	6	8	8	6	8
Remove	$CN^{0.9}$	2	2	2	2	2	2	2	2
Relocate	$CN^{0.9}$	9	9	7	7	9	9	7	9
Replace	$CN^{0.9}$	8	8	6	6	8	8	6	8
Modify	CN	11	11	3	3	11	11	3	11
LRU									
Install	Eq. 1*	8	8	5.2	4	7	6	6	6
Remove	CN	1	1	1	1	1	1	1	1
Relocate	$CN^{0.9}$	50	50	32	26	43	37	37	37
Replace	CN	3	3	3	3	3	3	3	3
Major Cable Run									
Install	$CN^{0.5}$	30	30	10	6	35	25	20	25
Remove	$CN^{0.7}$	11	11	3	3	11	11	11	11
Replace	$CN^{0.5}$	25	22	10	6	40	30	25	25
Cockpit Panel									
Install	$CN^{0.5}$	69	69	59	10	69	69	69	69
Remove	CN	1	1	1	1	1	1	1	1
Relocate	$CN^{0.5}$	29	29	20	5	29	29	29	29
Replace	CN	10	10	3	3	10	10	5	10
Modify	CN	5	5	5	5	5	5	5	5
Antenna Location									
Install	$CN^{0.7}$	30	30	30	10	30	30	30	30
Remove	$CN^{0.9}$	8	8	8	4	8	8	8	8
Relocate	$CN^{0.7}$	35	35	35	12	35	35	35	35
Modify	$CN^{0.7}$	15	15	15	8	15	15	15	15
Replace Antenna	CN	2	2	2	1	2	2	2	2

*Equation 1: $C(W/N)^{0.8}N^{0.8}$

3.2.2.9 Support Equipment Cost (202.1.1.1, 202.1.1.2, 202.1.2)

The equations for estimating the costs of single and multiple peculiar support equipment and common support equipment is a function of aircraft quantity and Group B average unit cost. Care must be taken that the Group B unit cost used as a regressor is only that of the Group B requiring the purchase of additional support equipment.

3.2.2.10 Mobile Training Set (202.2.1)

The cost of mobile training set (MTS) is the sum of the Group A first unit cost, the common Group B average unit cost, and the aircraft-peculiar Group B first unit cost.

3.2.2.11 Documentation (202.3.1, 202.3.2)

The estimating equations for documentation are shown in Table 2. The cost of Group A documentation is a function of the Group A development cost and the Group A average unit cost. The development cost used as a regressor includes the Group A engineering, prototype and test costs. The cost of support and training equipment documentation is a gradually decreasing percentage of the engineering cost for that equipment. In both cases, the data include engineering, technical, and management data.

3.2.2.12 Initial Spares (202.4.1, 202.4.4.1, 202.4.4.2, 202.4.4.3.1, and 202.4.4.3.2

The cost of initial spares was found to be a percentage of the corresponding kit cost. Since the percentage is assigned through a policy decision, a statistical analysis to develop a CER is less meaningful. The percentages presented in Table 2 are representative of the most often used percentages in the AVSTALL data bank. A few percentages derived from the data bank vary considerably from those values, but no explanation could be found to justify the variation. For the Group A and trainer mod kit spares, the AVSTALL data showed an increased percentage of spares for low aircraft mod quantities. This variation was included in the formation of the spares equation. The resulting spares estimates include both initial investment and expense spares.

3.2.3 Special GPS Cost Estimating Relationships

The special GPS CERs noted in Table 1 are not considered part of the AVSTALL cost model. These relationships have a narrower scope of application than those developed for AVSTALL, and are generally considered adequate only for avionics similar to GPS. Each of the cost relationships is discussed below.

3.2.3.1 RDT&E Cost (100)

For the GPS program the research, development, test and evaluation cost attributable to particular aircraft types includes the development of aircraft-peculiar Group B equipment to support GPS. This equipment includes the flexible modular interface (FMI) unit required for every aircraft, and the aircraft-peculiar control display unit (CDU) required for aircraft in which the GPS common CDU or a modification to existing aircraft CDU is not adequate for the GPS installation. To develop

an estimating relationship, the AVSTALL data base was reviewed for similar developments with a Group B first unit cost of up to $30,000. Then a simple ratio was generated to find the RDT&E cost. This relationship is:

RDT&E Cost = 42.54 (Sum of aircraft-peculiar Group B first unit costs)

3.2.3.2 Group B Modification Engineering Cost (201.1.2.3)

The engineering cost to modify existing aircraft CDUs to accommodate GPS is found using the same relationship as for the aircraft-peculiar Group B development cost. This relationship is:

CDU Mod Engineering Cost = 42.54 (Mod kit first unit cost)

3.2.3.3 Sustained Engineering Cost (201.2.2)

Sustained engineering cost is that of retaining the GPS user equipment contractor for production engineering support. This support includes engineering changes, documentation changes, and system engineering support of aircraft modifications. The cost is allotted as 5 percent of the Group B kit cost (Cost Element 201.2.1).

3.2.3.4 Group B Documentation Cost (202.3.3 and 202.3.4)

The cost of aircraft-peculiar Group B documentation is found using an estimating relationship based on the Group B engineering cost. Basic coefficients of the equation were determined through review of three previous Group B developments for Class V modifications. The resulting equation is presented below.

$$D_{B'} = B'_D \ (0.75\, e^{-B'_D/3000} + 0.25)$$

where

$D_{B'}$ = data cost

B'_D = aircraft-peculiar Group B development cost.

3.2.3.5 Group B Initial Spares Cost (202.4.2 and 202.4.3)

Group B initial spares cost is estimated using 20 percent of the Group B kit cost (Cost Element 201.2.1) and is representative of previous Group B procurements.

4
MODEL APPLICATION

4.1 GENERAL

To employ the AVSTALL cost model properly and effectively, it is important to understand its characteristics and the importance of the cost elements in the overall estimation of Class V aircraft modifications. In this section the intended application and management of AVSTALL is discussed, together with the impact of individual cost elements on a typical aircraft modification involving avionics.

4.2 MANAGEMENT

The AVSTALL cost model is intended for use at the outset of a Class V avionic development program. It should be computer-mechanized to allow initial tradeoff studies and to easily revise the cost estimate as the input values change. In the case of GPS, AVSTALL is used with a generalized cost program (GENCOST) developed by ARINC Research Corporation. As the development program matures and reliable cost estimates can be developed from contractor proposals, individual AVSTALL cost elements can be replaced with throughput values. Since some AVSTALL CERs are dependent on the results of other AVSTALL CERs, refining a cost element estimate improves the model's accuracy by more than that single element's contribution. As an example, supplying the Group A engineering cost will impact the Group A data CER and improve the data estimate. Through this process, the AVSTALL cost estimate can evolve and mature with a development program.

4.3 AVSTALL CHARACTERISTIC BEHAVIOR

The aircraft modification cost was studied to determine its sensitivity to the input parameters and cost elements of AVSTALL. The results of this study are useful in pointing out areas in which cost tradeoff analyses would be particularly beneficial. To perform the study, a typical aircraft modification was assumed – the installation of GPS user equipment into a fighter type aircraft. An aircraft quantity of 400 was designated, and the quantity of Class 1 trainers and MTS was taken as being typical of the ratio of training equipment to aircraft quantity of fighter aircraft. Naturally the percent impact of the cost elements and input parameters may change considerably for different aircraft modification cases. The one selected is considered typical of the type of modification that AVSTALL was designed to handle.

4.3.1 Input Parameters

Each of the AVSTALL cost elements was reviewed for the impact of particular input parameters, and the total modification impact was calculated. The results of this study are presented below.

Input Parameter	Modification Cost Impact (Pct.)
Aircraft Quantities	82.7
Learning Rate for Avionics Manufacturing	50.4
GPS Group B Common Kit Cost	46.0
Modification Actions (Total)	26.7
GPS Group B Aircraft-Peculiar Kit Cost	24.4
Installation Labor Rates	11.8
Learning Rate for Installation	11.6
Learning Rate for Group A Kit Assembly	8.5
Class 1 Trainer Quantity	0.9
MTS Quantity	0.8
GPS Group B Mod Kit Cost	0.5

4.3.2 Cost Elements

The aircraft modification cost was reviewed for its sensitivity to each of the AVSTALL cost elements. The effect on the overall modification cost includes that of the cost element alone and its effect on other cost elements by acting as a CER regressor. For example, the Group A kit development cost is used as a regressor in determining the Group A documentation cost. The results of this review are presented below. Cost elements with less than 0.5 percent total impact on modification cost were not included.

	Cost Element	Cost Element Impact on Total Mod Cost (%)	Total Impact on Mod Cost (%)
201.2.1	GPS Group B Kits (Common and Aircraft-Peculiar)	49.7	70.4
201.3.1.1	Aircraft Installation Labor	11.6	11.6
202.4.2	GPS Group B Spares	9.9	9.9
201.1.1.1	Group A Aircraft Kits	7.7	15.1
100	RDT&E (Aircraft-Peculiar Group B Engineering)	4.5	7.7

	Cost Element	Cost Element Impact on Total Mod Cost (%)	Total Impact on Mod Cost (%)
202.3.4	Group B Documentation (Aircraft-Peculiar Group B)	3.2	3.2
202.3.1	Group A Documentation	2.2	2.2
202.1.1.1	Single Peculiar SE	2.1	2.3
202.1.2	Common SE	2.1	2.4
201.1.2.1.1	Group A Aircraft Engineering	1.8	7.0
201.1.2.2	Class 1 Trainer Engineering	1.5	3.0
202.3.2	MTS/Trainer/SE Documentation	0.6	0.6
201.1.1.3	Group B Mod Kits	0.2	0.5

APPENDIX A

SUMMARY OF AVSTALL DATA BASE

MODIFICATION/COST DATA DOCUMENTATION

Title/Subject	TCTO (Aircraft)	Mod Nr (Date)	Form 44	Form 44A	Form 44B	Form 44C	Form 44 Data	G079 Products	G079 Data	AFLC Form 139	TCTO	TCTO Data	G037E	Partial PMD	
AFSATCOM															
EC/RC-135, B52G/H, FB-111A	(All)	F2784	X												
AFSATCOM	Unk	F2784													
Aircraft	(EC-135 All)	(May 76)	X						X					X	
Aircraft	(EC-135A)	(May 76)		X											
Aircraft	(EC-135C)	(May 76)		X					X						
Aircraft	(EC-135G)	(May 76)		X					X						
Aircraft	(EC-135H)	(May 76)		X					X						
Aircraft	(EC-135J)	(May 76)		X					X						
Aircraft	(EC-135P)	(May 76)		X					X						
AFSATCOM	Unknown	F2784													
Aircraft	(RC-135)	(May 76)	X	X					X					X	
AFSATCOM	1F-111(B)A-671	F2784													
Aircraft	(FB-111A)	(May 76)	X	X					X					X	
MTS	(FB-111A)	(May 76)			X										
Class I Trainer	(FB-111A)	(May 76)			X				X						
AFSATCOM (ECP 1596)	1B-52-2178	F2784													
Aircraft	(B52G/H)	(May 76)							X					X	
Class I Trainers	(B52G/H)	(May 76)							X						

MODIFICATION/COST DATA DOCUMENTATION

Title/Subject	TCTO (Aircraft)	Mod Nr. (Date)	Form 44	Form 44A	Form 44B	Form 44C	Form 44 Data	G079 Products	G079 Data	AFLC Form 139	TCTO	TCTO Data	G037E		
AFSATCOM Antenna	1C-137V-973	F2980													
Aircraft	(VC-137)	(Jul 78)							X						
Departure Warning System	1F-15A-734	Unk													
Aircraft	(F/T F-15)	(Unk)										X			
E-O Target Designator	1F-4E-588	F2787													
Aircraft	(F-4E)	(Unk)										X			
INS/AHRS	1C-141-1470	F2903											X		
Aircraft	(C-141)	(Sep 74)	X	X											
Aircraft	(C-141)	(Sep 76)	X	X											
Aircraft	(C-141)	(17Oct77)	X												
Aircraft	(C-141)	(24Oct77)	X					X	X		X				
Class I Trainer	(C-141)	(Sep 74)			X										
Class I Trainer	(C-141)	(Sep 76)			X				X						
Station Keep Sys (Gp B)	(C-141)	(Sep 74)			X										
Multi-Channel Recorders	1C-135-763	19001C													
Aircraft	(EC/KC/RC-135)	(Jul 78)							X			X	X		
Multi-Channel Recorders	1T-37B-528	Unk													
Aircraft	IT-37B)	(Unk)										X			

MODIFICATION/COST DATA DOCUMENTATION

Title/Subject	TCTO (Aircraft)	Mod Nr (Date)	Form 44	Form 44A	Form 44B	Form 44C	Form 44 Data	G079 Products	G079 Data	AFLC Form 139	TCTO	TCTO Data	G037E		
NAVSTAR GPS	Unk	Unk													
Aircraft	(C-141)	(Jul 76)	X	X											
Class I Trainer	(C-141)	(Jul 76)			X										
OMEGA (ARN-131).	1C-130-943	F2934													
Aircraft (RIW)option)	(C-130)	(Mar 76)	X	X						X					
Aircraft (organic option)	(C-130)	(Mar 76)	X	X				X	X	X	X	X	X		
PAVE LOW	Unk-NARF	F2996													
Aircraft	(HH-53C)	(Sep 78)						X	X						
PAVE PENNY	1A-7D-820	F2951													
Aircraft	(A-7D)	(Jul 78)							X						
PAVE TACK	1F-4E-626	F2917													
Aircraft	(F-4E)	(Dec 76)	X						X	X					
ARN-101	(F-4E)	(Dec 76)		X											
IMU	(F-4E)	(Dec 76)		X											
Control units	(F-4E)	(Dec 76)		X											
Group B	(F-4E)	(Dec 76)			X										
Support Equipment	(F-4E)	(Dec 76)			X										
MTS	(F-4E)	(Dec 76)			X										

MODIFICATION/COST DATA DOCUMENTATION

Title/Subject	TCTO (Aircraft)	Mod Nr (Date)	Form 44	Form 44A	Form 44B	Form 44C	Form 44 Data	G079 Products	G079 Data	AFLC Form 139	TCTO	TCTO Data	G037E	AF Form 2612 Data	Form 48
PAVE TACK	1F-4(R)C-667	F2917													
Aircraft	(RF-4C)	(Dec 76)	X						X	X					
ARN-101	(RF-4C)	(Dec 76)		X											
IMU	(RF-4C)	(Dec 76)		X											
Control units	(RF-4C)	(Dec 76)		X											
ASQ-154	(RF-4C)	(Unk)		X											
Group B	(RF-4C)	(Dec 76)			X										
Support equipment	(RF-4C)	(Dec 76)			X										
MTS	(RF-4C)	(Dec 76)			X										
PAVE TACK	Unk	Unk													
Aircraft	(F-111F)	(Unk)												X	
Pilot Operable Radar	1C-141-514 1C-141A-1515	16622B													
Aircraft	(C-141)	(May 78)						X							X
RIVET BAT	1A-7D-760	F2809													
Aircraft (radar homing)	(A-7D)	(Jul 78)					X		X			X	X		
* RIVET BAT	1F-4C-615	F2777													
	1F-4D-565	F2777A													
	1F-4E-591	F2777B													

*Note: Mod numbers and TCTO numbers on each line do not correspond to each other.

MODIFICATION/COST DATA DOCUMENTATION

	Title/Subject	TCTO (Aircraft)	Mod Nr (Date)	Form 44	Form 44A	Form 44B	Form 44C	Form 44 Data	G079 Products	G079 Data	AFLC Form 139	TCTO	TCTO Data	G037E		
*	RIVET BAT (Cont'd)	1F-4(R)C-652	F27777C													
	Aircraft	(F-4 (all))	(Jul 78)							X						
	Radar Warn Sys (ALR-46)	(F-4)	(Jul 78)					X		X			X			
	Class I Trainers	(F-4)	(Jul 78)					X		X						
	Phase II RIVET BAT	(F-4)	(Jul 78)							X						
	Refaired	(F-4)	(Jul 78)							X						
	Non-refaired	(F-4)	(Jul 78)							X						
	SEEK SILENCE	1F-4E-532	F1747													
	(ASQ-19B Secure Voice Radio)	1F-4-755														
	Aircraft	(F-4E)	(Jul 78)					X		X			X			
	Aircraft	(F-4C)	(Jul 78)							X			X			
	Tactical Electronic Warfare (TEWS)	1F-15A-700	Unk													
	Aircraft	(F/TF-15)	(Unk)										X			
	TEREC (AN/ALQ-125)	1F-4(R)C-669	F2707													
	Aircraft	(RF-4C)	(Jul 78)							X						
	Production Gp B option	(RF-4C)	(Dec 76)	X	X						X					
	Acceleration option	(RF-4C)	(Dec 76)	X	X						X					
	Contractor option	(RF-4C)	(Dec 76)	X	X											

*Note: Mod numbers and TCTO numbers on each line do not correspond to each other.

MODIFICATION/COST DATA DOCUMENTATION

Title/Subject	TCTO (Aircraft)	Mod Nr (Date)	Form 44	Form 44A	Form 44B	Form 44C	Form 44 Data	G079 Products	G079 Data	AFLC Form 139	TCTO	TCTO Data	G037E	Partial Pmd	
VOR/ILS (ARN-127)	Unk	F2848													
Aircraft	(OV-10)	(Jul 78)							X						
WILD WEASEL	Unk	F2740													
Aircraft	(F-4G)	(Dec 77)	X							X				X	
Blocks 42-45, Group A	(F-4G)	(Sep 77)		X											
AN/APR-38	(F-4G)	(Sep 77)		X											
Elec Warfare Avionics Integration Software FacEq	(F-4G)	(Sep 77)		X											
ASG-26A LCOSS	(F-4G)	(Sep 77)			X										
LAU-80A/A Launcher	(F-4G)	(Sep 77)			X										
ASM-32A-(SE)	(F-4G)	(Sep 77)			X										
AWM-13A (SE)	(F-4G)	(Sep 77)			X										
600-Gal Tank	(F-4G)	(Sep 77)		X											
A/F37U-T9-MTS															
Option for 3	(F-4G)	(Aug 77)			X										
Option for 4	(F-4G)	(Aug 77)			X										
Option for 5	(F-4G)	(Aug 77)			X										
DSCG installation	(F-4G)	(Aug 77)			X										
Gnd Playback Sta&Print Cap	(F-4G)	(Aug 77)		X											
LAU-118 launchers (HARM)	(F-4G)	(Aug 77)		X											

MODIFICATION/COST DATA DOCUMENTATION

Title/Subject	TCTO (Aircraft)	Mod Nr (Date)	Form 44	Form 44A	Form 44B	Form 44C	Form 44 Data	G079 Products	G079 Data	AFLC Form 139	TCTO	TCTO Data	G037E		
TEREC (AN/ALQ-125) (Cont'd)															
ALQ-125 (Group B)	(RF-4C)	(Dec 76)				X									
UHF Antenna Replacement	1C-130-920	65105B													
Aircraft	(C-130)	(Jul 78)							X			X			
VOR/ILS (ARN-127)	1T-37B-542	F2848													
Aircraft	(A-37)	(Jul 78)							X			X			
Aircraft	(T-37)	(Jul 78)					X		X			X			
Class I Trainer	(A/T-37)	(Unk)					X								
VOR/ILS (ARN-127)	1F-4-1056	F2848													
Aircraft	(F-4C/D/E)	(Jan 78)					X		X			X			
Class I Trainer	(F-4)	(Jan 78)					X		X						
Aircraft	(RF-4C)	(Jan 78)					X					X			
Class I Trainer	(RF-4C)	(Jan 78)					X		X						
MTS	(RF-4C)	(Jan 78)					X								
VOL/ILS (ARN-127)	1H-3-640	*F2645													
Aircraft	(CH-3E)	(Jul 78)							X						
VOR/ILS (ARN-127)	Unk	Unk													
Aircraft	(O-2)	(Unk)					X								

*Mod Nr. previously was F2848

MODIFICATION/COST DATA DOCUMENTATION

Title/Subject	TCTO (Aircraft)	Mod Nr (Date)	Form 44	Form 44A	Form 44B	Form 44C	Form 44 Data	G079 Products	G079 Data	AFLC Form 139	TCTO	TCTO Data	G037E		
AN/ALQ-122 AEW ECM "SNOE"	1B-52-2039	F2525													
Aircraft (ECP 1525)	(B-52G/H)	(Jul 78)					X		X			X			
AN/ALQ-127 Tail Warning Sys	Unk	F2923													
Aircraft	(B-52G/H)	---													
Class I Trainer		(Jul 78)							X						
AN/ALQ-137	1F-111(B)-670	F2960													
Aircraft	(FB-111A)	(Aug 78)					X		X						
Class I Trainer	(FB-111A)	(Jul 78)					X		X						
Support Equip	(FB-111A)	(Unk)					X								
AN/ALR-62 ECM Rcvr	1F-111-1168	F2957													
Aircraft	(FB-111A)	(Aug 78)					X		X						
AN/ALR-69	Unk	F2952													
Aircraft	(F-4D)	(Jul 78)					X		X						
AN/APQ-128 TFR (ECP 3195)	1F-111-973	F2824													
Aircraft	(F-111A/E)	(Aug 78)							X				X		
Class I Trainer	(F-111A/E)	(Jul 78)							X						
AN/ARN-89A ADF Sys	1H-3(H)F-577	Unk													
Aircraft	(HH-3F)	(Unk)										X			

MODIFICATION/COST DATA DOCUMENTATION

Title/Subject	TCTO (Aircraft)	Mod Nr (Date)	Form 44	Form 44A	Form 44B	Form 44C	Form 44 Data	G079 Products	G079 Data	AFLC Form 139	TCTO	TCTO Data	G037E	Form 48	
AN/ARN-118 TACAN	1A-7D-806	Unk													
Aircraft	(A-7D)	(Unk)										X			
AN/ARN-118 TACAN	1C-135-1041	Unk													
Aircraft	(C-135)	(Unk)										X			
AN/ARN-118 TACAN	Unk	Unk													
Aircraft	(F/RF-4C/D/E)	(Mar 78)												X	
AN/APX-80 Radar Subsys	1F-4E-587	F2771													
Aircraft	(F-4E)	(Jan 78)							X			X			
Trainer	(F-4E)	(Jan 78)							X						
AN/ASQ-151 E-O Viewing	1B-52-2012	F2595													
Aircraft	(B-52G/H)	(Jul 78)							X						
FM 622 FM Radio	1H-3-700	F1849													
Aircraft	(CH-3E)	(Jul 78)							X			X			

EXAMPLES OF AIRCRAFT MODIFICATION COST REPORTS

CLASS V MODIFICATION PROPOSAL AND ANALYSIS (MPA) SUMMARY

Oct. 24, 1977

1. Title: C-141 Improved Navigation System (INS/AHRS)

3. System/Equipment: [ ] Acquisition [X] Post Acquisition

4. Numbers
Modification No. 2903
Combat ROC No.
Program Action Directive No. R-04-036-(2)
ROC No. MAC ROC 6-73

5. Type of Study: [ ] Basic [X] Revision (No. 3)

6. Description: This modification proposal provides for improving C-141A aircraft navigational capabilities by installing dual inertial systems (INS), an attitude heading reference system, (AHRS) and a new Navigation Select Panel. The dual IN has been configured as completely redundant "stand alone" systems. The failure of one system will not affect the other system nor any aircraft sub-system dependent upon signal inputs from inertial systems. The INS selected for this program is basically an ARINC 561 (Carousel IVE) system and can be interchanged between different types of aircraft similarly equipped. The AHRS provides a back-up navigation mode in case of dual INS failure and will provide the third gyro source that is required by the all weather landing system (AWLS). (See attached continuation sheet)(withdrawn)

7. Quantities to be Changed
Production
In Service 273

8. Production Effectivity (Item No., Serial No.)

9. Engineering Responsibility

	AFLC	AFSC
System	[X]	[ ]
Group B	[X]	[X]
AGE	[X]	[X]
MTS	[X]	[ ]
Class I Trainers	[X]	[ ]

10. Status of Equipment

Qualification of Group B	[X] has	[ ] has not been completed
Qualification of AGE	[X] has	[ ] has not been completed
Qualification of MTS	[ ] has	[ ] has not been completed
Qualification of Trainers	[ ] has	[X] has not been completed
Adequate Procurement Data	[X] is	[ ] is not available

11. Costs shown for material and services are based on:
[ ] A Cost Preliminary Estimate [X] A Detailed Study of Factual Documentation

12. Cost and schedule estimates herein must be revalidated if the modification is not approved by ....

13. MODIFICATION COST SUMMARY

A Item	B Budget Program	C FY 75	D FY 76	E FY 77	F FY 78	G TOTALS
14. Engineering	P1100	1,345,168				1,345,168
15. Prototype	P1100	722,100				722,100
16. Testing	P1100	75,000				75,000
17. Proofing	DMIF			116,654		116,654
18. Data	P1100	1,000,790	226,968	265,200	360,300	1,853,258
19. Kits/Materials	P1100		13,421,400	29,281,930		42,703,330
20. RTW	P1100		1,867,977	2,959,923		4,827,900
21. Initial Spares Inv.	P1600		2,451,310	1,668,310	857,200	4,976,820
22. Initial Spares Exp.	4921		117,000	196,670	212,100	525,770
23. Special Tools	P1100	3,816				3,816
24. Training Aids/Devices	P1100			143,000		143,000
25. AGE (Peculiar - Single)	P1100	472,742	1,318,059			1,790,801
26. AGE (Peculiar-Multiple)						
27. AGE (Common)	P1200				2,203,100	2,203,100
28. Installation Cost (C)	DMIF			574,272	2,185,920	2,760,192
29. Installation Cost (O)	DMIF			1,153,478	4,451,331	5,604,809
30. FY Totals		3,619,616	19,402,714	36,359,437	10,259,951	
31. Grand Total						69,651,718

32. Installation Labor Unit Man-Hours 1636.6 Total Man-Hours 390,752 Man-Hour Rate $21.77

33. Cost of Spares Obsolescence: 8,682,210
34. Cost of AGE Obsolescence: NONE
35. Cost of AGE Spares Obsolescence: NONE

36. SYSTEM MODIFICATION SCHEDULE

A. Qty	B. Agency[1]	C. In & Out	D. FY 76 1	2	3	4	Total	E. FY 77 1	2	3	4	Total	F. FY 78 1–2	3–4	Total	G. FY 79 1–2	3–4	Total
1	C	IN			1*		1		*Prototype									
	C	OUT			1		1											
161	D	IN							1	9	23	33	69	59	128			
	D	OUT								2	15	17	66	65	131	13		13
111	CT	IN								3	15	18	47	45	92	1		1
	CT	OUT									7	7	47	50	97	7		7

[1] Use the following codes to show type of agency programmed to complete each quantity:
D–Depot, DT–Depot Team, C–Contract, CT–Contract Team, B–Base

37. Supporting Actions

Material Acquisition	[X] is required	[ ] is not required
Modification of Gp B	[ ] is required	[X] is not required
Modification of AGE	[ ] is required	[X] is not required
Modification of MTS	[ ] is required	[X] is not required
Modification of Class I Trainers	[X] is required	[ ] is not required

Equipment Development and Testing:

Group B	[X] is required	[ ] is not required
AGE	[X] is required	[ ] is not required
MTS	[ ] is required	[X] is not required
Class I Trainers	[X] is required	[ ] is not required

AFLC/AFSC FORM [illegible] 44 REPLACES AFLC FORMS WHICH IS OBSOLETE AFLC-WPAFB-DEC [illegible]

Technical Risk	☐ High	☒ Low	Block 45	Cost Risks	☒ High ☐ Low Block 46
40 Interrogation of Mounted Items				☐ is required	☐ is not required

41. Additional Training Requirements

See Block 48 continuation sheet

42. Effect of Modification on Performance Characteristics and on Other Related Configuration Changes

With the exception of a possible wieght reduction in the avionics bay area, there is no known or anticipated effect on performance characteristics as a result of this modification.

43. Impact on Safety

None

44. Impact of the Modification on Life Support Systems/Equipment or its Interfaces

None

45. Implications for Personnel Sub-Systems Development

None

46. Logistics Support Capability

Is Contractor Logistics Support Required ☐ Yes ☐ No (If answer is yes, identify limitations requiring support, time frame involved and projected cost.)

See Block 48 continuation sheet

47. AFSC/AFLC Responsibilities

See Block 48 continuation sheet

48. Remarks

See attached remarks continuation sheet

49. Recommendations of Initiating Activity ( )

See Block 48 continuation sheet

50. Signature of Agency Responsible for Preparation

51. AFLC/AFSC Position

Signature

CLASS V MODIFICATION PROPOSAL AND ANALYSIS (MPA) MATERIEL ACQUISITION

Sep 76

2. Title

3. System/Equipment
☐ Acquisition
☒ Post Acquisition

4. Numbers
Modification No. 2903
Request Action Directive No. 84-036
Contract
ROC No.
ROC Ltr MAC 6-73

5. Type of Study
☐ Joint
☒ Rev. No. 2

6. Prepared by
J. R. King, WR-ALC/MMSRAB/2922

7. Costs shown for material and services are based on
☐ A Cost Preliminary Estimate
☒ A Detailed Study of Factual Documentation

8. Costs estimated herein must be revalidated if the modification is not approved by 31 Dec 76

9. ACQUISITION REQUIREMENTS AND COSTS

A Item	B Budget Program	C Lead Time	D Unit Cost	E FY 75	F FY 76	G FY 77	H FY 78	I TOTAL
GROUP A								
10. Engineering	P1100	1 Qtr		607,300				607,300
11. Prototype	P1100	2 Qtr		722,100				722,100
12. Testing	P1100	1 Qtr		75,000				75,000
13. Proofing	DMIF	1 Qtr			13,000			
14. Data	P1100	2 Qtr		881,800				881,800
15. Mod Kit Cost	P1100	2 Qtr	20.5K		1,751,100	3,833,500		5,584,600
16.								
17. Initial Spares Cost ( ) Inv.	P1600	2 Qtr			106,800			106,800
18. Initial Spares Cost ( ) Exp	4921	2 Qtr			48,100			48,100
19.								
20.								
21. Installation Cost (C)								
22. Installation Cost (D)	DMIF		12.4K			1,103,000	2,279,600	3,382,600
23. FY Total				2,286,200	1,919,000	4,936,500	2,279,600	11,421,300
24. Mod Kit Qty				1	86	186		273
GROUP B								
25. Engineering	P1100	2 Qtr		499,700				499,700
26. Testing								
27. Data	P1100	2 Qtr		339,000	427,100	59,200		825,300
28. Mod Kit Cost (TNS)	P1100	2 Qtr	126K		10,363,500	23,365,400		33,728,900
29. " " (AHRS)	P1100	2 Qtr			1,028,800	2,397,700		3,426,500
30. Group B Spares Cost (%) Inv.	P1600	2 Qtr			2,419,000	1,312,200		3,731,200
31. Group B Spares Cost (%) Exp.	4921	2 Qtr			60,100	39,300		99,400
32. Group B M&O Inv.								
33. Group B M&O Exp.								
34. Bench Mock-Up	P1100	2 Qtr			143,200			143,200
35. RTU-TNS	P1100				1,183,200	1,476,300		2,659,500
36. RTU-AHRS	P1100				687,300	1,506,600		2,193,900
37. FY Total				838,700	16,312,200	30,156,700		47,307,600
38. Mod Kit Qty				1	86	186		273
AGE REQUIREMENTS (PECULIAR-SINGLE APPLICATION)								
39. Engineering								
40. Testing								
41. Data	P1100	8 Qtr					360,300	360,300
42. Equip (End Items)								
43. TNS Field	P1100	2 Qtr	69.4K	82,400	643,400			725,800
44. TNS Depot	P1200	8 Qtr	886.9K				1,081,200	1,081,200
45. AHRS Field	P1100	2 Qtr	118.6K	179,100	807,400			1,186,500
46. AHRS Depot	P1200	8 Qtr	224.3K				1,121,900	1,121,900
47. Initial M&O Parts Cost 20 %) Inv.	P1600	8 Qtr					857,200	857,200
48. Initial M&O Parts Cost (5 %) Exp.	4921	8 Qtr					212,100	212,100
49. FY Totals				461,500	1,450,800		3,632,700	5,545,000
AGE REQUIREMENTS (PECULIAR MULTIPLE APPLICATION)								
50. Equip. (End Items)								
51.								
52.								
AGE REQUIREMENTS (COMMON)								
53. Equip. (End Items)								
54.								
55.								

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56. AGE REQUIRING PROCUREMENT

A Noun and FSC/FSN	B Budget Program	C Lead Time	D Need Date	E Qty	F Unit Cost	G FY	H FY	I FY	J FY
57. AGE (PECULIAR-SINGLE APPLICATION)									
Alignment Fixtures	P1100	2 Qtr	FY76	10	700	7,000			
58. AGE (PECULIAR-MULTIPLE APPLICATION)									
59. AGE (COMMON)									

60. System/Sub-System/Equipment Integration Plan

The INS and AHRS have been procured on separate competitive contracts. The INS contractor (Delco Electronics) is the integration contractor. Aircraft Serial No. 65-269 is the prototype aircraft and the AHRS was furnished as GFE. Prototyping began in March 1976. Flight test was flown from mid April 1976 through June 1976. Kit proofing will be in Jan 1977. Installation will begin in May 1977 and will be accomplished during the PDM cycle and a drop-in program at the rate of 19 per month (PDM and drop-in).

61. Acquisition Plan

62. Remarks

Block 11: This $722K is for one "A" kit, one "B" kit, and cost to prototype modification on one aircraft.

Block 12: Testing will be accomplished in accordance with MAC test project 1-31-75.

Block 14, 27, 41: Data costs figures include both engineering and handbook data requirements.

Block 22: Installation cost computed in FY75 hourly labor rates ($20.00 depot).

Block 34: $143,200 is for 2 sets INS LRU and 2 sets of AHRS LRU's to construct 2 hot bench mock up maintenance trainers.

Block 35 and 36: Rationale for RIW is addressed in Block 46 of AFLC/AFSC Form 44.

Block 43 and 45: Ten (10) sets of field AGE are required (6 CONUS, 2 Offshore plus 2 for ATC).

Block 57: These fixtures are required at 6 CONUS and 2 Offshore bases.

63. Signature

CLASS V MODIFICATION PROPOSAL AND ANALYSIS (MPA) EQUIPMENT MODIFICATION

☐ Modification of Op S ☐ Modification of Mobile Trainer Set
☐ Modification of AGE ☒ Modification of Class I Trainers

1. Date	2. Title	3. System/Equipment
	C-141 Flight Simulator Improved Navigation System	A/F37A-T24 & T24A (C-141)

4. Numbers a	Combat	5. Type of Study	
Modification No.	ROC No.	☒ Basic	☐ Acquisition
Rapmin Action Directive No. MAC	ROC No. 6-73	☐ Rev. No.	☐ Post Acquisition

6. Prepared by	7. Quantities to be changed	8. Production Effectivity N/A
Ogden ALC/MMKTB/E. Thiree	Production 0 In Service 6	Item No. ..... Serial No. .....

9. Costs shown for material and services are based on
☒ A Best Preliminary Estimate ☐ A Detailed Study of Fastest Documentation

10. Cost and schedule estimates herein must be revalidated if the modification is not approved by Feb 1975-Nov 02, 31 Dec 76

11. COST ESTIMATES AND RELATED INFORMATION

A Item	B Budget Program	C Lead Time	D Unit Cost	E FY 75	F FY 76	G FY 77	H FY 78	I TOTAL
12. Engineering	RP11	5		*250,000				250,000
13. Tooling								
14. Proofing								
15. Data	RP11	5		100,000				100,000
16. Mod Kit Cost	RP11		50K	**300,000				300,000
17.								
18. Initial Spares Cost (%) Inv.	RP16			30,000				30,000
19. Initial Spares Cost (%) Exp.	4921			30,000				30,000
20. Inst. Cost (C)	DMIPCMS					121,400		121,400
21. Inst. Cost (O)								
22. FY Totals				710,000		121,400		831,400
23. Grand Totals								
24. Mod Kit Qty				6				6

25. Installation Labor Unit Man-Hours 800 Total Man-Hours 4800 Man-Hour Rate $21.75

26. MODIFICATION SCHEDULE (Non-Concurrent)

A. Qty	B. Agency[1]	C. In & Out	D. FY 1	2	3	4	Total	E. FY 1	2	3	4	Total	F. FY 1-2	3-4	Total	G. FY 1-2	3-4	Total
3	CT					2	2	2	2	2		6						
						2	2	2	2	2		6						

[1] Use the following codes to show type of agency programmed to complete each quantity.
O—Depot, OT—Depot Team, C—Contract, CT—Contract Team, B—Base

27. EQUIPMENT REQUIRING MODIFICATION

A NOUN	B FEDERAL STOCK NUMBER
Flight simulator (Link manufactured)	6930-066-4571
Flight simulator (Curtiss-Wright manufactured)	6930-988-8126

28. Remarks Prototype of one each Link and one each Curtiss-Wright manufactured Flight Simulators are required.
A Formal Engineering Change Proposal (ECP) outlining simulator requirements will be required. Costing information contained herein will change when formal ECP is received. The study and G079 will then be adjusted to reflect actual costs and schedules.
*Engineering includes two (2) each prototype, (Escalated per LGXW request).
**Cost of Government Furnished EQuipment (GFE) is not included in modification kit costs since GFE requirement cannot be defined until receipt of ECP for Mission Flight Simulator is accomplished.
Installation cost estimates based on FY 75 labor rates.
AFR 19-1 and 19-2 have been considered and environmental conditions are not effected.
Two quarters Administrative lead time for contract award and three quarters Production lead time.

29. Signature

AFLC/AFSC FORM DEC 78 448 REPLACES AFSC/AFLC FORM 448, WHICH IS OBSOLETE. AFLC-WPAF 6-JUL 73 93

INCLUDED FOR ILLUSTRATION ONLY

CLASS V MODIFICATION PROPOSAL AND ANALYSIS (MPA) DEVELOPMENT, TESTING AND ACQUISITION

☐ Group B ☐ Mobile Training Sets
☐ AGE ☐ Class I Trainers

1. Title

2. Systems/Equipment

3. Numbers
Modification No. .....
Reports Action Directive No. .....
Combat
ROC No. .....
ROC No. .....
☐ Acquisition
☐ Post Acquisition

4. Type of Study ☐ Basic ☐ Revision (No. .....)

5. Prepared by (Command and Symbol)

6. Cost Shown for Material and Services is Based on
☐ A Best Preliminary Estimate ☐ A Detailed Study of Factual Documentation

7. Cost estimated herein must be revalidated if the modification is not approved by .....

8. DEVELOPMENT, TESTING AND ACQUISITION

A Item	B Lead Time	C Comd	D Source	E FY	F FY	G FY	H FY	I Total Cost
Development								
Testing								
Production								
Data								

DEVELOPMENT PROGRAM

9. Item to be Developed and Technical Description

10. Development Plan

11. Degree of confidence placed in success of Development Program .....%.

TEST PROGRAM

12. Item to be Tested (Nomenclature/Spec Number/Part Number)

13. Test Director (Command)

14. Participating Agencies

AFLC/AFSC FORM 662 TO 44C

PART E7-M/D MODIFCATION SCHEDULE AND COST SUMMARY

MOD NO F2903 IMPROVED NAV SYSTEM

(Date Modification Project Directive Issued by the Directorate of Material Management to the Directorate of Maintenance) → MPD ISSUED 75 JAN

		1978					1979					1980					1981
	QTR	1ST	2ND	3RD	4TH	TOTAL	1ST	2ND	3RD	4TH	TOTAL	1ST	2ND	3RD	4TH	TOTAL	TOTAL
MOD SCHEDULE																	
	IN	57	61	58	45	221											
PRGM COMPL IN WORK		56	62 ← *(Schedule Change Shown on Line Below Original Entry)*														
270 207 18	OUT	59	61	67	50	237	14				14						
KIT PROOF	IN																
PRGM COMPL IN WORK																	
2 2	OUT																
PROTOTYPE	IN																
PRGM COMPL IN WORK																	
1 1	OUT																

(Production Lead Time in Quarters) → P L
(Type Contract) (C=Fixed Price Incentive) → T C

REQUIREMENT/CONTR	P L	T C	BPAC	PREVIOUS	197T<76<	1977	1978	1979	1980	1981
AAU GROUP A KITS	4	C	11476L *(Budget Code to be Charged)*		1053847	3659821				
UNIT COST					12254	19676				
QUANTITY					86	186				
ABU GROUP B KITS	4	C	11476L		10362808	22847232				
• UNIT COST					120498	122835				
QUANTITY					86	186				
ACU CMPNT MOD *(Component Modifications)*	4		11476L		1034045					
ADU DATA	4	C	11476L	661790 *(Spent Before FY 7T)*		236446				
GP-ADATA ← *(Group A Data)*										

(FISCAL YEAR COST)

PART E7-M/D MODIFICATION SCHEDULE AND COST SUMMARY

MOD NO F2903 IMPROVED NAV SYSTEM

MPD ISSUED 75 JAN

REQUIREMENT / CONTR	P L	T C	BPAC	PREVIOUS	197T<76<	1977	1978	1979	1980	1981
				FISCAL YEAR COST						
ADU DATA	4	C	11476L	339000						
GP-BDATA ← (Group B Data)										
ADU DATA	4	C	11476L				← (None Approved)			
AGE-DATA ← (Data for Support Equipment. Note Delayed Delivery Associated with RIW)							360300 ← (Proposed)			
AHU ENGRG/PRO/TEST	4	C	11476L	2142268						
(Engineering, Prototype, Testing)										
APU SPARES-EXP	4	C	6H		117000	105406	207900			
GPA/B SP ← (Group A and B Expense Spares - Bits/Pieces)										
APU SPARES-EXP	4	C	6H				212100			
AGE/SP ← (Same for Support Equipment)										
ARU SPARES-INV	4	C	16476L		13052					
GPA-SP ← (Group A Investment Spares - Repair Cycle Items)										
ARU SPARES-INV	4	C	16476L		2133508	1427971				
GPB-SP ← (Same; for Group B)										
ARU SPARES-INV	4	C	16476L		309916					
(Investment Spares)										
ARU SPARES-INV	4	C	16476L				800000 ← (Approved)			
AGE SP ← (For Support Equipment. Note Delayed Delivery-RIW)							857200AK ← (Proposed. Will be Reviewed/Adjusted at Next of 3 Annual USAF/AFLC/ALC Reviews).			
ATU SPECIAL TOOLS	4	C	11476L	3816						
AUU BENCH MOCKUP	4	C	11476L			25080	(See Note Lower Left Corner)			
UNIT COST						12540				
QUANTITY						2				

(Note) (Reason Code as Listed in AFLCR 66-21, ATCH 2)

AK-NONE OF THE ABOVE APPLY

PART E7-M/D MODIFICATION SCHEDULE AND COST SUMMARY

MOD NO F2903 IMPROVED NAV SYSTEM

MPD ISSUED 75 JAN

REQUIREMENT / CONTR	P L	T C	BPAC	PREVIOUS	197T(76)	1977	1978	1979	1980	1981
AVU NEW COMMON SE	8	C	129990							
D/AG INS ← (Depot Support Equipment for INS)							1081200			
AVU NEW COMMON SE	8		129990							
DEP/AHRS ← (Depot Support Equipment for AHRS)							1121900			
AWU PCR SINGLE SE	2	C	11476L	81991	634967					
INS/FLD ← (Peculiar C-141 Support Equipment for Field Use)										
AZU OTHER	4	C	11476L		1180677	1540523				
INS/RIW ← (Reliability Improvement Warranty for INS)										
UNIT COST					1180677	1540523				
QUANTITY					1	1				
BBU GROUP B KITS	4	C	11476L		1065050	2391940				
AHRS ← (AHRS is a Second Group B Kit)										
UNIT COST					12384	12860				
QUANTITY					86	186				
BDU DATA	4	C	11476L		226968					
AHRS ← (Data for AHRS)										
BWU PCR SINGLE SE	4	C	11476L	390751	677030					
AHRS/FLD ← (Same as AWU; Except this is for AHRS)										
BZU OTHER		C	11476L		687300	1469400				
AHRS/RIW										
UNIT COST ← (Same as AZU; Except this is for AHRS)					687300	1469400				
QUANTITY					1	1				

PART E7-M/D MODIFICATION SCHEDULE AND COST SUMMARY

MOD NO F2903

MPD ISSUED 75 JAN

REQUIREMENT / CONTR	P L	T C	BPAC	PREVIOUS	197T<76<	1977	1978	1979	1980	1981
				FISCAL YEAR COST						
INTERSVC INSTL			6E ← (Labor Cost)			1844404	6117338			
TOTAL REQUIREMENTS				3619616	19496168	35548223	7337338 ← (Approved) 9957983 ← (Proposed) (See ARU, SE Spares, INV)			
- - - BPAC SUMMARY - - -				PREVIOUS	197T<76<	1977	1978	1979	1980	1981
BP 11476L				3619616	16922692	32170442	← (None Approved for FY 78) 360300 ← (Proposed)			
12							2203100			
16					2456476	1427971	800000 857200			
6E						1844404	6117338			
6H					117000	105406	420000			

TOTAL APPROVED FOR ALL YEARS 66001345

TOTAL PROPOSED FOR ALL YEARS 68621945