Chapter Five

COST ANALYSIS

Our cost analysis of the E-2C program alternatives the Navy might consider addresses two main areas: acquisition costs, which include all costs associated with development and production, and the costs of operating, maintaining, and supporting the E-2C. The acquisition cost analysis in this chapter focuses on the cost impact from airframe life extension modifications and the mission suite upgrade required to convert Group II aircraft to aircraft with either CEC or RMP capability. The operations and support (O&S) analysis examines the implications for future E-2C O&S costs of developing a fleet of modified aircraft versus building new ones. We did not study the system design and development costs associated with the RMP.

This cost analysis is intended to provide a common basis of cost comparison among options; thus, we reduce costs to a common metric of dollars per flight hours of life. These figures should not be interpreted as budget costs.

ACQUISITION COSTS ANALYSIS

We considered two modifications to Group II E-2C configurations: the HE2000, which incorporates CEC technology, and E-2Cs that incorporate both CEC and RMP capability.[1] For both the CEC and RMP capability, the acquisition cost analysis includes service-life extension, including parts replacement, and retrofit for the performance-

[1]In this chapter, we use the terms CEC and RMP to refer to the HE2000 configuration and RMP configuration, respectively.

enhancement mission suite, which comprises modification, electronics, and installation. Also included in the analysis are system engineering and program management (SEPM) and retrofit support costs.

Detailed modification-cost estimates for the CEC analysis are based on actual costs of previous E-2C modification activities and were deemed to be thorough enough to be incorporated directly into this study. Modification costs for the RMP and SLEP costs were less certain and are subject to wide variances due to the differing perceptions the government and contractor personnel involved with the E-2C program have of the scope of the modification work. To account for these differing opinions, a range of costs was estimated. We anticipate that the final cost will tend toward the middle of the range.

SLEP and modification are not totally independent activities. For example, a new fuselage may be required for the RMP because it costs more to modify the old fuselage than it does to buy a new one. If properly designed for RMP loads and systems, that new fuselage would require no service-life extension actions. Therefore, we account for the new fuselage under modifications rather than as a SLEP cost. Therefore, the SLEP cost for the RMP is significantly less than that for CEC.

To simplify the data presented in this chapter, we have assumed that the nominal service life of a new-procurement aircraft is 10,000 hours, although some systems or structural parts may need to be replaced sooner and others may last longer than 10,000 hours. Similarly, the objective of the SLEP is to extend the airframe life another 5,000 hours, although individual parts or systems on the aircraft may last for longer or shorter periods of time. Costs and comparisons among alternatives are based on these assumptions of aircraft service life, without attempting to make definitive assessments of the life of each component part.

Pre-existing E-2C Program Configurations and Required Upgrades

A total of 47 Group II E-2C aircraft of various configurations are being considered for SLEP/MOD. Table 5.1 summarizes the major upgrade packages required by each group of aircraft to bring that group to

Table 5.1

Upgrade Packages Required to Bring E-2C Group II Aircraft to CEC Configuration

Upgrade Package	Basic	NAV	MCU
Navigation	X	N/A	N/A
Mission computer	X	X	N/A
CEC	X	X	X
Number of E-2Cs	23	18	6

CEC configuration. The aircraft are distinguished in the table primarily by the state of their navigation equipment (NAV) and their mission computer upgrade (MCU). For example, the NAV group of aircraft already has an updated navigation package installed and MCU aircraft already have the navigation package installed and the mission computer upgrades. Thus, the table indicates that only the Basic configuration group of the Group II aircraft requires the MCU and NAV packages.

The specifics of the upgrade to the RMP configuration for the 47 aircraft represented in Table 5.1 will be further defined as part of the future RMP system development and demonstration (SD&D) contract. In our cost analysis, we are erring on the conservative side, assuming that the RMP upgrade would involve replacing the existing radar, navigation equipment, and mission computer.[2] Thus, the cost to SLEP/MOD any Group II aircraft to RMP capability is the same as it is for any other Group II aircraft being upgraded to the RMP configuration, regardless of their preexisting capability.

Ground Rules and Assumptions for Acquisition Cost Study

The following ground rules and assumptions were used in the development and production cost analysis:

- All costs are in FY2000 dollars.

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[2]The E-2C navigation system and mission computer may need to evolve due to parts obsolescence or performance requirements.

- Estimates are based on RAND research, NAVAIR (AIR 4.2),[3] and contractor information.
- The scope of the SLEP activity is based on discussions with NGC and NAVAIR (AIR 4.3.3[4] and the PMA-231).
- SEPM/Level of effort[5] (SEPM/LOE) and retrofit support unit costs are based on the assumption that four aircraft will enter the SLEP/MOD process every year.
- Unit costs are calculated as "stand alone" costs; that is, it is assumed there is no simultaneous new production. There would be cost savings on SLEP/MODs that occur while the current production contract is in place due to the sharing of SEPM/LOE and production support costs.
- Costs were estimated using a "low estimate/most likely estimate/high estimate" methodology to reflect uncertainty regarding the ability to refurbish major components and the ability to properly define or specify all requirements.

Other specific assumptions are raised in the discussion of the individual SLEP/MOD cost elements, which follows.

SLEP/MOD Cost Elements

The discussion now turns to each of these cost elements and contrasts the CEC costs for those elements with the costs for the RMP. A summary of each SLEP/MOD element as it relates to cost estimates appears in Table 5.2.

Modifications. Table 5.3 shows low and high cost estimates for the CEC and RMP modifications and the most-likely estimates that fall within that range. The CEC estimate is from AIR 4.2 and is based on a previously modified E-2C. (The content of the modification estimate

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[3]AIR 4.2 is the NAVAIR office responsible for cost estimates and analysis.

[4]AIR 4.3.3 is the NAVAIR office responsible for aircraft structural issues.

[5]*Level of effort* is a cost-estimating method that involves counting the number of people who have a specific skill required to perform a job.

Table 5.2

SLEP/MOD Element Activities Relating to Cost

Element	Related Activities or Definition
Modifications	Comprises aircraft alterations required for integrating the new electronics equipment. Includes airframe rework, wiring changes, replacement airframe components, and testing.
SLEP	Strictly speaking, this element comprises the correction of aircraft fatigue and related deficiencies in order to extend the specification life (in hours) of the airframe. In terms of cost, this element also includes the collection of repair items that would be corrected at the time of a SLEP/retrofit. Examples range from cold-working rivet holes to remanufacturing the rear of the fuselage.
Electronics equipment	Includes new-capability electronics equipment being installed as part of the retrofit.
Installation	Includes the removal of outdated electronics equipment and installation of updated electronics equipment. Also includes testing and checkout.
SEPM/LOE	Comprises the LOE engineering and analysis activities that support ongoing SLEP/retrofit and fleet operations. Those activities include system engineering, program management, fleet support, material support, and other engineering activities. Also included is SEPM for several activities charged directly to the E-2C program.
Support	Captures production and logistics support activities that are assumed to continue during the SLEP/MOD phase.

consists primarily of structural changes to the airframe to accommodate the new electronics.) Labor, material, overhead, and fees for contractor work are included.

The RMP estimate is less certain than the CEC estimate. Exactly what the modification entails is in a state of flux, with current assessments indicating that significant modification to the fuselage or a new fuselage, and also perhaps a new WCS, may be required.[6] The driving issues are the accommodation of the electronic equipment and the

[6]Modification approaches that involve replacing bulkheads and longerons have been deemed too risky and expensive, and often lead to excessive tooling and difficulty in maintaining fuselage shape characteristics.

Table 5.3

Average Unit Modification Cost Estimates, All Group II E-2Cs (in millions of FY2000 dollars)

	Low Estimate	Most-Likely Estimate	High Estimate
CEC	10.6	10.6	10.6
RMP	18.0	19.0	24.0

anticipated 2,500-pound airframe weight increase from the modification.

We assume that the RMP SD&D will produce a new fuselage design that can accommodate the CEC as well as all RMP requirements. The WCS will be either new or enhanced. If it is new, it will be charged to the "high estimate" modification case. Enhancements are charged to the "low estimate" and "most-likely estimate" SLEP cases (discussed later in this chapter). Development cost risk is born by the RMP SD&D. Fuselage and WCS estimates are based on information from NGC, adjusted for SLEP assumptions regarding the wing center section.

Structural Life Extension Program. The SLEP cost element contains both fatigue-life and repair-related costs. The costs were developed through discussions with AIR 4.3.3, AIR 4.2, and NGC, through comparisons with the C-2 SLEP, and through our own cost-modeling efforts. A wide difference of opinion exists as to what the SLEP work content requirements will be, leading to a wide range of cost estimates. We have resolved the high and low estimates by putting forth a "most-likely" estimate under the assumption that further discussion will result in a revised estimate that falls somewhere in between the low and high figures.

The estimated schedule for the CEC SLEP is two years for nonrecurring design engineering, eight months lead-time for parts procurement, and 18 months to complete the SLEP/retrofit. To make the best use of the program as a production "gap-filler" for NGC–Saint Augustine as the current production contract tails off, a nonrecurring start in 2002 is indicated.

The RMP technology will not be available earlier than 2008. Nonrecurring SLEP requirements over and above those addressed in the CEC could be accomplished concurrent to the RMP development. These concurrent activities would affect the RMP SD&D in that the SD&D's focus on new aircraft design and production would have to be broadened to include the requirements of the airframes being SLEP/modified. We now briefly review the nonrecurring cost estimates for SLEP and then discuss the recurring cost estimates in some detail.

Based on our review of the C-2 SLEP and our discussions with NGC and AIR 4.3.3, we estimate that the total *nonrecurring costs* of the SLEP (for example, design costs) will fall in the $30 to $50 million range. The uncertainty in the estimate stems from lack of a clear definition of the total required design work. The required work has a complementary aspect—further analysis of the fatigue-life issues may result in less time expended in designing the modification kits and a lower per-unit SLEP cost. This lowered cost, taken across the E-2C fleet, would justify increased nonrecurring costs.

We next examine the SLEP elements in terms of their recurring costs, such as the costs of labor and materials and the overhead costs required to sustain production of SLEP/MOD E-2Cs. Table 5.4 lists estimated recurring costs for each CEC and RMP SLEP activity.

Table 5.4

SLEP Average Unit Recurring Cost Estimates (in millions of FY2000 dollars)

	CEC Cost Estimates			RMP Cost Estimates		
SLEP Item	Low	Most-Likely	High	Low	Most-Likely	High
Fuselage	0.1	0.5	2.9	N/A	N/A	N/A
Nacelles	0.1	0.2	0.3	0.1	0.2	0.3
Wing center section	0.1	0.3	1.7	0.1	0.5	N/A
Empennage	0.1	0.9	2.7	0.1	0.9	2.7
Outer wing panels	2.6	2.6	2.6	2.6	2.6	2.6
Pylon	0.1	0.2	0.3	0.1	0.2	0.3
Wiring	1.0	1.5	2.0	N/A	N/A	N/A
Landing gear	0.1	0.3	0.5	0.1	0.3	0.5
Obsolescence	0.3	0.4	0.5	0.3	0.4	0.5
Rotodome	0.1	0.5	1.0	N/A	N/A	N/A
Total	4.6	7.4	14.5	3.4	5.1	6.9

NOTE: Cells noted with N/A reflect new items that have zero SLEP costs.

Fuselage—The range of cost estimates for the CEC fuselage represents our view of the AIR 4.3.3 description of the work content (the low estimate), the NGC position (the high estimate), and an analogy to the SLEP costs experienced on the C-2 program (the most-likely estimate). The low estimate provides for cold-working and other minor structural repair. The high estimate includes re-skinning the rear fuselage and is a result of applying prior RAND estimating technology.[7] The cost estimate is based on a rough estimate of the new weight that is replacing the old weight during the SLEP (10 percent of the fuselage, or 566 pounds). The range of estimates is large, but further analysis and discussion should reduce that range. We think the C-2 experience is the best measure of the final outcome. We assume that the RMP will include a new fuselage, as stated earlier. Hence, there is no SLEP cost for this element under the RMP upgrade.

Nacelles—The range of cost estimates for both CEC and RMP reflects minor repair to the nacelles (engine enclosures) at the low end to replacement of the nacelles at the high end. The most-likely estimate is based on the assumption that moderate work will be required.

Wing Center Section—The CEC work on the WCS ranges from minor rework with the low estimate to significant repair, including re-skinning of the WCS, with the high estimate. The most-likely estimate provides for removal and rework by using cold-working. This is another case in which the analysis leading up to the SLEP will likely make a significant difference in the actual cost.

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[7]Cost-estimating relationships for aircraft modifications were published in Birkler and Large (1981). The data from which these estimating relationships were derived are pertinent to the E-2C because of its 1960s origin. To apply these estimating relationships, we calibrated them to E-2C modification and production experience, in accordance with the process described by Birkler and Large. The following table compares the nominal published factors to the results of our calibration:

Factor	Nominal Value	Calibrated Value
Engineering	0.75	0.6
Tooling	0.5–1.0	0.25
Production	1.0	0.8
Quality control	0.07–0.17	0.1
Material	1.0	1.0
Cost improvement curve	0.77	0.95

The RMP includes cold-working of the WCS at the low-estimate end, removal and strengthening as the most-likely cost estimate work, and replacement of the WCS at the high-estimate end (included in modification cost).

Empennage—The estimates for this element are the same for both the CEC and RMP alternatives. The low estimate is for minor rework, and the high estimate provides for replacement of the empennage (tail assembly) if the fatigue life cannot be sufficiently extended through repair. The most likely estimate provides for substantial rework and was derived from the Birkler-Large (1981) methodology using replacement of 20 percent of the weight (or 228 pounds) as the parameter for the most-likely scenario.

Outer Wing Panels—The life of these components cannot be economically extended to 15,000 hours for either the RMP or CEC. They must be replaced before 10,000 hours. The estimate is the cost for a pair of new panels, based on AIR 4.2 data. NGC's costs were comparable to the AIR 4.2 estimates.

Pylon—This structure connects the rotodome antenna to the fuselage. The CEC estimate range equals the RMP range. We are including cost estimates for pylon SLEP as part of the entire estimate as a contingency against possible SLEP rework/replacement.

Wiring—The wiring estimate for the RMP is zero because we assume that the new fuselage and extensive WCS work will automatically provide new wiring. For the CEC, we developed a range based on the C-2 estimate.

Landing Gear—The range is the same for both CEC and the RMP. Fatigue life is not an issue because testing has shown that the landing gear can last until the 15,000-flight-hour level. However, corrosion and the gear eventually wearing out must be addressed. The low end of the cost-estimate range addresses maintenance actions while the high end covers replacement. The most-likely estimate is an average of the end points. If the increased aircraft weight of the RMP requires a new landing gear design, the cost could exceed the high range.

System Hardware Obsolescence—This cost element provides for the replacement of hardware items that can no longer be maintained economically, primarily due to age and out-of-inventory status. The

SLEP/MOD activity is an opportune time to deal with these issues; therefore, a contingency fund is set aside for that purpose. The FY2000 Operations and Support Modification Kit procurement estimate of $565,000 has been used to estimate the amount of this contingency fund. The SLEP/MOD itself will replace many pieces of equipment, reducing the requirement for obsolescence rework done as part of the SLEP.

Rotodome—The rotodome is the rotating antenna on top of the E-2C. A new rotodome is part of the RMP upgrade; therefore, no SLEP cost was calculated for the RMP. For CEC, the rotodome has no identified fatigue life issues, but corrosion failures have been identified. The range of estimates reflects the range of SLEP activities, from minor maintenance to removal of the antenna and its installation in a new canister. The estimates are based on AIR 4.2 actual costs, as analogies to the cost of a new rotodome.

Electronics and Installation. The estimated CEC electronics and installation costs are summarized in Table 5.5 for each configuration of Group II aircraft (the table is organized like Table 5.1 in terms of defining the Basic, NAV, and MCU aircraft groups). These data are based on information provided by AIR 4.2. In the table, NAV refers to the group of aircraft that already has the navigation package installed and MCU refers to the group of aircraft that already has the navigation package installed as well as mission computer upgrades. The

Table 5.5

E-2C Group II Aircraft Primary CEC Retrofit Electronics and Average Unit Cost Estimates (in millions of FY2000 dollars))

	Basic	NAV	MCU
Retrofit			
Navigation upgrade	X	N/A	N/A
Main computer upgrade	X	X	N/A
Cooperative engagement capability	X	X	X
Estimated Unit Costs			
Electronics cost	11.2	10.1	8.5
Installation cost	4.1	2.3	2.2
Number of Aircraft	23	18	6

Basic group receives the standard automatic flight control system, and both the Basic and NAV groups receive the mission computer upgrade and the advanced control indicator set. All three configurations receive satellite communications, a vapor cycle upgrade, electronic support measures, the CEC system, a power approach stability augmentation system, a main power distribution box, a fault reporting system, and aircraft change directives.

RMP cost estimates for electronics and installation are less certain than the CEC cost estimates because the system is still in development. RMP is currently assumed to include a new radar, rotodome, advanced IFF subsystem, advanced mission computer, advanced tactical workstations, advanced communications system, cockpit modifications, and generators. The cost estimates for RMP electronics and installation have been developed through discussions with AIR 4.2 and NGC and are summarized in Table 5.6. These costs are in addition to the costs for the MCU electronics package that provides the CEC capability ($8.5 and $2.2 million, as shown in Table 5.5) for all Group II aircraft because the RMP installation will replace the navigation and mission computer electronics that constitute the upgrades on the NAV and MCU aircraft groups.

The installation cost range in Table 5.6 reflects the uncertainty associated with the NGC–Saint Augustine facility's labor rates. Because RMP SLEPs cannot start until 2007, business forecasts are a concern. If the business base at Saint Augustine decreases from its current level, labor rates will increase. (The business-base issue is discussed in more depth in Chapter Six.) The high installation-cost estimate reflects the possibility of these higher labor costs.

System Engineering and Program Management/Level of Effort. This cost element was developed using an analogy to activities related to

Table 5.6

RMP Electronics and Installation Average Unit Cost Estimates (in millions of FY2000 dollars)

	Low Estimate	Most-Likely Estimate	High Estimate
Electronics cost	18.5	20.0	22.5
Installation cost	3.9	5.9	7.9

the NGC–Bethpage facility that support the current E-2C production. Table 5.7 lists the elements of the estimated costs for new production and SLEP retrofit for SEPM/LOE.

The system engineering/fleet support estimated costs are assessed to be about the same for new production and SLEP/retrofit because these activities would be required whether production or retrofit was being done. The program management/material support cost element is adjusted to account for the change in the nature of the work from managing the flow of primarily electronics materials for SLEP versus managing the wide variety of materials required for new production activities. Therefore, the SLEP/retrofit estimate is lower than the production estimate for this element because of the narrower range of materials being supported.

The row labeled "Other support" in Table 5.7 includes electrical wiring and fabrication of composite parts in addition to several smaller support activities. The SLEP/Retrofit values in the table reflect all of the support activities and a small portion of the electrical wiring work and fabrication of composite parts. The $35–$40 million range for the SLEP/retrofit represents the total cost per year. The total divided by the number of SLEP/retrofits per year (four) results in average unit cost values ranging from $8.5–$10 million for SEPM/LOE. The same values are used in the case of a CEC upgrade or the RMP.

SLEP/MOD Support. An annual production support value of $16 million was developed by analogy to the production support levels recently experienced by the E-2C program. It is assumed that the CEC and RMP SLEP/MOD programs will receive the same level of

Table 5.7

Estimated Costs for New Production and SLEP Retrofit for SEPM/LOE (in millions of FY2000 dollars)

SEPM/LOE Element	New Production	SLEP/Retrofit
System engineering/fleet support	25.7	25.7
Program management/material support	16.3	7.2
Other support	14.3	6.0
Total	56.3	38.9 (35.0–40.0)

support. The $16 million total production support value is divided by four to calculate the $4 million per aircraft average unit cost that is used for all values in the cost range.

Acquisition Cost Summary

Table 5.8 summarizes the CEC SLEP/MOD cost estimates for the Basic configuration Group II E-2C aircraft.

Table 5.9 compares the CEC SLEP/MOD cost estimates for the Group II Basic, NAV, and MCU aircraft configurations. The major differences for the three variants are in the electronics and installation costs.

Table 5.10 summarizes the RMP SLEP/MOD estimated average unit costs for all Group II aircraft. The RMP modification introduces new navigation and computer equipment; therefore, the NAV and MCU aircraft have no cost advantage over the Basic aircraft.

Table 5.8

Average Unit Cost Estimates for CEC SLEP/MOD, Basic E-2C Group II Configuration (in millions of FY2000 dollars)

Cost Element	Low Estimate	Most-Likely Estimate	High Estimate
Modifications	10.6	10.6	10.6
SLEP	4.6	7.4	14.5
Electronics	11.2	11.2	11.2
Installation	4.1	4.1	4.1
SEPM/LOE	8.8	9.8	10.0
Support	4.0	4.0	4.0
Total	43.3	47.1	54.4

Table 5.9

Average Unit Cost Estimates for CEC SLEP/MOD, Three E-2C Group II Configurations (in millions of FY2000 dollars)

E-2C Variant	Low Estimate	Most-Likely Estimate	High Estimate
Basic	43.3	47.1	54.4
NAV	40.4	44.2	51.5
MCU	38.7	42.5	49.8

Table 5.10

Average Unit Cost Estimates for RMP SLEP/MOD, All E-2C Aircraft (in millions of FY2000 dollars))

Cost Element	Low Estimate	Most-Likely Estimate	High Estimate
Modifications	18.0	19.0	24.0
SLEP	3.4	5.1	6.9
Electronics	27.0	28.5	31.0
Installation	6.1	8.1	10.1
SEPM/LOE	8.8	9.8	10.0
Support	4.0	4.0	4.0
Total	67.3	74.5	86.0

The next section addresses the impact of O&S estimates on SLEP/MOD costs. The conclusion of this chapter combines acquisition and O&S costs for a total assessment of SLEP/MOD costs versus new production costs.

OPERATION AND SUPPORT COSTS ANALYSIS

In this section, we explain the methodology used to estimate operating and support costs for maintaining the E-2C inventory. The O&S analysis is based on a fixed number of E-2C aircraft in inventory, all of which have the same configuration. The only factor that changes in the O&S analysis is whether the aircraft are new acquisitions or are modified existing aircraft. The sole factor in the O&S cost difference between new and modified aircraft will be the age of the components that are *not* replaced during modification. Components replaced during modification will be of the same age as those on newly procured aircraft and therefore should incur the same O&S costs.

We expect equipment age to be related to maintenance costs primarily because of three conditions: fatigue, corrosion, and parts obsolescence. All three of these conditions affect the cost to upgrade or modify an E-2C. *Fatigue* is the weakening or failure of material from repeated stress cycles. Aircraft parts, particularly airframe structures and engine parts, are subject to stresses during use. Structural fatigue is the primary determinant of an aircraft's service life. *Corrosion* is the damage over time to metals caused by exposure to the environment. Corrosion control is part of the E-2C routine maintenance at the organizational level of maintenance (aboard ship). *Obsolete parts* are parts constructed with outmoded technology or on production lines that have closed. Obsolete parts can take longer to replace or can be more costly to repair or replace than nonobsolete parts. The E-2C has a long list of obsolete equipment composed mostly of avionics items. These items, or the parts for them, are no longer available or are difficult to repair because they are made with outmoded technology.

Estimating the relationship between the age of aircraft components and the cost to operate and support an aircraft is difficult to do for a number of reasons. Components of various ages and various costs are interchanged among aircraft, making it difficult to ascertain the exact replacement costs for parts on an aircraft. Furthermore, the dollars spent on maintaining an aircraft over time can change due to resource availability, organizational changes, maintenance practices, and other factors. In fact, O&S funds spent in a given year by an organization are strongly affected by factors other than the age and condition of the equipment. These difficulties prevented our being able to estimate a specific relationship between the age of aircraft components and the cost to operate and support the E-2C.

Figure 5.1 illustrates how age-related O&S costs would behave over time, with a notional point at which aircraft are inducted for modification. Age-related costs would be greatest for an unmodified fleet of existing aircraft, as illustrated by the “Existing fleet” line in the figure. Modified aircraft would incur lower costs after the induction point because some of the aged equipment would be modified or replaced, and the age-related O&S costs of that equipment would be reduced to the same cost as that of new equipment. New aircraft would incur the lowest age-related O&S costs because all the equipment on the aircraft would be new.

O&S Cost-Estimating Approach

The methodology for estimating the O&S cost difference between new and modified aircraft is composed of five steps:

1. Identify age-related maintenance costs among total O&S costs.
2. Identify equipment not replaced during modification activities.

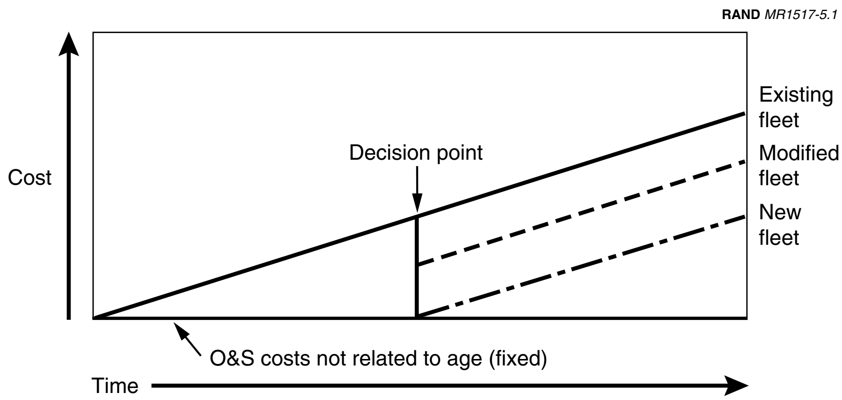

Figure 5.1—Age-Related O&S Cost Behavior

3. Determine maintenance costs (labor and parts) by equipment element.
4. Determine maintenance cost increase due to age.
5. Calculate maintenance cost increase by equipment element due to age.

Step 1: Establish Baseline Age-Related Maintenance Costs. Total O&S costs are defined by the O&S cost element structure required by the Office of the Secretary of Defense Cost Analysis Improvement Group. The cost element structure provides a standard set of definitions used by all Department of Defense services. The elements in that cost structure are shown in Table 5.11.

Total O&S costs for the elements listed in Table 5.11 were $7 million per aircraft per year based on a three-year average of E-2C costs from FY1996 to FY1998 (Crowley, 2001).[8]

[8]The $7 million cost per unit includes $1.8 million for indirect support costs and reflects the increased emphasis on identifying total ownership costs of the E-2C program. O&S costs for weapons systems do not always include indirect support costs.

Table 5.11

O&S Cost Element Structures and E-2C Costs per Unit

Cost Element Structure	Cost (in millions of FY2000 dollars)
Mission personnel	**1.67**
Operations	0.41
Maintenance	0.89
Other mission personnel	0.37
Unit-level consumption	**1.55**
Petroleum, oil, and lubricants/Energy consumption	0.12
Consumable material/Repair parts	0.27
Depot-level repairables	1.13
Training munitions/Expendable stores	0
Other	0.03
Intermediate maintenance	**0.29**
Maintenance	0.17
Consumable material/Repair parts	0.12
Other	0
Depot	**0.96**
Overhaul/Rework	0.60
Engine repair	0.19
Other	0.17
Contractor support	**0**
Sustaining support	**0.76**
Support equipment replacement	0
Modification kit procurement/Installation	0.66
Other recurring investment	0
Sustaining engineering support	0.06
Software maintenance support	0.02
Simulator operations	0.02
Other	0
Indirect support	**1.80**
Personnel support	1.45
Installation support	0.35
Total O&S	**7.00**

NOTE: Those items with zero costs do not apply to the E-2C program.

Age-related maintenance costs were determined through a two-step analysis of the cost elements. In the first step, five of the seven major O&S cost elements (mission personnel, unit-level consumption, intermediate maintenance, depot, and sustaining support) were determined to be potentially age related. These cost elements constitute 74 percent of total O&S costs for the E-2C.[9]

In the second step, major portions of the elements of mission personnel, depot airframe overhaul/rework, and sustaining support were excluded from being age related for the purposes of this analysis or because of certain factors related to the E-2C itself. The rationale for excluding each element is given in Table 5.12.

Table 5.12

Elements Excluded from Analysis of Age-Related Maintenance Costs

Cost Element	Reason for Exclusion
Operations personnel	These are personnel required to operate the E-2C aircraft. The specific mission, rather than age of the equipment, determines the number of required personnel.
Maintenance personnel	This element was initially judged to be sensitive to aircraft age. For carrier-based aircraft maintenance, however, the number of personnel in this element was reasoned to be largely insensitive to the age of aircraft and was excluded from the calculation for two reasons: (1) much of the workload is driven by routine maintenance, such as inspections and corrosion prevention and (2) staffing at the operations level is largely fixed. Reduced workload due to newer equipment would be more accurately described as cost avoidance rather than cost savings in that personnel would probably perform other maintenance tasks if they were not performing routine maintenance on E-2Cs. This is our assumption and not a Navy position.
Other mission personnel	Most of these individuals are headquarters personnel with an administrative and command function or are other personnel whose mission is not related to maintenance.
Petroleum, oil, and lubricants /Energy consumption	Fuel consumption depends much more on usage and equipment than on age.
Other unit-level consumption	This element contains temporary additional duty costs in the AIR 4.2 analysis, which are not related to equipment age.

[9]Percentages were calculated from the E-2C O&S costs reported in Crowley (2001).

Table 5.12 (continued)

Cost Element	Reason for Exclusion
Depot airframe overhaul and rework and other costs	These elements were initially judged to be related to age. However, the airframe will be overhauled and reworked extensively as part of the modification, and the cost of the modification is included in the procurement estimate. Depot costs were therefore excluded from the O&S estimate as age-related costs.
Modification kit procurement and installation	This cost element funds modifications to maintain readiness and improve flight safety. This element was excluded from the calculation of O&S cost savings because the SLEP/MOD program will improve the readiness and flight safety of the modified aircraft, so there will be no need for additional O&S-funded modification kits. Therefore, there will be little difference in age-related maintenance costs between modified and new aircraft.
Sustaining engineering support	The relationship of this element to age-related maintenance is unknown, but the LOE nature of this element suggests that it is not age related.
Software maintenance support	Software maintenance was excluded as age related for the reason that it is more a function of capability than age because software code does not deteriorate with time.
Simulator operations	This element was excluded because it is related to training rather than age.
Indirect support	Indirect support is a cost allocation for headquarters personnel, retirement funding, and other expenses that are only loosely related to the direct costs of the E-2C fleet. The costs are a function of total personnel and are insensitive to small changes in personnel numbers in the E-2 fleet.

Step 2: Identifying Equipment That Is Replaced or Not Replaced. Table 5.13 identifies by work unit code (WUC) and name the replaced or modified equipment that drives the top 70 percent of E-2C O&S costs. The table also indicates whether equipment was replaced for the CEC or the RMP alternative.

Step 3: Determining Maintenance Costs According to the Equipment Being Serviced. Maintenance costs by equipment were determined through a two-step process: (1) obtaining the proportion of equipment costs per O&S element and (2) applying the proportions to the total O&S cost, as described here. The proportion of equipment costs per O&S element was obtained from NAVAIR's Logistics

Table 5.13

Equipment Contributing to 70 Percent of the E-2C O&S Costs

WUC	Equipment Item	CEC	RMP	O&S Cost ($)	Percentage of Total O&S Costs	Cumulative Percentage of O&S Costs
223	T56 turboprop engine			47,594,670	16	16
726	APS-145 radar set		X	40,157,271	14	30
325	Variable pitch propellers	X	X	20,299,397	7	37
30	Maintenance inspections			18,859,872	6	43
728	Radar/navigation system computer group	X	X	13,782,817	5	48
29E	Power plant system			11,179,910	4	52
40	Corrosion preventer			10,752,324	3	55
724	APX-178/9 control indicator		X	7,784,928	3	58
734	Navigation system	X	X	7,774,588	2	60
761	ALR 59 or 73 countermeasures receiver set			5,706,362	2	62
111	Fuselage	X	X	5,478,315	2	64
631	UHF communications	X	X	5,133,620	2	66
135	Landing gear			4,474,474	2	68
13E	Landing gear			4,023,107	1	69
56X	Flight Reference Association equipment	X	X	3,725,345	1	70

Management Decision Support System (LMDSS).[10] The LMDSS was used to calculate cost proportions for each cost element rather than the absolute cost because the LMDSS database does not receive data from all fleet organizations and therefore the data do not reflect total

[10]LMDSS is a NAVAIR database that contains detailed organization and intermediate-level O&S costs. The costs are available for aircraft type/model/series (T/M/S) and by equipment detail for each T/M/S. The available data date back to 1999. Costs from calendar years 1999 and 2000 were taken from the LMDSS.

fleet O&S costs. The LMDSS data do, however, reflect the costs of labor and repair parts.

To capture all fleet costs for the E-2C, a yearly average based on O&S costs from FY1996 through FY1998 was used, as reported in Crowley (2001). The costs reported by Crowley were compared with those reported in the Visibility and Management of Operating and Support Costs (VAMOSC) database[11] and those costs were found to be similar. Proportional costs by equipment for each O&S element in the LMDSS were applied to the element cost total from the Crowley report to determine yearly maintenance cost by equipment.

Step 4: Determining Maintenance Cost Increase Due to Age. Based on prior RAND research, we are using an age-related compounded cost-growth rate of 2.3 percent per year per aircraft. This cost-growth rate is within the range found in other studies, most recently a study by the U.S. Congressional Budget Office, which found evidence of age-related cost growth of 1 to 3 percent per year for military aircraft (U.S. Congressional Budget Office, 2001).

However, some studies have suggested higher rates of O&S cost growth for military aircraft. We are reluctant to use higher rates of growth because of the difficulty in properly attributing cost increases to age. Cost increases attributed to physical age could in reality be cost increases that are due to developments over time, such as changes in technology or capability, operational requirements, or organizational practices. A distinction such as this is important to this study because we are comparing the costs of alternatives that differ only with respect to age and are otherwise the same in all other respects that would drive O&S cost increases.

As a sensitivity measure, we used a 7 percent growth factor to test the effect on the results. This higher growth factor, as compared with the 2.3 percent per year per aircraft used in previous studies, resulted in higher O&S estimates for the SLEP/MOD alternatives and lower estimates for the new procurement alternatives but did not change the rank order of the cost-analysis results at the end of this chapter.

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[11]The VAMOSC is a Navy-owned database used to maintain historical O&S cost information.

Step 5: Calculating the Maintenance Cost Increase by Equipment Due to Age. For the purposes of this analysis, O&S costs were calculated for the following four cost categories:

- Costs that are insensitive to age
- Costs of equipment that is modified or replaced
- Costs of equipment that is not modified or replaced
- Savings from the difference between the age of existing equipment and the age of the equipment being modified or replaced.

The O&S costs are based on FY1996 through FY1998 average annual E-2C costs expressed in FY2000 dollars. These costs were adjusted by the equipment reliability and maintainability improvements estimated by NGC. The improvements resulted in an estimated 8 percent savings in the CEC O&S costs compared with the O&S costs of the current fleet and an additional 8 percent savings in the RMP O&S costs compared with aircraft with CEC (Northrop Grumman Corporation, 2000).

The O&S costs were calculated for each of the four cost categories over a ten-year period following modification. (Ten years is the approximate additional service life of a SLEP aircraft.) The age-sensitive calculations are sensitive to the time period over which the costs are calculated; that is, the age in years at modification plus the number of years after modification. In this analysis, the average age of an aircraft at induction was calculated to be 23 years. This age is derived from a schedule based on four inductions per year starting no sooner than the 8,000-flight-hour point.

The O&S costs that are insensitive to age are the total maintenance cost elements determined to be age insensitive in Step 1 of the O&S cost-estimating methodology.

The O&S cost of equipment being modified or replaced was calculated using several steps. Both modified and replaced equipment is considered new in terms of age, but because our available data are from the fleet in FY1996 through FY1998, we cannot determine the O&S costs of new E-2C equipment. Our major premise is that the O&S costs of equipment are "moving targets" that depend on the age of the equipment.

The first step in calculating the O&S cost of equipment being modified or replaced is to determine the average E-2C age during the FY1996 through FY1998 period that is the basis for our average annual O&S costs. The average age of aircraft in the fleet was readily calculated from aircraft delivery schedules.

Next, we were interested in the O&S cost of the equipment when it was new. To determine this cost, we assumed that the O&S costs had been rising due to age at 2.3 percent per year over the lifetime of the E-2C. We then used the 2.3 percent annual growth rate factor in reverse for the lifetime of the equipment to calculate the estimated (reduced) cost of the equipment when it was new. Having calculated the O&S cost of new E-2C equipment, we used the 2.3 percent annual growth rate factor to increase the yearly cost over ten years, which is the time period of interest.

The major equipment cost drivers for replaced or modified equipment include the following:

- Digital data converter
- Radio frequency amplifier
- Variable pitch propeller
- Azimuth range indicator
- Inertial measurement unit
- Propeller control assembly
- Variable pitch aircraft propeller system
- Displacement gyro
- Digital data computer
- Azimuth range indicator
- Engine accessories installation
- Digital data converter
- Equipment related to wing tip light cover
- Digital display
- Power driven rotary pump

- Nacelle induction system installation
- Radar modulator
- Equipment related to air cooling turbine
- Equipment related to landing gear tires
- Trigger pulse amplifier
- Radio frequency power meter
- Main landing gear wheels/tires.

The cost of equipment that is neither modified nor replaced was calculated using a rationale that is consistent with the one we just described for new or modified equipment. We began with the FY1996 through FY1998 average annual cost of the equipment and determined the average age of the fleet during that time. Then we calculated the average (older) age at the time of induction into the modification process and estimated the (increased) cost of the equipment at the time of induction by using the 2.3 percent growth factor. Finally, we increased the yearly O&S cost of the equipment over ten years using the 2.3 percent growth rate factor to determine the O&S cost during the period of interest.

The cost savings due to aged equipment that is not modified or replaced were calculated by subtracting the estimated cost of new equipment not replaced from the estimated cost of aged equipment not replaced over the ten-year period following induction.

O&S Cost Results

Both the CEC and RMP options provide for equipment that is forecast to be more reliable than existing equipment and should result in O&S costs that are lower than those incurred by the current fleet. The RMP alternative replaces a larger amount of equipment with greater savings from forecasted reliability and thus the RMP incurs a lower total O&S cost than does CEC. Both programs retain the existing aircraft engines, which contribute significantly to O&S costs. The CEC modification would save roughly $0.5 million per aircraft per year in O&S costs when compared with retaining all current equipment for ten years.

O&S Cost Summary

Table 5.14 summarizes the O&S cost results per aircraft for the CEC and RMP alternatives. The first row of the table shows average annual costs in constant FY2000 dollars over the ten years of life following modification. Because the O&S costs are over a time stream, the second row shows the average annual costs in discounted dollars. The discount rate is the 3.2 percent rate mandated by the Office of Management and Budget in circular A-94. The constant FY2000-dollar costs are of greater interest for programming and budgeting purposes than the discounted dollar costs. However, the discounted costs are presented here to sum them with procurement costs to produce the total cost summary at the end of this chapter.

O&S Cost Observations and Conclusions

The O&S estimates presented in this chapter contain a significant amount of indirect costs ($1.8 million per aircraft), which reflects a general trend in emphasizing O&S cost estimating in system total ownership costs. The per-aircraft estimates are therefore significantly higher than the O&S estimates without this large indirect-cost element. The indirect costs in addition to personnel, sustaining support, and depot costs were judged in the context of the E-2C program to be insensitive to equipment aging and are therefore constant across the CEC and the RMP new-aircraft and SLEP alternatives. These age-insensitive elements amount to roughly $5 million per aircraft—the bulk of O&S costs.

Table 5.14

O&S Cost Results per Aircraft (in millions of FY2000 dollars)

	CEC		RMP	
	SLEP	New Procurement	SLEP	New Procurement
Average O&S cost per year	7.0	6.5	6.6	6.3
Discounted average O&S cost per year	5.9	5.4	5.6	5.3

OVERALL COST ANALYSIS RESULTS

Table 5.15 presents the procurement and O&S costs for four E-2C alternatives: CEC SLEP modification, CEC new procurement, RMP SLEP modification, and RMP new procurement. The table shows procurement and discounted O&S costs in millions of dollars and shows the cost of buying one additional hour of aircraft life for procurement and O&S in thousands of dollars for all four options. SLEP/modification costs reflect the most likely cost for upgrading of the Group II Basic configuration. O&S costs are expressed in discounted dollars to allow a logical summation with procurement costs, which are incurred at the beginning of the ten-year period.

COST ANALYSIS OBSERVATIONS AND CONCLUSIONS

The cost analysis in this chapter compared the procurement and O&S costs for the CEC and RMP E-2C alternatives. The CEC and RMP alternatives offer different equipment and different capabilities at different costs. Therefore, the decision on which configuration to select must take into consideration differences in operational capa-

Table 5.15

Overall Cost Analysis Results

	CEC		RMP	
	SLEP/ Modification	New Procurement	SLEP/ Modification	New Procurement
Life in flight hours	5,000	10,000	5,000	10,000
Flight hours per year	480	480	480	480
Procurement cost ($M)	47.1	80.0	74.5	90.0
Discounted O&S cost per year ($M)	5.9	5.4	5.6	5.3
Procurement cost per flight hour ($K)	9.4	8.0	14.9	9.0
O&S cost per flight hour ($K)	12.3	11.3	11.7	11.0
Total cost per flight hour ($K)	21.7	19.3	26.6	20.0

NOTE: The new procurement cost estimates are rounded to the nearest ten million dollars to avoid disclosing government cost positions.

bility of the aircraft, which is beyond the scope of this analysis. Modifying the CEC configuration is significantly less expensive (about 20 percent less) than modifying the RMP configuration but offers less operational capability.

The choice between modification and new procurement for each configuration is a decision between alternatives with the same equipment and operational capability. The new and modified aircraft differ only in their expected service lives—10,000 hours for new aircraft versus 5,000 hours for SLEP/modified aircraft. Table 5.15 presents costs using the metric of cost per hour of service life. Calculating the costs in this way normalizes the new and modification alternatives to a comparable basis. The cost-per-hour results show that modification of aircraft to the CEC configuration is 13 percent more expensive than new procurement. Modification to the RMP configuration is the costliest alternative; it is 33 percent more expensive than buying new RMP aircraft.

Although this analysis has shown how the costs of the alternatives differ in absolute terms using the metric of cost per hour of service life, many factors influence the decision of whether to SLEP/MOD the existing fleet of E-2Cs or procure new ones, including availability of funds, inventory management, and industrial base issues.