Title: Defender vs. Challenger Analysis

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Defender Vs. Challenger Analysis

EMGT 535 -- Engineering Economics

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Project Summary

The defender versus challenger analysis presented in this paper reflects an ongoing project for the Esco Corporation. Esco is considering the purchase of two new machines for use in their steel foundry. The first machine is a core machine and the second machine is a molding machine. Both new machines are highly automated and utilize the isocure process that uses petrochemical-bonded sand to make cores and molds. The isocure process is considered a "cold" process because the resin in the sand is catalyzed by exposure to carbon dioxide gas without the addition of heat. This process makes the loose sand hard so that molten steel may be poured into the molds.

The defender is a complete array of seven shell core machines and five shell molding machines. The shell process is an old process that was invented in the 1940's by Cronin, a German foundry man. The shell process also uses petrochemical-bonded sand but it differs from the isocure process because the catalyst must be activated by the addition of heat. The heat is supplied by burning natural gas in burners to heat the cast iron tooling to 500 degrees Fahrenheit. The sand is merely poured onto the tooling and allowed to catalyze. As soon as a sufficient thickness of sand is hardened over the tooling, the loose sand is removed and the mold is stripped from the tooling and prepared for use.

The cycle time for producing a shell mold and shell core averages about four to five minutes each. In contrast, the isocure machines average one minute per cycle. Due to the reduction in cycle time, two isocure machines, called the challenger, can produce the same output as several shell molding and core machines. Therefore, the analysis for the challenger does not include any adjustments for increase in manufacturing capacity. The defender versus challenger analysis is merely a comparison of the annual equivalent costs for both types of machines.

The minimum attractive rate of return (MARR) is set by corporate policy at 20%. The MARR is set at 20% so that the castings can be sold to the customer at a reduction in cost. The cost reduction is expected from both the defender and the challenger. This reduction in manufacturing cost is deemed necessary by upper management so that Esco can reduce it steel casting prices and gain an increase in market share from its competitors. Esco's top competitors for domestic markets are Caterpillar, Case, and Komatsu.

As stated above, the defender utilizes twelve machines that are operated on three shifts resulting in a staff of 36 men. The challenger consists of two isocure machines which would replace the twelve shell machines and would require 30 fewer machine operators. The cost for the wages, benefits, and health insurance for the machine operators are expected to rise rapidly in the future. The defender's high staffing requirements results in high expected operating cost increases.

As stated above, the defender uses natural gas to provide heat for catalyzing the sand. Therefore, the operating cost for the defender is greatly dependent on the price of natural gas. The challenger's operating costs are more stable due to the fact that petrochemicals are only used in the resin. The operating costs increase for the defenders are expected to remain 5% above the challenger due to the high use of natural gas. A risk analysis will be included in this paper to show the effect that rising natural gas prices may have on the operating cost.

Defender Data - Shell Core and Molding Machines

Current Market Value (at time 0)	$915,000
Marginal Tax Rate	40%
Minimum Attractive Rate of Return (MARR)	20%

The Defender is fully depreciated.
Remaining Useful Life 10 Years

Defender Before-Tax Operating & Maintenance Costs (35% Annual Increase Expected)

Time Period	O&M Costs
1	$465,000
2	627,750
3	847,463
4	1,144,074
5	1,544,500
6	2,085,076
7	2,814,852
8	3,800,050
9	5,130,068
10	6,925,591

Note: See table entitled "Risk Analysis Under Various States of Nature" for O&M costs under increasing petroleum prices.

Challenger Data -- Isocure Core and Molding Machines

Total Purchase Price and Installation Expenses $1,922,690

Machine	Installation	Price

Isocure Core Machine		$ 283,700
	43,000	
Sand Handling Equipment		10,500
	8,500	
Spray Wash Station		8,500
	5,000	
Air Scrubber (3000 cfm)		38,000
	18,000	
Isocure Molding Machine		1,197,040
	55,000	
Automated Conveying System		75,000
	22,500	
Sand Handling Equipment		12,500
	3,750	
Sand Heater		4,500
	1,350	
Binder Storage		4,500
	1,350	
Air Scrubber (3000 cfm)		65,000
	25,000	
Remove 12 Old Machines		12,000
	28,000	

Expected Useful Life	10 Years
Marginal Tax Rate	40%
Minimum Attractive Rate of Return (MARR)	20%

MACRS Depreciation Used:

Property is 7-Year Class for Manufacturing Equipment
200% Declining Balance and Half-Year Convention Used
Note: See table entitled "Depreciation Analysis for Challenger"

Challenger Before-Tax Operating & Maintenance Costs (30% Annual Increase Expected)

Time

Period	O&M Costs
1	$ 80,000
2	104,000
3	135,200
4	175,760
5	228,488
6	297,034
7	386,145
8	501,988
9	652,585
10	848,360

Note: See table entitled "Risk Analysis Under Various States of Nature" for O&M costs under increasing petroleum prices.

Defender Calculations

After-Tax Salvage Value = Current Market Value * (1-Tm)

After-Tax O&M = Before-Tax O&M * (1-Tm)

Capital Recovery =
(Initial Investment, I - After-Tax Salvage Value, S) * (A/P,20%,N) + (I*S)

Annual Equivalent of O&M =
(Sum of Present Worth O&M) * (A/P,20%,N)

Total Annual Equivalent Cost = Capital Recovery + Annual Equivalent of O&M

Challenger Calculations

MACRS Depreciation Schedule from CASH Software
(See table entitled Depreciation Analysis for Challenger)

Depr. Amount = Depr. Rate * Investment
Note: Multiply Depreciation Amount for 1st & Last Year by 0.5

Book Value = Initial Investment - Cumulative Depreciation

Taxable Gains (Losses) = Expected Market Value - Book Value

Gains Tax = Taxable Gains * Tm

Net After-Tax Salvage Value = Expected Market Value - Gains Tax

Annual Depreciation Tax Credits = Depr. Amount * (Tm)

Annual Equivalent of After-Tax O&M = (Present Worth of all A/T O&M) * (A/P,20%,N)

Total Annual Equiv. Cost = A.E. of A/T O&M + Depr. Tax Credit + Capital Recovery)

Evaluation of Annual Equivalent Costs for Defender and Challenger

Now that the annual equivalent costs have been calculated for the defender and challenger, an evaluation will be made to select the period with the lowest annual cost.
The time period with the lowest annual cost is considered the economic service life of the machine. It is important to note that a marginal cost for keeping the defender one more year should be included. Often, the defender should be retained longer than the economic service life if its marginal costs are lower than the challenger's. The graph entitled "Marginal Cost For Keeping Defender" shows the application of a marginal cost analysis.

The economic service lives for the defender and challenger will be compared in two ways. The first comparison uses an annual expected annual operating and maintenance cost increase of 35% for the defender and 30 % for the challenger. Past trends in the industry show these values to be the most probable. The second comparison of annual equivalent costs incorporates risk by showing the effect that various states of nature have on the expected operating and maintenance costs. The critical state of nature is the cost of petroleum products, especially natural gas, because it has the most significant impact on the expected annual equivalent costs for both the defender and challenger.

Economic Service Life Determination

The economic service life for the defender, using a 35% annual increase in O&M costs, occurs in year 3. The defender's lowest annual equivalent cost is $455,661. The economic service life for the challenger, under the same state of nature, occurs in year 8. The lowest annual equivalent cost for the challenger $485,231. However, the analysis is not complete. The defender's annual equivalent cost in year 4 is still lower than the challenger's annual equivalent cost in year 8, a marginal cost analysis will be performed on the defender to determine if it is economical to keep the defender until year 4.

The marginal cost analysis looks at the incremental cost incurred for keeping the defender one more year. The table entitled "Defender Marginal Cost Analysis" shows the marginal costs of keeping the defender for one additional year. The equation used to calculate marginal cost is shown below the table. Finally, the graph entitled "Marginal Cost For Keeping Defender" shows the results of the marginal cost analysis. The marginal cost analysis shows that although the annual equivalent cost for the defender in year 4 is still cheaper than the lowest annual cost for the challenger, year 3 would be the optimum time to replace the defender. This is due to the fact that the incremental cost for keeping the defender from year 3 until year 4 is $566,378. This value exceeds the challenger's annual equivalent cost of $485,231. Thus, marginal analysis reaffirms the decision to keep the defender for 3 years, then replace it with the challenger every 8 years.

Risk Analysis of O&M Estimates

This comparison of annual equivalent costs incorporates risk by showing the effect that various states of nature have on the expected operating and maintenance costs. To reiterate, the critical state of nature is the cost of petroleum products, especially natural gas, because it has the most significant impact on the expected annual equivalent costs for both the defender and challenger.

The table entitled "Risk Analysis Under Various States of Nature" attempts to show the effect that increasing petroleum costs has on the before-tax operating and maintenance costs and on the decision-making process. Three different states of nature are shown below:

State of Nature		Annual O&M Increase	
Petroleum Prices	Probability	Defender	Challenger

Increase Slightly	0.2	20%	15%
Increase Moderately	0.6	35%	30%
Increase Greatly	0.2	50%	45%

State of Nature - Slight Increase in Petroleum Prices

The first state of nature to be analyzed is the slight increase in petroleum prices. The graph entitled "Risk Analysis of O&M Estimates - Petroleum Cost Increases Slightly" shows that the lowest annual cost for the defender occurs in year 4. The Challenger's lowest annual cost occurs in year 10, which is the end of its useful life. Therefore, under slightly increasing petroleum prices, the defender should be replaced after 4 years and the challenger should be replaced every 10 years. A marginal cost analysis also verifies this decision because the marginal cost for keeping the defender, from year 4 to year 5, is $470,475 which is higher than the $428,713 annual cost for the challenger.

State of Nature - Moderate Increase in Petroleum Prices

The second state of nature to be analyzed is the moderate increase in petroleum prices. The graph entitled "Risk Analysis of O&M Estimates - Petroleum Cost Increases Moderately" shows that the lowest annual cost for the defender occurs in year 3. The Challenger's lowest annual cost occurs in year 8. Therefore, under moderately increasing petroleum prices, the defender should be replaced after 3 years and the challenger should be replaced every 8 years. A marginal cost analysis also verifies this decision because the marginal cost for keeping the defender, from year 3 to year 4, is $566,378 which is higher than the $485,231 annual cost for the challenger.

State of Nature - High Increase in Petroleum Prices

The last state of nature to be analyzed is the high increase in petroleum prices. The graph entitled "Risk Analysis of O&M Estimates - Petroleum Cost Increases Greatly" shows that the lowest annual cost for the defender occurs in year 3. The Challenger's lowest annual

decision. In reality, the states of nature change constantly. A detailed decision tree could be made which allows for an annual change in the state of nature. However, this analysis would be very time consuming.

Conclusion

The equivalent annual cost analysis performed in this project provides engineering managers with a powerful tool for comparing the annual costs of various machines over

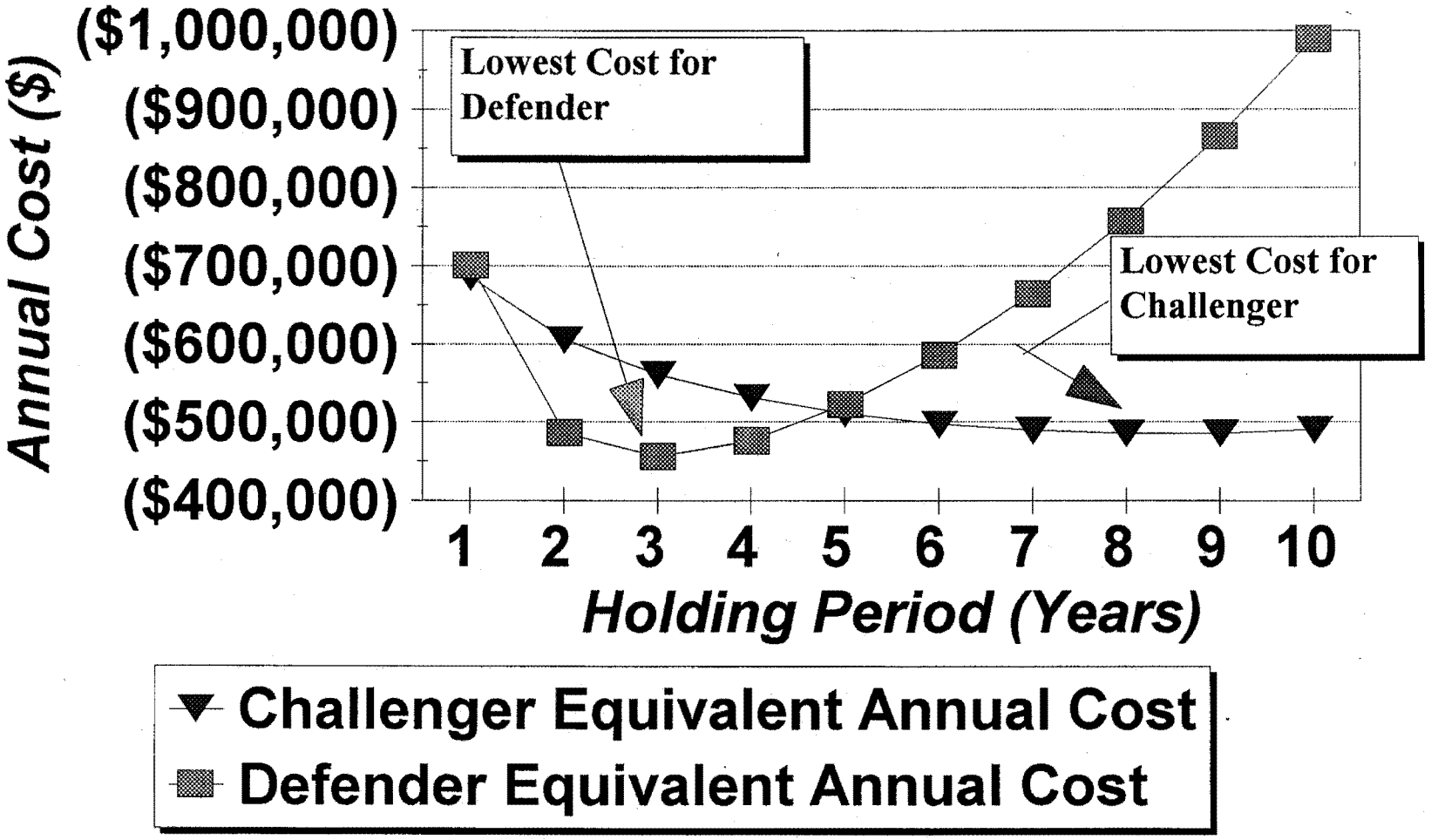
their entire life cycle. Marginal cost analysis can be performed after finding the economic service lives for each alternative to determine the incremental cost for operating the defender for an additional year. Marginal cost analysis helps to determine the optimum replacement time.

Risk is present in all decision making activities. In this project, the element of risk was incorporated by showing the effect that rising petroleum prices has on the decision making process. Under each state of nature, the decision about when to replace the defender was slightly different. In addition, the state of nature affected the decision of when to replace the challenger. A simple decision tree was shown to allow the engineering manager to quantify the expected cost of each decision point.

In conclusion, under slightly increasing petroleum prices, the defender should be replaced after 4 years and the challenger should be replaced every 10 years. Under moderately increasing petroleum prices, the defender should be replaced after 3 years and the challenger should be replaced every 8 years. Under highly increasing petroleum prices, the defender should be replaced after 3 years and the challenger should be replaced every 6 years.

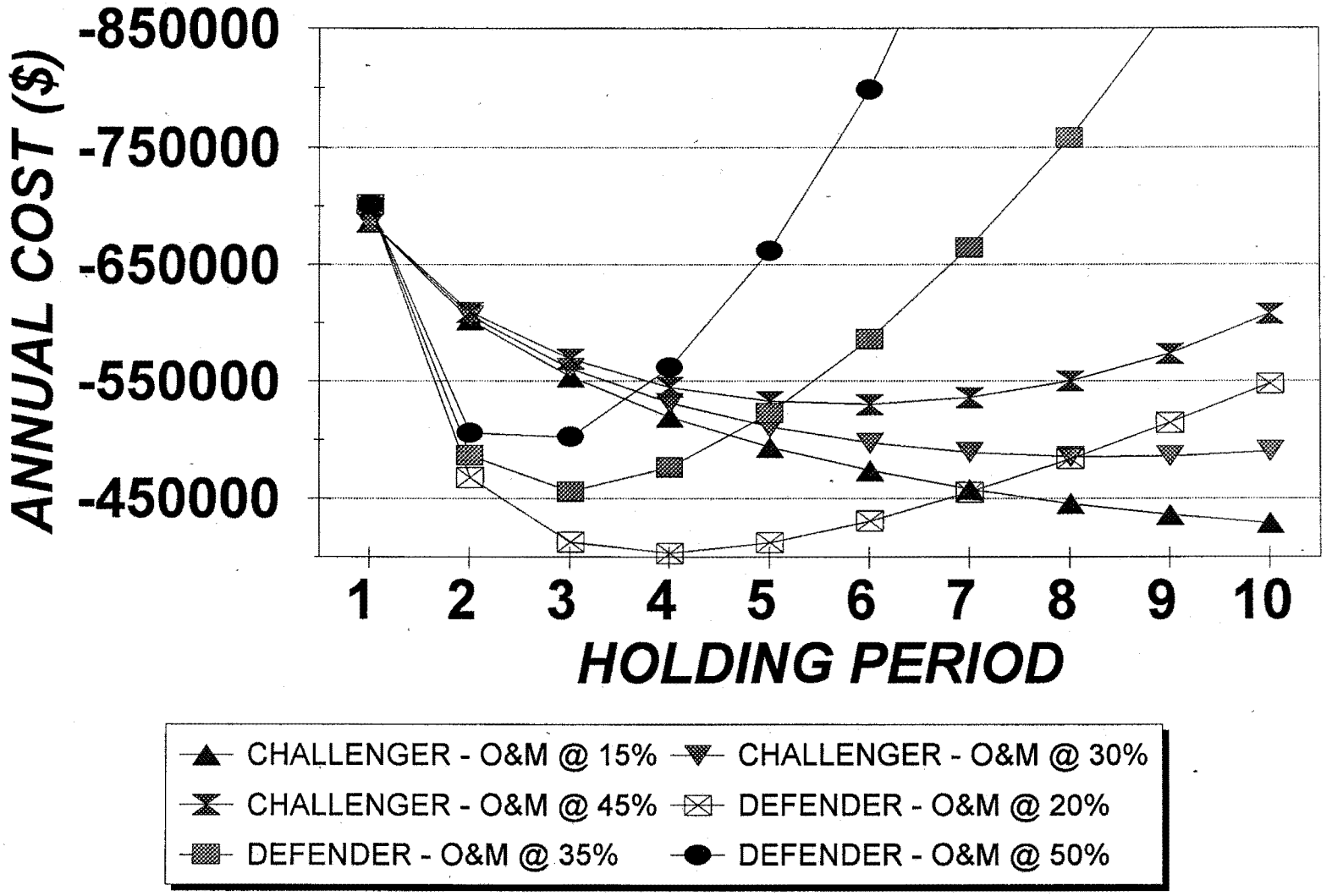
Defender vs. Challenger

Equivalent Annual Cost Comparison



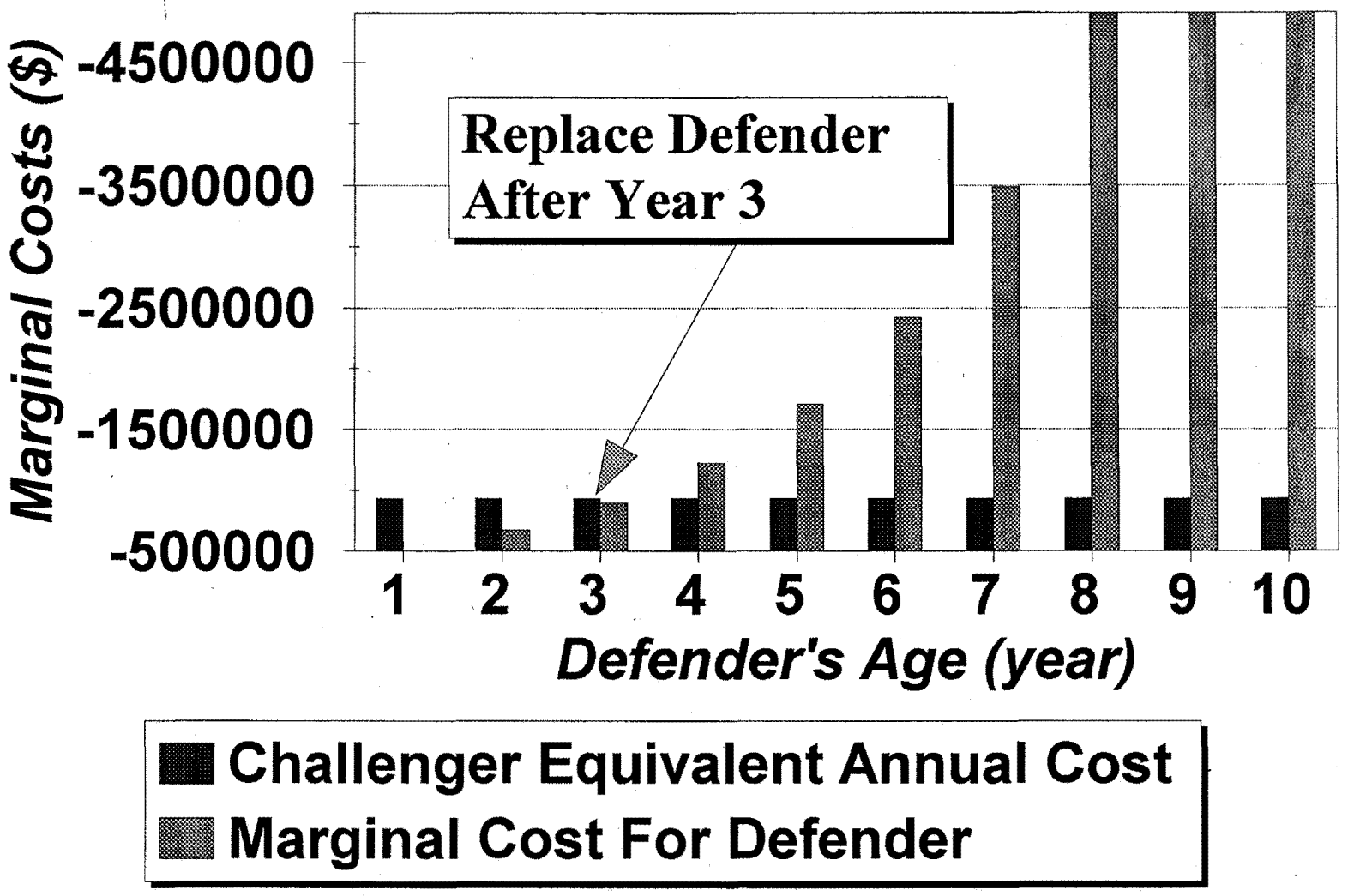
RISK ANALYSIS OF O&M ESTIMATES

FOR DEFENDER AND CHALLENGER



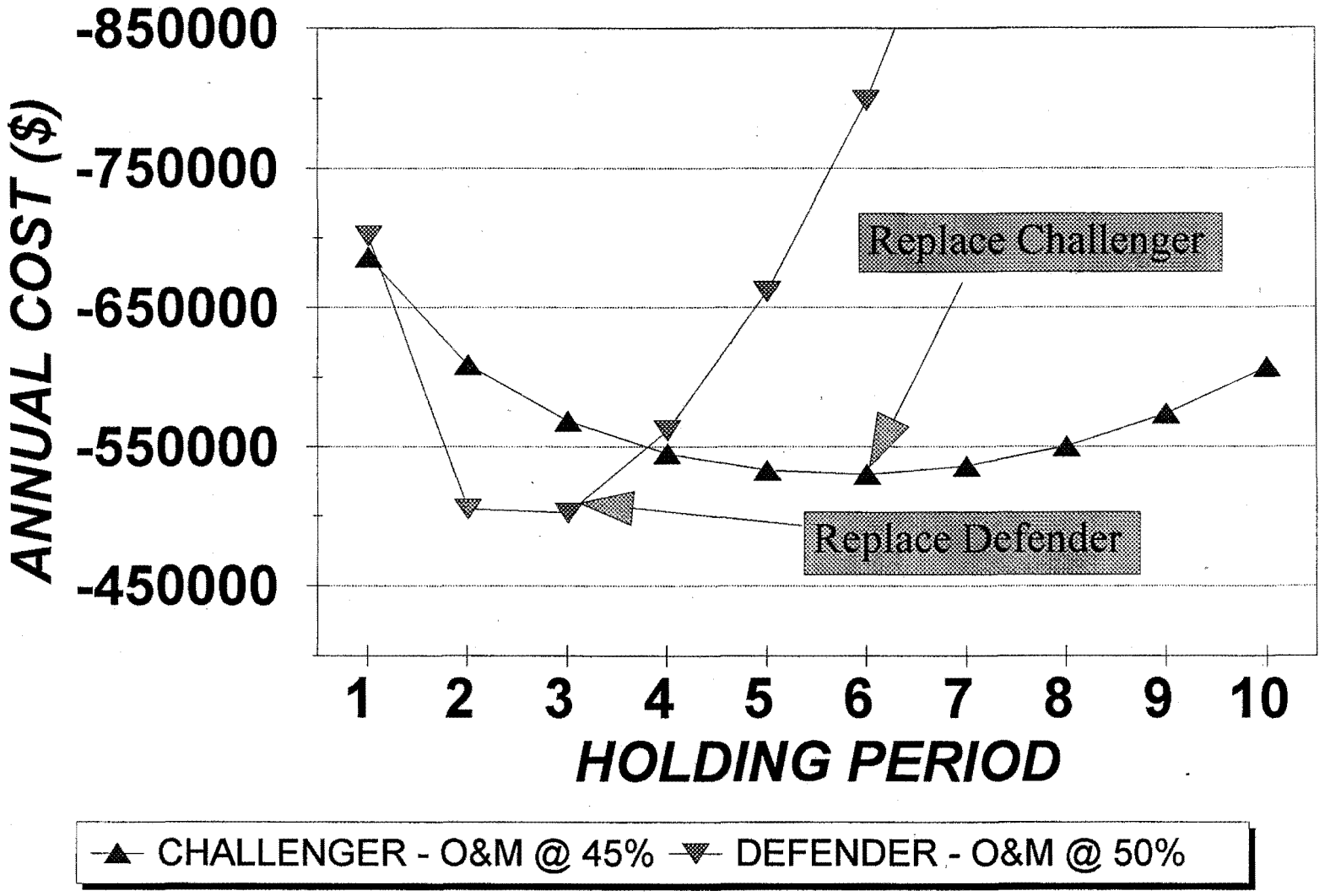
Marginal Cost For Keeping Defender

High Petroleum Increase



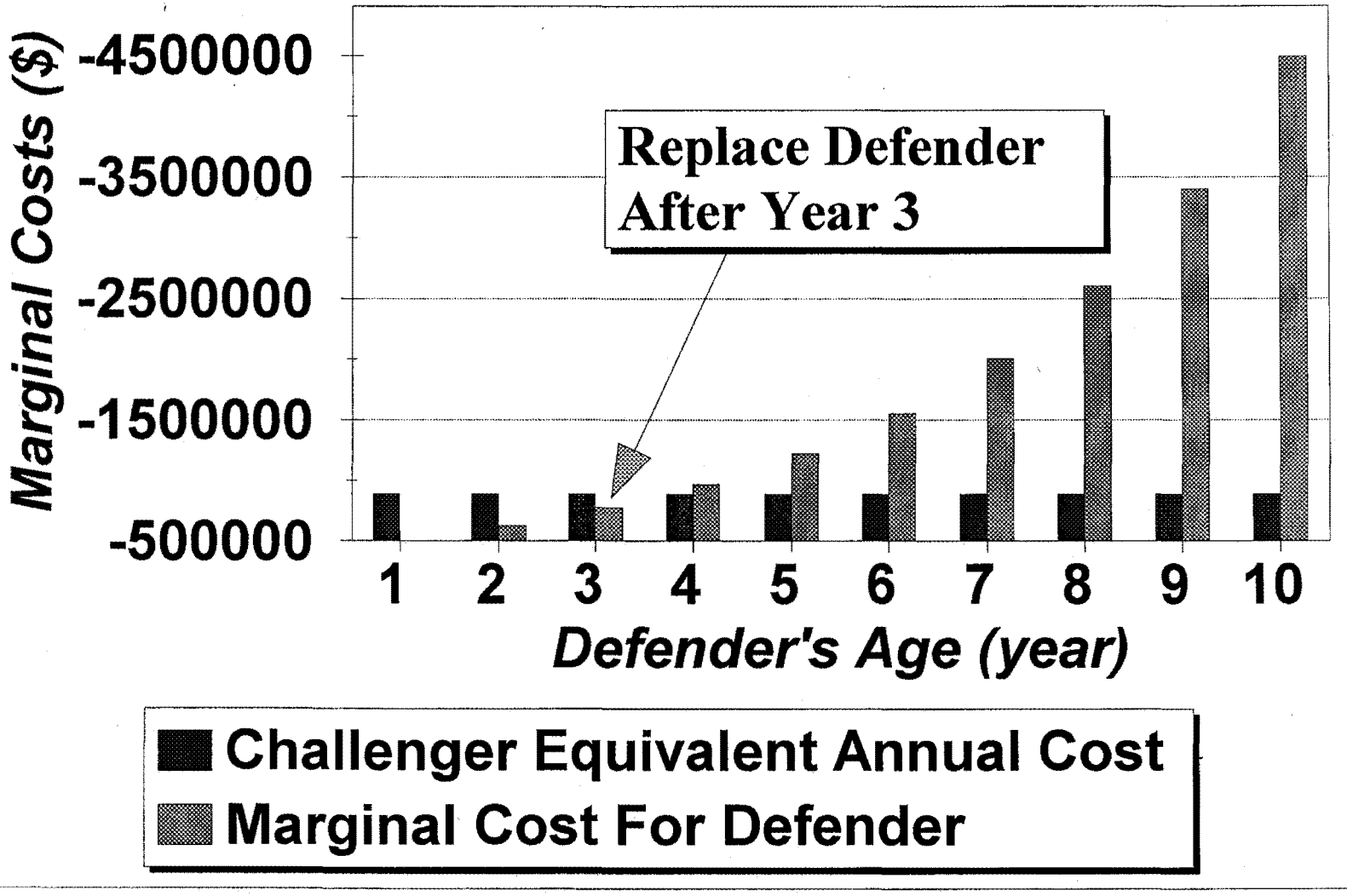
RISK ANALYSIS OF O&M ESTIMATES

PETROLEUM COST INCREASES GREATLY



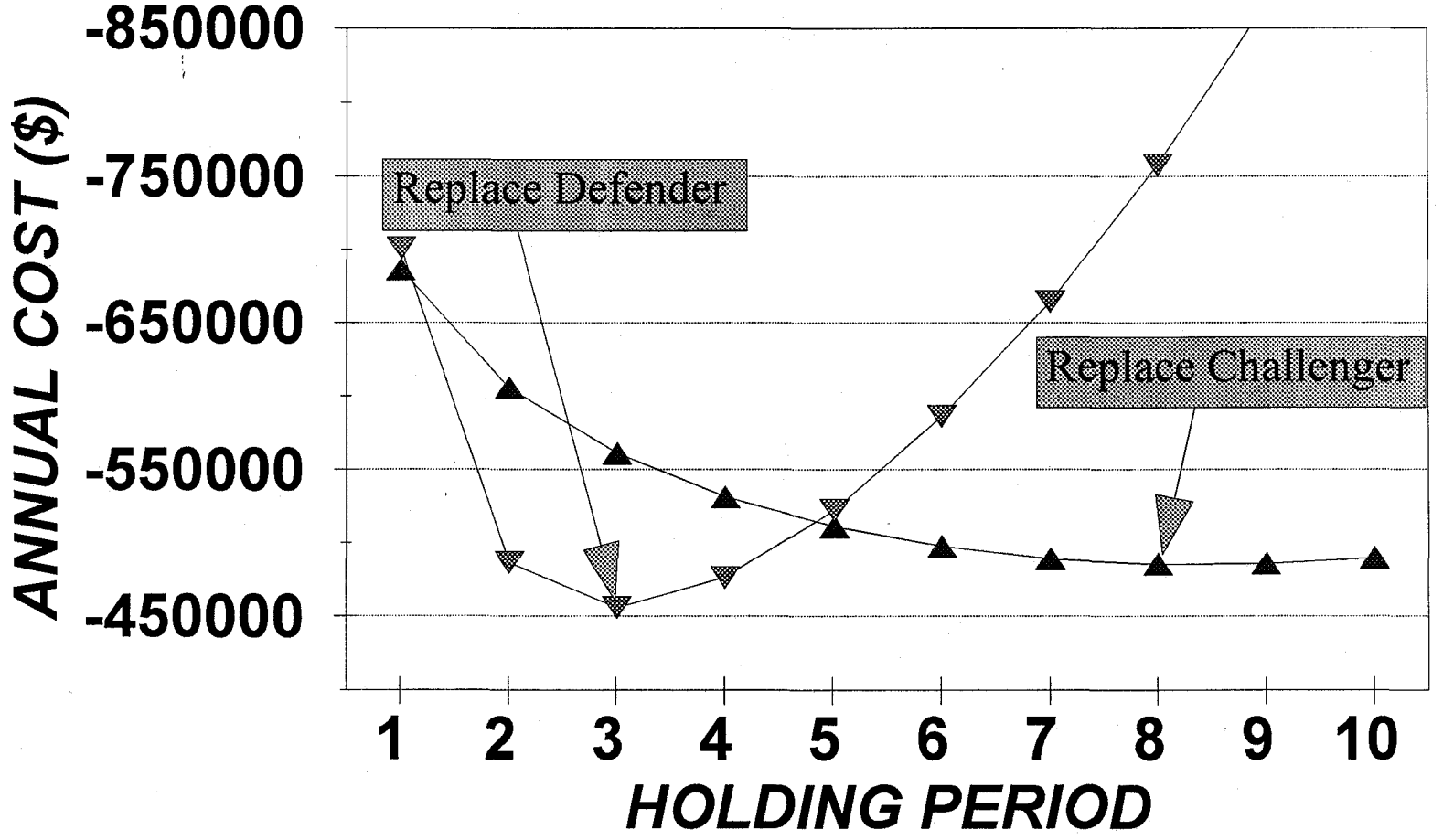
Marginal Cost For Keeping Defender

Moderate Petroleum Increase



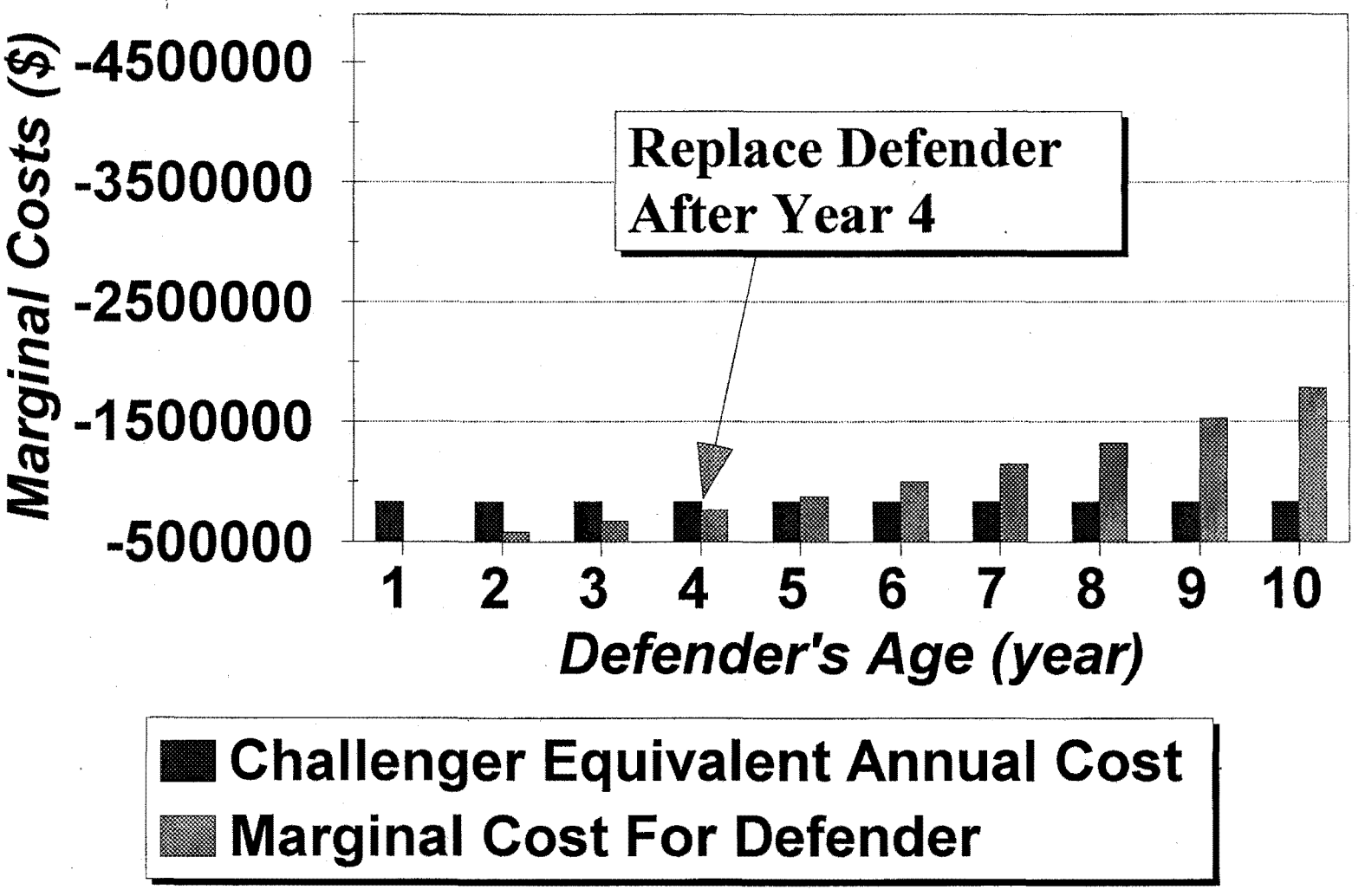
RISK ANALYSIS OF O&M ESTIMATES

PETROLEUM COST INCREASES MODERATELY



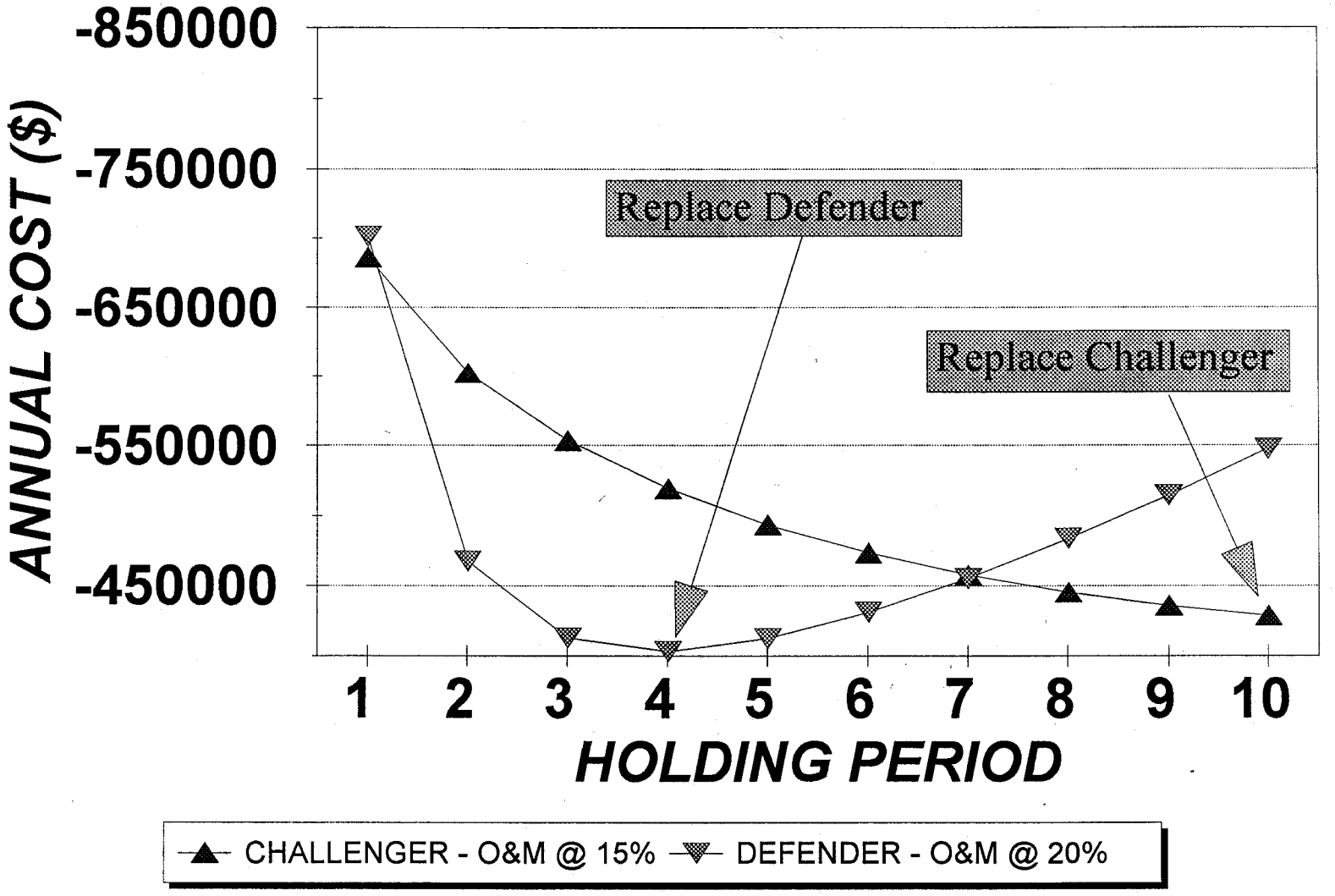
Marginal Cost For Keeping Defender

Slight Petroleum Increase



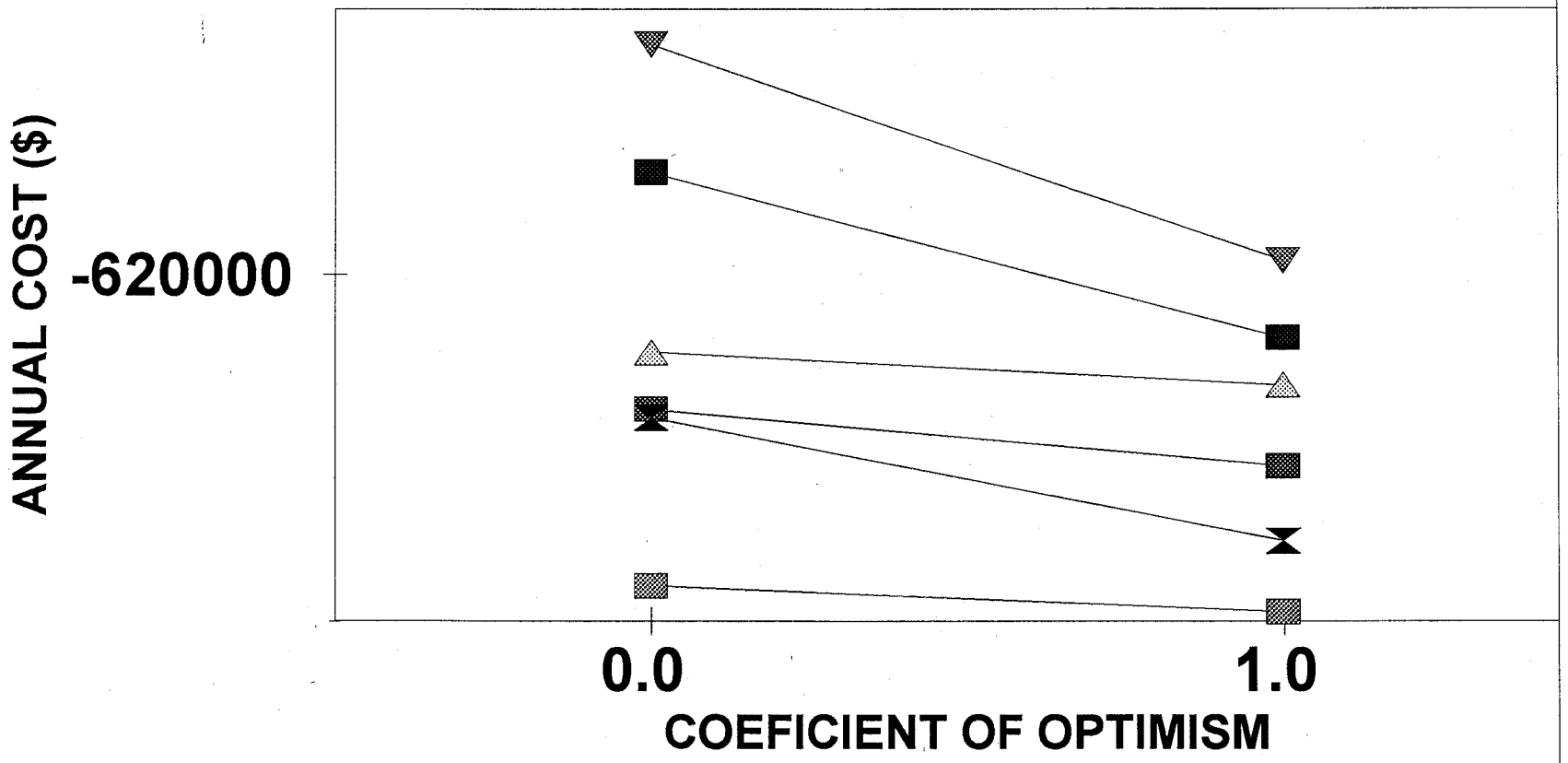
RISK ANALYSIS OF O&M ESTIMATES

PETROLEUM COST INCREASES SLIGHTLY



COEFFICIENT OF OPTIMISM

AFFECT OF TIME & STATE OF NATURE



Net After-Tax Salvage Value for Challenger

Holding Period	Before-Tax O&M	Permitted Annual Depreciation Over Holding Period 1	2	3	4	5	6	7	8	9	10
1	($80,000)	$274,752									
2	($104,000)	$274,752	$235,433								
3	($135,200)	$274,752	$470,867	$168,139							
4	($175,760)	$274,752	$470,867	$336,278	$120,072						
5	($228,488)	$274,752	$470,867	$336,278	$240,144	$85,848					
6	($297,034)	$274,752	$470,867	$336,278	$240,144	$171,696	$85,752				
7	($386,145)	$274,752	$470,867	$336,278	$240,144	$171,696	$171,504	$85,848			
8	($501,988)	$274,752	$470,867	$336,278	$240,144	$171,696	$171,504	$171,696	$42,876		
9	($652,585)	$274,752	$470,867	$336,278	$240,144	$171,696	$171,504	$171,696	$85,752	$0	
10	($848,360)	$274,752	$470,867	$336,278	$240,144	$171,696	$171,504	$171,696	$85,752	$0	$0

Depreciation Analysis for Challenger

MACRS Depreciation Used
Property is 7-Year Class for Manufacturing Equipment
200% Declining Balance and Half-Year Convention Used.

Year	Depr. Rate	Depr. Amount	Cum. Depr.
1	14.29%	$274,752	$274,752
2	24.49%	$470,867	$745,619
3	17.49%	$336,278	$1,081,898
4	12.49%	$240,144	$1,322,042
5	8.93%	$171,696	$1,493,738
6	8.92%	$171,504	$1,665,242
7	8.93%	$171,696	$1,836,938
8	4.46%	$85,752	$1,922,690
9	0.00%	$0	$1,922,690
10	0.00%	$0	$1,922,690

Total Asset Cost Including Installation =	$1,922,690
	$1,922,690
	$1,922,690
	$1,922,690
	$1,922,690
	$1,922,690
	$1,922,690
	$1,922,690
	$1,922,690
	$1,922,690
	$1,922,690
	$1,922,690

Net After-Tax Salvage Value for Challenger (Continued)

Holding Period	Total Depreciation	Book Value	Expected Market Value	Taxable Gains	Gains Tax (40%)	Net After-Tax Salvage Value
1	$274,752	$1,647,938	$1,500,000	($147,938)	($59,175)	$1,559,175
2	$510,186	$1,412,504	$1,275,000	($137,504)	($55,002)	$1,330,002
3	$913,758	$1,008,932	$1,083,750	$74,818	$29,927	$1,053,823
4	$1,201,970	$720,720	$921,188	$200,467	$80,187	$841,001
5	$1,407,890	$514,800	$783,009	$268,209	$107,284	$675,726
6	$1,579,490	$343,200	$665,558	$322,358	$128,943	$536,615
7	$1,751,090	$171,600	$565,724	$394,124	$157,650	$408,075
8	$1,879,814	$42,876	$480,866	$437,990	$175,196	$305,670
9	$1,922,690	$0	$408,736	$408,736	$163,494	$245,241
10	$1,922,690	$0	$347,425	$347,425	$138,970	$208,455

Challenger Annual Equivalent Cost Calculation

Holding Period	Before-Tax O&M	Annual Depreciation Tax Credits Over the Holding Period 1	2	3	4	5	6	7	8	9	10
1	($80,000)	$109,901									
2	($104,000)	$109,901	$94,173								
3	($135,200)	$109,901	$188,347	$67,256							
4	($175,760)	$109,901	$188,347	$134,511	$48,029						
5	($228,488)	$109,901	$188,347	$134,511	$96,058	$34,339					
6	($297,034)	$109,901	$188,347	$134,511	$96,058	$68,678	$34,301				
7	($386,145)	$109,901	$188,347	$134,511	$96,058	$68,678	$68,602	$34,339			
8	($501,988)	$109,901	$188,347	$134,511	$96,058	$68,678	$68,602	$68,678	$17,150		
9	($652,585)	$109,901	$188,347	$134,511	$96,058	$68,678	$68,602	$68,678	$34,301	$0	
10	($848,360)	$109,901	$188,347	$134,511	$96,058	$68,678	$68,602	$68,678	$34,301	$0	$0