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Costs and Benefits of Alternative Drug Testing Programs

Jules I. Borack

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13. ABSTRACT *(Maximum 200 words)*

A computerized model for determining costs and benefits of alternative drug testing programs was developed, which compared drug use in the Navy with a demographically equivalent group of civilians. The benefits of deterring and detecting drug users were compared with the costs of drug testing to determine net benefits. Benefits of testing were based on the estimated decrease in the number of drug users and the corresponding increase in employee productivity or value. The costs of testing included laboratory testing costs, employee time required to participate in testing, and were computed with and without the costs of replacing detected personnel. The testing rate, which maximizes the net benefits of testing, was greatly affected by the prevalence of drug use in the civilian sector and the decrease in productivity resulting from drug use. Laboratory testing costs also significantly affected the magnitude of optimal test rates. The rate of drug testing strongly influenced the benefits as well as the costs of testing and the effectiveness of the testing program. Estimates derived from the model indicated that present levels of Navy drug testing were cost beneficial. Annual net benefits were estimated at approximately $200 million exclusive of personnel replacement costs.

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Foreword

This report was prepared as part of the In-House Independent Laboratory Research Program task (Program Element 0601152N, Project R0001, Work Unit 0601152N.R0001.17) 'Techniques for Estimating A Conceptual Model of Drug Testing" sponsored by the Office of Naval Research. The objective of this task is to develop a conceptual framework for determining an appropriate random urinalysis drug testing program. This effort provides a framework that extends and integrates methodologies for measuring detection and deterrence developed as part of the Statistical Methods for Drug Testing project (Program Element 0305889N, Work Unit 0305889N.R2143DR001) sponsored by the Chief of Naval Personnel (PERS-63).

The author wishes to thank Mark Chipman for his assistance in the development of this manuscript and Murray Rowe for his continuing support of this effort. The author also wishes to thank Dr. David Blank of PERS-63 for his leadership and dedication to Navy drug demand reduction research and development.

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Summary

Background

The Navy's zero tolerance drug policy has been in effect since 1981. Since then the Navy has pursued an aggressive urinalysis testing program. The objectives of this testing program have been to deter and detect drug abuse. All officer and enlisted personnel are subject to random urinalysis testing on a continuing basis. Current policy (Chief of Naval Operations, 1994) directs Navy Commands to test 10 to 30 percent of their members each month. The program has been successful; the proportion of service members testing positive for drugs has fallen from approximately 7 percent in 1983 to less than 1 percent in recent years. The annual cost of the testing program is approximately $20 million. The cost of drug testing is high but any drug abuse impacts readiness, health, and safety. Therefore, it is of extreme importance that the Navy continue to evaluate and improve its drug testing program and develop an efficient drug testing strategy. However, the Navy and other organizations have no technology for judging the effectiveness and efficiency of their testing programs. No technique exists for estimating the costs and benefits of current testing programs and for assessing the impact of testing at alternative test rates.

Borack and Mehay (1996) developed a conceptual model for determining an optimal drug testing program. The model integrated the concepts of deterrence, detection, and the cost of drug abuse to establish a process that generates costs and savings due to testing.

Objective

Using the model, this research were to (1) estimated the costs and benefits of drug testing at alternative monthly test rates and (2) determined test rates that achieve maximum net benefits in terms of the difference between the productivity gain due to lower drug use and the costs of drug testing.

Methodology

Cost-benefit analyses were performed based on the conceptual model of Borack and Mehay (1996). Inputs to the model include current enlisted and officer inventories, the proportion of demographically comparable civilians who used illicit drugs during a 30-day period, a factor measuring suboptimal test strategies, average regular military compensation, average costs of replacing detected personnel, laboratory testing costs, and a measure of the impact of drug used measured as the proportion of performance degraded by drug use. The latter measure was based on studies that compare earnings of substance abusers (alcohol and illicit drugs) with others in the labor force. The model estimates the proportion and number of users deterred and detected at specific monthly test rates and the corresponding savings due to lower drug use. The model also computes the costs of testing and compares them with the savings resulting from lower drug use to yield the net benefits of testing at alternative test rates.

Results and Conclusions

The costs and benefits of drug testing were strongly affected by a number of variables. Since drug use in the Navy is associated with drug use in the civilian sector, higher levels of civilian-sector drug use were associated with increasing benefits of drug testing. Similarly, the level of performance degradation associated with drug use was strongly related to the benefits accrued from drug testing; that is, the greater the impact of drug use on performance, the larger the benefits of testing. Not surprisingly, increased laboratory test costs (or time lost by employees while undergoing testing) decreased the benefits of testing and lowered the test rate associated with maximum benefits. At monthly testing levels of 20 percent, the Navy presently appears to be achieving significant benefits from drug testing. Excluding the cost of replacing detected personnel, net annual drug testing benefits approximate $200 million. Additional modest increases in net benefits could be achieved for testing rates up to 58 percent, but at significantly higher cost.

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Introduction

The Navy's zero tolerance drug policy has been in effect since 1981. Since then, the Navy has pursued an aggressive urinalysis testing program. The objectives of this testing program have been to deter and detect drug abuse, as well as provide data on the prevalence of drug abuse. All uniformed personnel are subject to random urinalysis testing on a continuing basis. Current policy (Chief of Naval Operations, 1994) directs Navy commands to test 10-30 percent of their members each month. The program has been successful; the proportion of sampled service members testing positive for drugs has fallen from approximately 7 percent in 1983 to less than 1 percent in recent years. The annual cost of the testing program is approximately $20 million. Because of the effects of drug abuse on readiness, health, and safety, it is important that the Navy continue to evaluate and improve its drug testing program and develop an efficient drug testing strategy. However, the Navy and other organizations have no technology for judging the effectiveness and efficiency of their testing programs. No technique exists for estimating the costs and benefits of current testing programs or for assessing the impact of testing at alternative test rates.

Borack and Mehay (1996) developed a conceptual model for determining an optimal drug testing program. The model integrated the concepts of deterrence, detection, and cost of drug abuse to establish a process for determining relationship between the costs and benefits of drug testing. Figure 1 reproduces the conceptual model. Deterrence is assumed to occur first, and detected individuals are derived from the proportion of users who are undeterred. The productivity loss (or equivalently, lower value) of undetected and undeterred users represents the cost of drug use to the Navy. This cost can be compared to productivity loss that would occur if no testing were conducted in order to estimate the savings that result from drug testing. The cost of testing includes laboratory testing costs, the time required to participate in testing, and, optionally, the cost of replacing detected personnel. These costs can be compared to savings in order to estimate the net benefits of drug testing. Mathematical expressions were developed, which estimated the proportion of individuals deterred or detected (Borack 1996a, 1996b, 1997) based on alternative monthly test rates. Figure 2 reproduces a measure of the deterrence effect of testing: the percentage change in drug users (relative to a demographically equivalent group of civilians) associated with alternative monthly drug test rates. The function exhibits a classic diminishing returns pattern—increased testing increases deterrence but at a decreasing rate. The model estimated that Navy drug use would be somewhat lower (approximately 9%) than corresponding civilian use even if there were no drug testing. This difference could be caused by self-selection or other aspects of Navy life.

Estimated monthly and annual probabilities of detection are graphically depicted in Figures 3 and 4. These estimates are based on patterns of drug use described in Borack and Mehay (1996). The probability of detection during a month is approximately linearly related to the monthly test rate while the probability of detection during a year exhibits diminishing returns. In order to escape detection during a year, an individual must remain undetected in each of its 12 months.

The following sections outline the model and describe a number of costs-benefits analyses based on alternative assumptions about the efficiency of testing, laboratory testing costs, productivity losses due to drug use, and other factors.

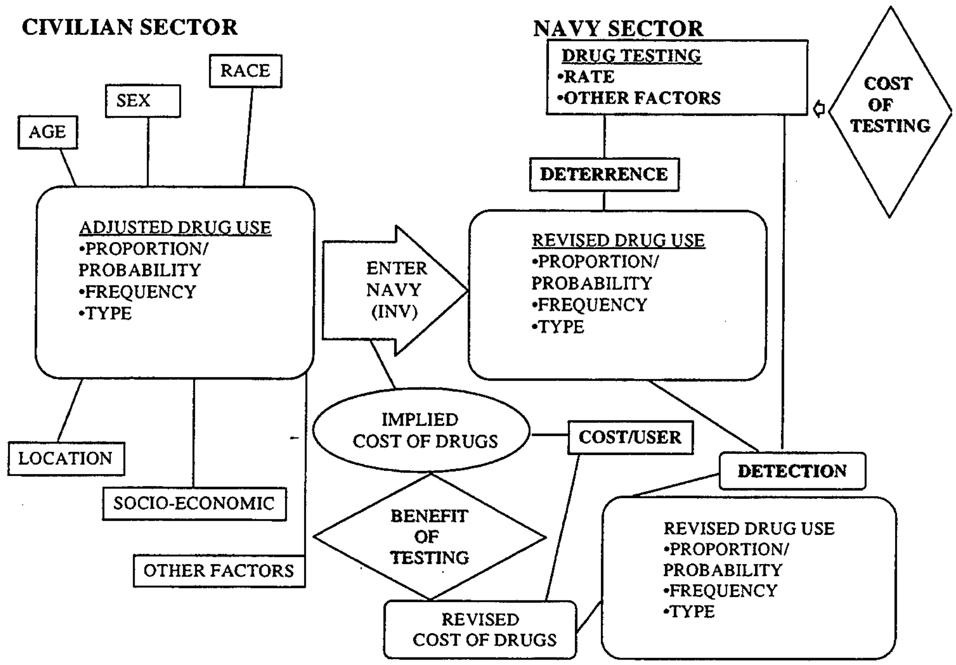

Figure 1. Conceptual model for determining an optimal drug detection program.

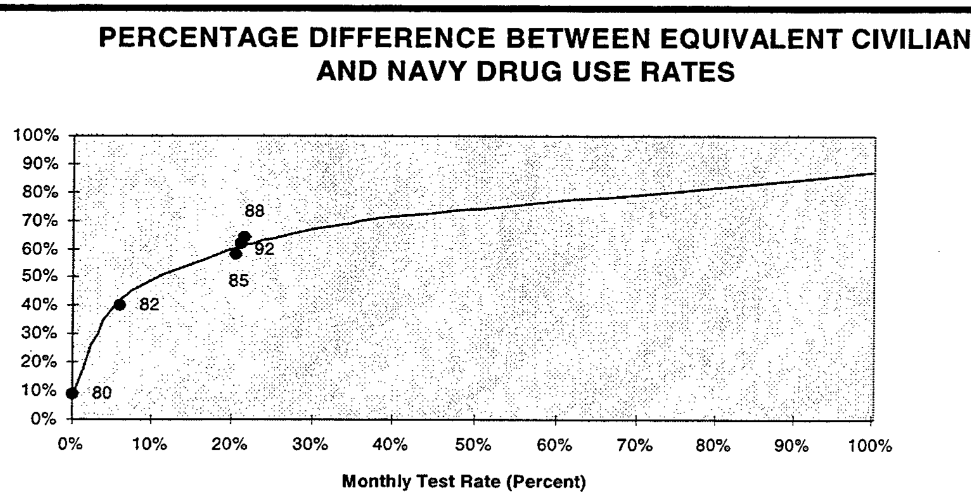

Figure 2. Percentage difference between equivalent civilian and Navy 30-day drug use rates.

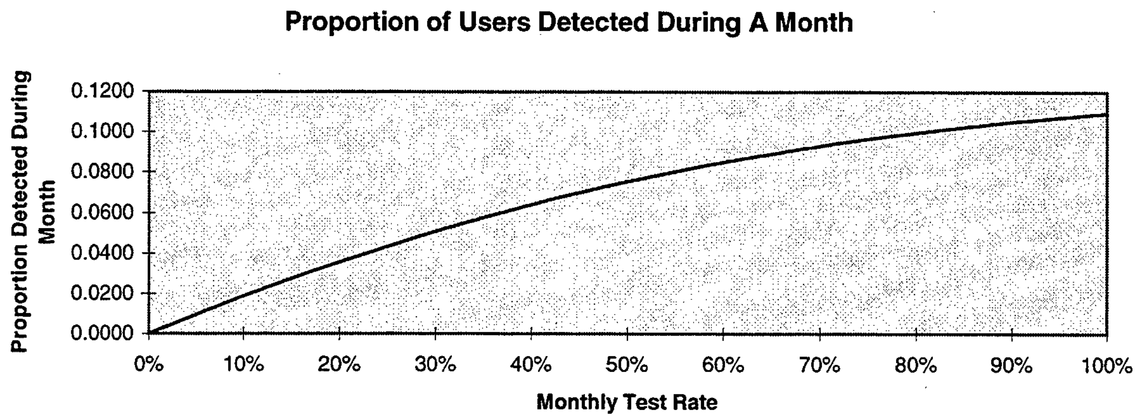

Figure 3. Probability of detection during a month as a function of the monthly test rate.

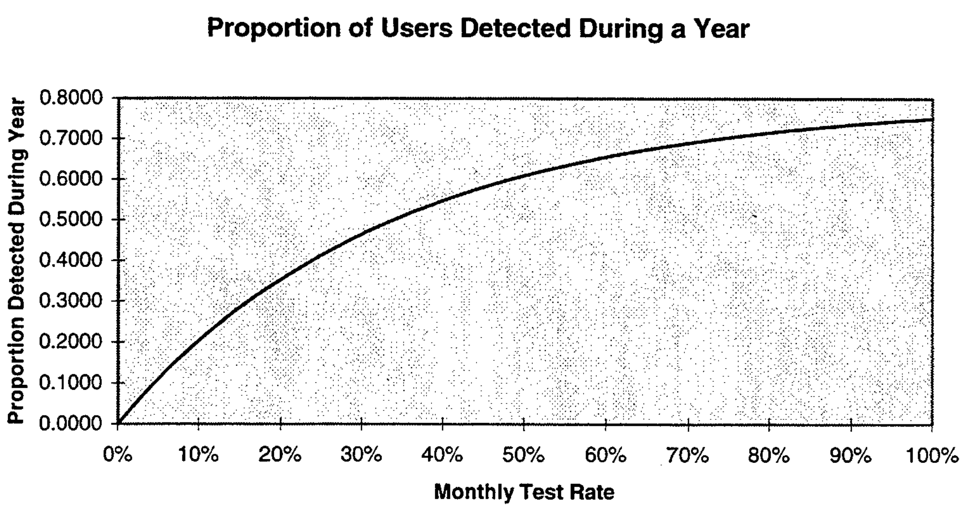

Figure 4. Probability of detection during a year as a function of the monthly test rate.

Objective

The objectives of this research were to (1) estimate the costs and benefits of drug testing at alternative monthly test rates and (2) determine test rates that achieve maximum net benefits in terms of the difference between the productivity gain due to lower drug use vs. the costs of drug testing.

Methodology

This section describes model structure, inputs, outputs, and computation strategies.

Model Structure

Figure 5 provides an overview of the costs-benefits model. Drug testing benefits are described on the left side of the diagram. First, the expected number of drug users in the absence of drug testing was determined. The number of users was estimated from civilian surveys of drug use adjusted for demographic differences between civilians and Navy personnel. Frequency and type of drug use were determined from Department of Defense surveys of drug use among Navy personnel.

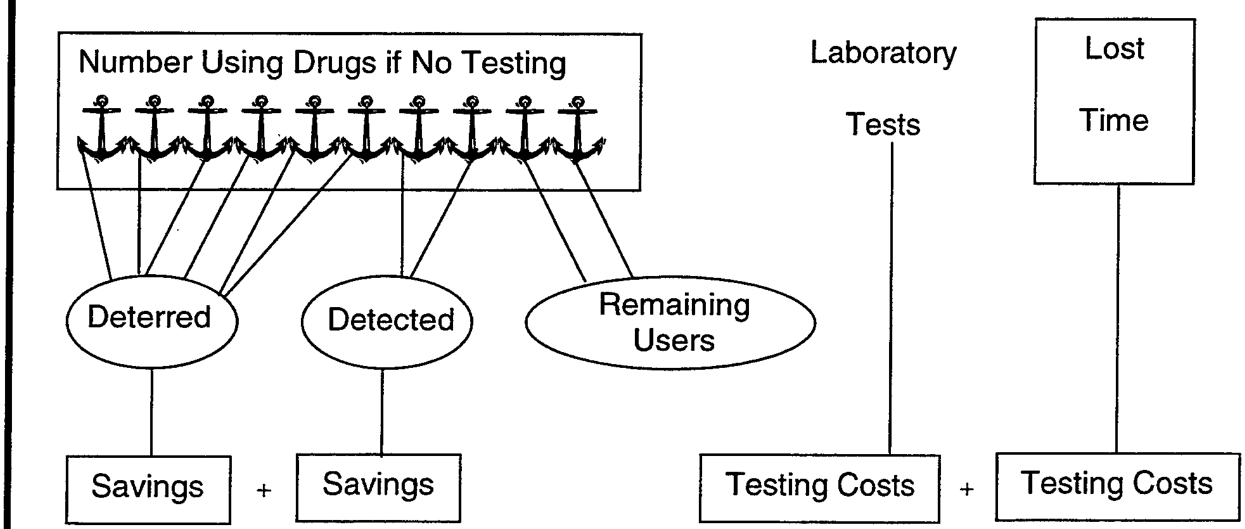

Figure 5. Overview of costs-benefits model.

Drug testing decreases drug use in two ways. First, testing deters drug use. The model estimates the proportion and number of users deterred when testing at a given monthly rate and eliminates them from the pool of individuals who are drug users. Savings are measured as a percentage of average regular military compensation (RMC) (Borack & Mehay, 1996). Additional savings accrue through the detection of undeterred users. The model estimates the proportion and number of remaining drug users detected by testing at the given monthly test rate. Savings are again measured as a percentage of average RMC, however, the savings per individual resulting from detection are slightly lower than the savings due to deterrence. This is due to the fact that a relatively small proportion of detected personnel will be replaced by individuals who are drug users. Total savings are the sum of the savings resulting from deterrence and detection. Savings that result from deterring potential users are typically far greater than those that accrue from detecting personnel.

The right hand side of the diagram illustrates the cost of testing. The cost of testing includes laboratory costs, the time required to undergo testing and optionally, the cost of discharging (and replacing) detected personnel. The net benefits of testing represent the difference between savings and costs. [1]

Model Inputs

Table 1 presents a list of inputs to the drug testing policy analysis and optimization model. Note that the model can relate to the entire Navy or a subset, such as a specific command. Details concerning calculation of these inputs and additional model assumptions can be found in Borack and Mehay (1996). Unless otherwise stated, model calculations use the input values presented in Table 1. The enlisted and officer inventories represent active strength as of the end of fiscal year 1995. Civilian-equivalent drug use rates were derived from recent surveys of civilian substance abuse (Bray, et. al, 1995). The imperfect detection factor was derived from the difference between the estimated probabilities of detection and the proportion of personnel actually detected during fiscal years 1993 and 1994. Other values are as described in Borack and Mehay (1996). Note that the first four inputs are necessary in order to estimate the number of Navy drug users in the absence of testing; the next two inputs are required to compute the savings per detected or deterred user; the final two inputs pertain to the costs of testing. Definitions of these inputs are presented in Appendix A.

Table 1

Model Inputs and Default Values

Inputs		
Enlisted Inventory	=	386,842
Officer Inventory	=	60,627
Enlisted-Equivalent Civilian Drug Use	=	10.21%
Officer-Equivalent Civilian Drug Use	=	8.03%
Average RMC	=	$24,968
Drug Use Performance Degradation	=	29%
Imperfect Detection Factor	=	20%
Average Replacement Cost	=	$31,286
Average Laboratory Cost	=	$9.69

[1] Since known drug users would be discharged from the Navy in the absence of a drug testing program, the cost of replacing such personnel can be considered to be unrelated to the testing. Therefore, it is suggested that the savings and net benefits of testing be computed without regard to replacement costs.

Model Calculations and Outputs

Estimation of the Deterrence and Detection Effects of Testing

In order to estimate the deterrence effect of testing, it was necessary to estimate the proportion of personnel who would use drugs and the frequency of their drug use in the absence of testing. Let $p_{30,0}$ represent the proportion of Navy personnel who would use drugs at least once during a 30-day period in the absence of drug testing.

Estimates of $p_{30,0}$ were constructed for 1980, 1982, 1985, 1988, 1992, and 1995 by demographically adjusting data from civilian surveys of drug use (Burt, Biegel, Carnes, & Farley, 1980; Bray, et al.,1983; 1986; 1988; 1992; 1995). Estimates of $p_{30,p}$, the proportion of Navy personnel using drugs at least once during a 30-day period if the monthly test rate were p, were obtained directly from corresponding year surveys of drug use among military personnel (WWS) (Bray, et al., 1986; 1988; 1992; 1995), and are presented in Table 2. The column headed r represents the ratio of the number of laboratory tests to the corresponding annual inventory; the column headed p represents the corresponding average proportion tested during a month (monthly test rate).

Table 2

Estimates of $p_{30,0}$ and $p_{30,p}$ for Fiscal Years 80, 82, 85, 88, 92, and 95

Fiscal Year	$p_{30,0}$	$p_{30,p}$	r	p
80	.363	.330	0.000	0.000
82	.270	.162	0.725	0.060
85	.244	.103	2.442	0.204
88	.150	.054	2.562	0.214
92	.105	.040	2.518	0.210
95	.099	.038	2.309	0.185

In order to estimate the relationship between the underlying test rate, p, and the deterrence effect, a logarithmic regression model was fit to the percentage difference between $p_{30,0}$ (i.e., the proportion of drug users among an equivalent group of civilians) and $p_{30,p}$ *(PDIFF)* as a function of the logarithm of p, yielding the following parameter estimates:

$$PDIFF(p) = .878 + .172\ln(p)$$

The value of p was scaled upward by one unit to avoid zero values. The corresponding values of adjusted R^2 and F were .986 and 341.79, respectively, which were both highly significant. In order to estimate the deterrence effect of testing, the percentage difference between testing at rate p and not testing (i.e., testing at rate 0), $\frac{PDIFF(p) - PDIFF(0)}{1 - PDIFF(0)}$, was computed. Figure 6 graphically depicts this relationship. Estimation of the proportion of undeterred users detected during the year is detailed in Appendix B and was discussed in the introduction and graphically represented in Figure 4.

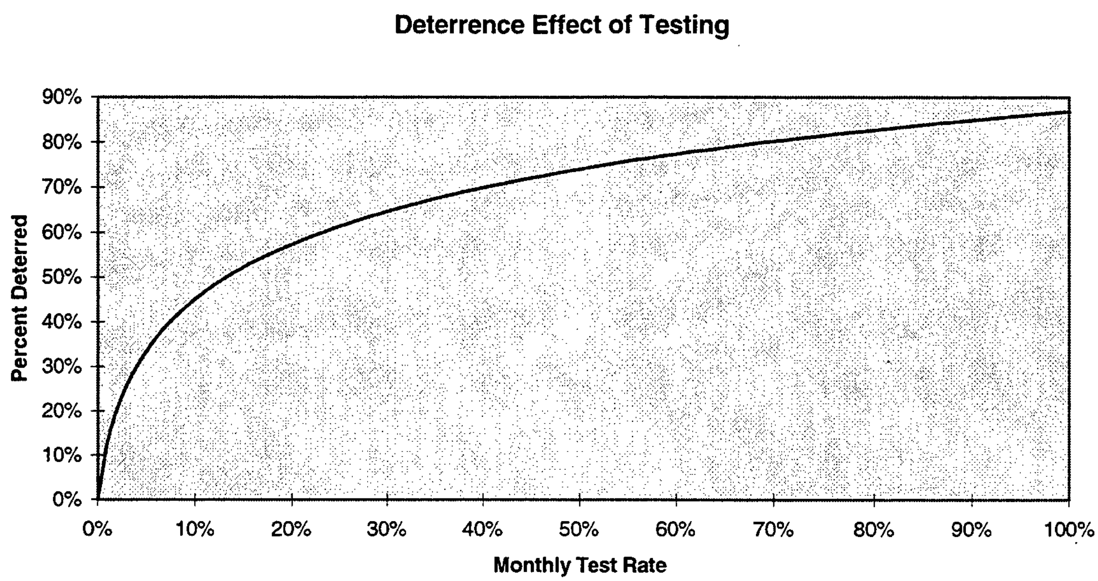

Figure 6. Deterrence effect of testing at specific monthly test rates model outputs.

Table 3 provides a list of intermediate model outputs. Definitions of these outcomes are presented in Appendix A. A number of these outputs are used to calculate the net benefits of drug testing at specific monthly test rates. Outputs were computed using a monthly test rate of 20 percent.

The primary model outputs are the net benefits of drug testing. Definitions of these outputs are presented in Appendix A. Table 4 presents the net benefits of drug testing (including and excluding replacement costs) using the baseline inputs at the 20 percent monthly test rate. It is questionable whether replacement costs should be considered as a component of the drug testing program since detected individuals would have been discharged from the Navy had their drug use been otherwise known.

Table 3

Intermediate Model Outputs

Outcomes		
Savings	=	$210,828,659
Deterrence Savings	=	$168,216,671
Number Deterred	=	23,232
Potential # of Users	=	40,553
Average Cost of User	=	$7,240.72
Percent Deterred	=	57.29%
Detection Savings	=	$42,611,988
Detection Average User Savings	=	$6,960.43
% Replacement Users	=	3.87%
Number Detected	=	6,122
Number Undeterred	=	17,321
% Detected in Year	=	35.34%
% Detected in Month	=	3.57%
% Detect in Year if Best	=	43.97%
% Detect in Month if Best	=	4.71%
Total Annual Costs	=	$204,086,316
Total Laboratory Costs	=	$10,406,339
Annual Number of Tests	=	1,073,926
Annual Lost Time (Hours)	=	178,988
Cost of Lost Time	=	$2,147,848
Replacement Costs	=	$191,532,129
# Detected or Deterred	=	29,354
% Detected or Deterred	=	72.38%
Comparable Civilian Use	=	44,365

Table 4

Primary Outputs

Maximize		
Net Benefits	=	$198,274,472
Deterrence Savings	=	$6,742,343

Definitions of these primary outputs are presented in Appendix A.

A complete chart of model inputs and outputs appears in Figure 7.

Drug Testing Costs and Benefits

Test Rate	
Rate =	20%

Maximize	
Net Benefits =	$198,274,472
Net Ben incl Repl =	$6,742,343

Inputs	
Enlisted Inventory =	386,842
Officer Inventory=	60,627
% Enlisted Users if Civ =	10.21%
% Officer Users if Civ =	8.03%
Average RMC =	$24,968
Drug Use Perf Degrad =	29%
Imperf Detection Factor =	20%
Avg Replacement Cost =	$31,286
Average Laboratory Cost	$9.69

Outcomes	
Savings =	$210,828,659
Deterrence Savings =	$168,216,671
Number Deterred =	23,232
Potential # of Users =	40,553
Avg Cost of User =	$7,240.72
Percent Deterred =	57.29%
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Total Annual Costs =	$204,086,316
Total Laboratory Costs =	$10,406,339
Annual Number of Tests =	1,073,926
Annual Lost Time (Hours) =	178,988
Cost of Lost Time =	$2,147,848
Replacement Costs =	$191,532,129
# Detected or Deterred =	29,354
% Detected or Deterred =	72.38%
Comparable Civilian Use =	44,365

Figure 7. Costs and benefits for baseline inputs at the 20 percent monthly test.

Results

The data in Figure 7 represent the programmatic costs and benefits for the specified baseline input values. A 20 percent monthly testing rate is estimated to result in annual net benefits (excluding replacement costs) of approximately $198.3 million. The test rate, which maximizes these net benefits, is 58 percent. Figure 8 presents programmatic costs and benefits for testing at this monthly rate. Net benefits are higher at this level but costs are also substantially greater.

Optimal Drug Test Rate

Test Rate	
Rate =	58%

Maximize	
Net Benefits =	$232,194,006
Net Ben incl Repl =	$41,662,977

Inputs	
Enlisted Inventory =	386,842
Officer Inventory=	60,627
% Enlisted Users if Civ =	10.21%
% Officer Users if Civ =	8.03%
Average RMC =	$24,968
Drug Use Perf Degrad =	29%
Imperf Detection Factor =	20%
Avg Replacement Cost =	$31,286
Average Laboratory Cost	$9.69

Outcomes	
Savings =	$268,881,535
Deterrence Savings =	$225,709,792
Number Deterred =	31,172
Potential # of Users =	40,553
Avg Cost of User =	$7,240.72
Percent Deterred =	76.87%
Detection Savings =	$43,171,743
Detection Avg User Sav =	$7,088.92
% Replacement Users =	2.10%
Number Detected =	6,090
Number Undeterred =	9,381
% Detected in Year =	64.92%
% Detected in Month =	8.36%
% Detect in Yr if Best =	80.77%
% Detect in Mnth if Best =	12.84%
Total Annual Costs =	$227,218,558
Total Laboratory Costs =	$30,410,800
Annual Number of Tests =	3,138,369
Annual Lost Time (Hours) =	523,062
Cost of Lost Time =	$6,276,729
Replacement Costs =	$190,531,030
# Detected or Deterred =	37,262
% Detected or Deterred =	91.88%
Comparable Civilian Use =	44,365

Figure 8. Costs and benefits for selected inputs at the 58 percent monthly test rate.

The impact of testing at alternative monthly rates can be determined. Using these baseline inputs, Figures 9, 10, 11, and 12 present the number of individuals deterred, the percentage of users detected, the number of users detected and the net benefits of testing (excluding replacement costs), respectively as a function of the monthly test rate. As depicted in Figure 11, the number of individuals detected reaches a maximum value and then declines for higher values of the monthly test rate. This occurs because the increase in the percent detected is being overcome by the decreasing number of individuals who are still undeterred. Similarly, net benefits including replacement declines as more individuals are detected and then increases as more are deterred but fewer are detected leading to a corresponding drop in replacement costs.

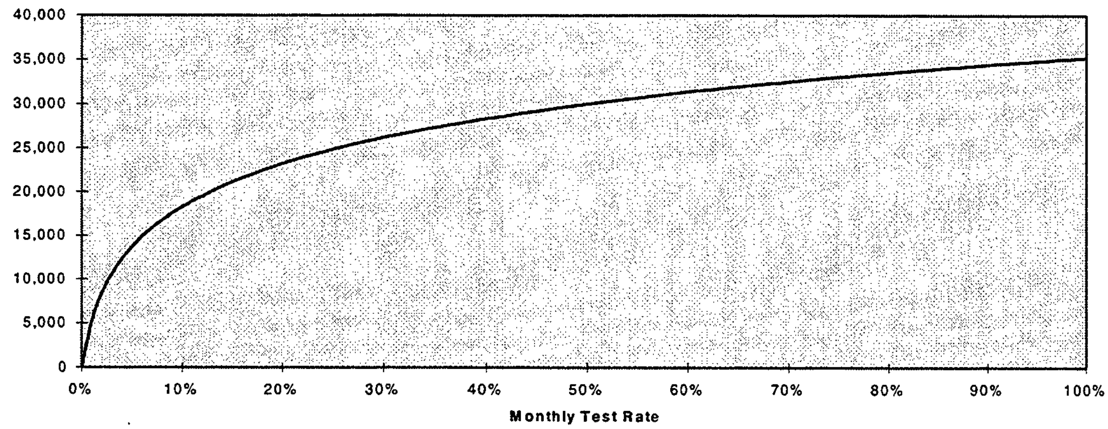

Figure 9. Number of drug users deterred for baseline inputs.

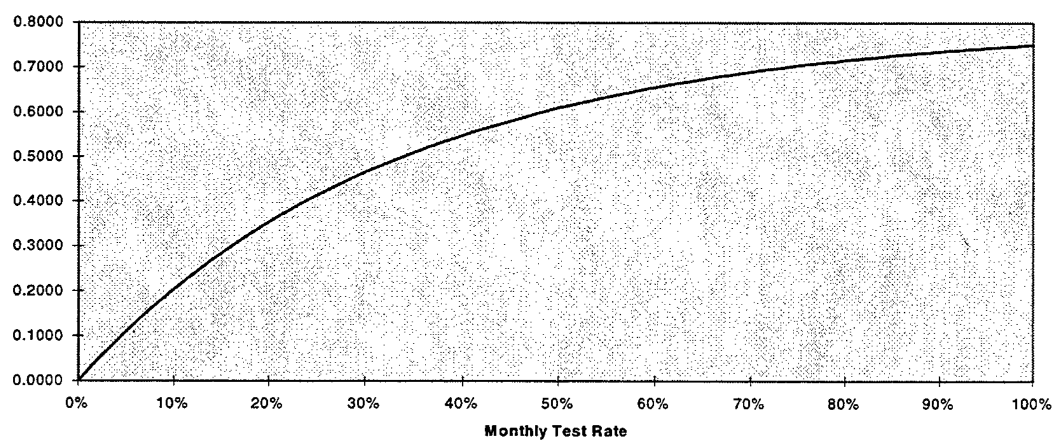

Figure 10. Proportion of individuals detected during year for baseline inputs.

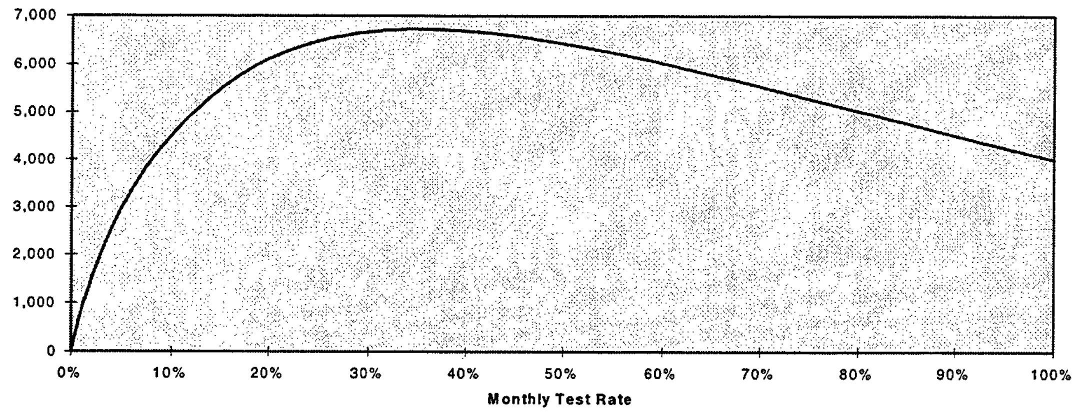

Figure 11. Number of individuals detected during year for baseline inputs.

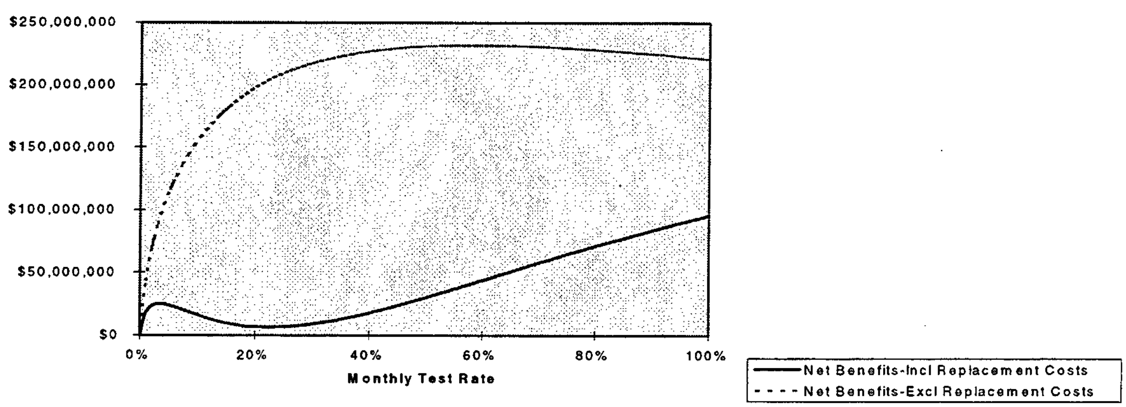

Figure 12. Net benefits of testing for baseline inputs.

The baseline scenario was compared to three alternative scenarios, which illustrate alternative assumptions about the magnitude of drug use, the cost of drug use, and the cost of drug testing. The four scenarios were as follows:

1. Baseline.

2. Performance degradation and other losses due to drug use cost 50 percent of RMC (vs. 29%).

3. Civilian drug use increases 50 percent from present levels.

4. Laboratory drug testing costs increase 100 percent from present levels.

The second scenario illustrates situations where jobs are more dangerous, where security risks are higher, or where teamwork may be especially important; the third scenario typifies commands that may be located in areas of heightened drug use; and the last scenario demonstrates the impact of testing costs.

Figure 13 presents net benefits of testing (excluding replacement costs) for the four scenarios. Observe that under scenario 2 (higher performance degradation), net benefits at all test levels increase substantially over baseline values. The monthly test rate, which maximizes net benefits, increases to 76 percent. In general, higher performance degradation resulting from drug use is associated with higher net benefits of testing. Under scenario 3 (greater drug use in the civilian sector, therefore greater use in the Navy in the absence of testing), net benefits at all test levels were also higher than corresponding baseline values. These results were based on an increase in civilian-equivalent drug use resulting in 15.32 percent of enlisted-equivalent and 12.05 percent officer-equivalent civilians using drugs within a 30-day period. The net benefits of testing increase with greater drug use at all test rates; the test rate, which maximized net benefits, was 72 percent. Finally, under scenario 4 (laboratory test costs double) net benefits were uniformly below baseline values. The monthly test rate which maximized net benefits declined to 42 percent.

These scenarios illustrate the impact of alternative drug use patterns, productivity losses, and laboratory costs on programmatic costs and benefits. Table 5 summarizes the major outcomes of these four scenarios. In general, increased testing costs decrease net benefits of testing while increased drug use and/or greater productivity loss (or associated health/accident costs) due to drug use tend to increase the net benefits of testing.

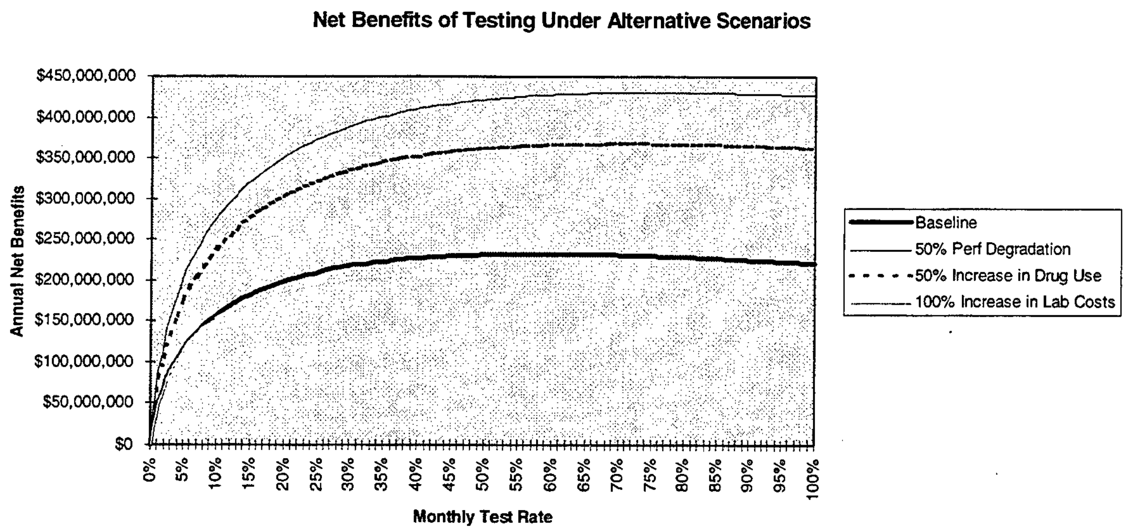

Figure 13. Net benefits for baseline and alternative scenarios.

Table 5

Comparisons Between Alternative Drug Testing Scenarios

Scenario	Net Benefits at 20% Test Rate	Net Benefits at 20% Test Rate Including Replacement	Rate that Maximizes Net Benefits	Net Benefits at Optimal Test Rate
Base	$198.2M	$6.7M	58%	$232.2M
50% Performance Degradation	$350.9M	$159.4M	76%	$430.3M
50% Increase in Civilian Drug Use	$302.4M	$15.1M	72%	$367.9M
100% Increase in Lab Costs	$187.9M	-$3.7M	42%	$206.5M

Conclusions and Recommendations

The costs and benefits of drug testing were strongly affected by a number of variables. Drug use in the civilian sector is associated with drug use in the Navy; therefore higher levels of civilian-sector use were associated with increasing benefits of drug testing. Similarly, the level of performance degradation associated with drug use was strongly related to the benefits accrued by drug testing; that is, the greater performance (or employee value) was impacted by drug use, the larger were the benefits of testing. Not surprisingly, increased laboratory test costs (or time lost by employees while undergoing testing) were associated with decreased benefits of testing and therefore call for lower testing levels in order to achieve maximum benefits. At monthly testing levels of 20 percent, the Navy presently appears to be achieving significant benefits from drug testing. Excluding the cost of replacing detected personnel, net annual drug testing benefits approximate $200 million. Additional modest increases in net benefits could be achieved for testing rates up to 58 percent, but at significantly higher cost.

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Appendix A

Definitions of Model Inputs, Intermediate Model Outputs, and Primary Model Outputs

A. Model Inputs

Enlisted Inventory: The number of enlisted personnel.

Officer Inventory: The number of officer personnel.

Enlisted Civilian Drug Use Equivalent: The percentage of civilians demographically equivalent to enlisted personnel who use drugs.

Officer Civilian Drug Use Equivalent: The percentage of civilians demographically equivalent to officer personnel who use drugs.

Average Regular Military Compensation: The average compensation of Navy personnel (including benefits) weighted by relative drug use.

Drug Use Performance Degradation Factor: The proportion of performance degraded by drug use, or equivalently, the lower value or increased cost of drug users vice non-users.

Imperfect Detection Factor: The proportion by which the detection algorithms overstate the probability of detection during a year. Algorithms assume all days are equally likely to be test days.

Average Replacement Cost: The average cost of replacing detected personnel weighted by relative drug use.

Average Laboratory Cost: The average cost of a drug laboratory test.

B. Intermediate Model Outputs

Savings: The total cost savings due to the deterrence and detection effects of drug testing.
Savings = Deterrence Savings + Detection Savings.

Deterrence Savings: Savings due to deterring drug users.
Deterrence Savings = Average Cost Per User * Number Deterred

Potential Number of Users: The number of drug users if there were no testing.
Potential Number of Users = Number of Comparable Civilian Users * (1 -*PDIFF(0)*)

Average Cost of User: The average cost of a drug user to the Navy.
Average Cost of User = Average RMC * Performance Degradation Factor

Percent Deterred: Percentage of individuals deterred at this monthly test rate. Value is obtained from the deterrence function pictured in Figure 6.

Detection Savings: The savings to the Navy from detecting drug users.
Detection Savings = Number Detected * Detection Average User Savings

Detection Average User Savings: The average cost of a drug user modified by a factor which represents the proportion of detected personnel who will be replaced by drug users. These savings are therefore slightly less than the average cost of a user.
Detection Average User Savings = Average Cost of User * (1 - Percent of Replacement Users)

Percent of Replacement Users: The percentage of detected personnel who will be replaced by users. The deterrence effect is assumed to apply to replacements.
Percent of Replacement Users = (Potential Number of Users/(Enlisted Inventory + Officer Inventory)) * (1 - Percent Deterred)

Number Detected: Number of individuals detected within a year.
Number Detected = Percent Detected in Year * (Enlisted Inventory + Officer Inventory)

Number Undeterred: Number of users not deterred.
Number Undeterred: Potential Number of Users - Number Deterred

Percent Detected in Year: Percentage of users detected within one year.
Percent Detected in Year = 1 - (1 - Percent Detected in Month) ^12

Percent Detected in Month: Percentage of users detected within one month.
Percent Detected in Month = 1-((1-(1-Imperfect Detection Factor)*Percent Detected in Year if Best)^(1/12))

Percent Detected in Year if Best: Percentage of users detected within one year assuming all days are potential test days, etc.
Percent Detected in Year if Best = 1 - (1 - Percent Detected in Month if Best) **12

Percent Detected in Month if Best: Percent of users detected within one month assuming all days are potential test days, etc.
Percent Detected in Month if Best = 0.244*Rate - 0.0417 * (Rate**2) where rate represents the monthly test rate. For further details see Borack & Mehay.

Total Annual Costs: The total cost of drug testing including the cost of replacing detected personnel.
Total Annual Costs = Total Laboratory Costs + Cost of Lost Time + Replacement Costs.[1]

Annual Number of Tests: The number of drug tests administered during the year.
Annual Number of Tests = (Enlisted Inventory + Officer Inventory) * Rate * 12.

Annual Lost Time (Hours): The amount of time required to undergo testing.
Annual Lost Time (Hours) = Annual Number of Tests * (1/6)

Cost of Lost Time: The cost of the time required to undergo testing.
Cost of Lost Time = Annual Lost Time (Hours) * (Average RMC / 2080.67)

Replacement Costs: The total cost of replacing detected personnel.
Replacement Costs = Number Detected * Average Replacement Cost

Number Detected or Deterred: The number of individuals detected or deterred per year by drug testing.
Number Detected or Deterred = Number Detected + Number Deterred

Percent Detected or Deterred: The percentage of individuals detected or deterred by drug testing.
Percent Detected or Deterred = (Number Detected or Deterred)/(Potential Number of Users)

Comparable Civilian Use: Estimated number of personnel who would use drugs if they behaved like a comparable group of civilians. As discussed in the introduction, this figure is slightly higher than the potential number of drug users.
Comparable Civilian Use = Enlisted Inventory * Enlisted Civilian Drug Use Equivalent + Officer Inventory * Officer Civilian Drug Use Equivalent

[1] Depending on user preferences, replacement costs can include the costs of separating detected personnel. If the model is run with replacement costs = separation costs, then the cost of replacing personnel should be viewed as the cost of separating personnel. In this case, net benefits including replacement costs would refer to net benefits including the costs of separating personnel.

C. Primary Model Outputs

Net Benefits: The net benefits of drug testing. Replacement Costs are not included.
Net Benefits = Savings - Total Laboratory Costs - Cost of Lost Time

Net Benefits including Replacement Costs: The net benefits of drug testing including the costs to replace detected personnel.
Net Benefits including Replacement Costs = Savings - Total Annual Costs

Appendix B

Estimation of Detection Effect of Testing

Detection Effect

The detection effect of drug testing can be measured by the probability of detecting drug users with specific patterns of drug usage. The probability of detection is affected by numerous factors, including patterns of drug use, frequency of drug use, potency of the drug, and the sensitivity level of the test (Stoloff, 1985). Drug users may also be gaming or non-gaming; i.e., they may or may not vary their drug intake depending upon their perceived probability of detection. Borack (1997) has developed an algorithm for the probability of detecting a non-gaming user during a month with a given monthly test rate (p).[1] Similarly, Borack (1995) developed an algorithm for determining an optimal strategy for a gaming drug user, which assumes that the user will choose his "next" day of drug use so as to minimize the probability of detection. For example, if a drug is detectable for one day and no testing is conducted on Sunday and Monday, the user will prefer to use drugs on Sunday, or on Saturday after normal testing time. For a specific monthly test rate, p, and test strategy, these algorithms permit estimation of the probability of detecting a gaming drug user during the month as well as the expected time until detection. In general, the expected number of months until detection, $E(TTD_p)$ can be calculated from the geometric distribution (Feller, 1957),

$$E(TTD_p) = \frac{1 - P(TTD_p)}{P(TTD_p)} + .5, \tag{1}$$

assuming that detection occurs at the mid-point of the month. Thus, the detection effect of testing at monthly rate p can be defined as $P(DET_p)$, the proportion of drug users detected during the period (e.g., month, year). We assume that detection effects do not vary by day or demographic group. From (1) it is clear that the detection effect of drug testing of current employees depends on the underlying pattern of drug use. Data from the 1992 Worldwide Survey were analyzed to estimate the underlying pattern of drug use. Table B-1 presents the self-reported frequency of drug use of specific drugs by Navy personnel within the past 30 days.

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1 Briefly, the probability of detection for a non-gaming user is:

$$P(DET_p) \cong p \sum_{i=1}^{W} \alpha_i \frac{\binom{M-i}{k-1}}{\binom{M}{k}}$$

where p is the monthly test rate, α_i is the probability, if selected for testing, of testing positive i days after drug usage, M is the total number of days in the period (e.g., a month), W is the length of time (in days) the drug remains detectable (i.e., wear-off period), and k is the number of days the individual uses drugs during the period. The values of α_i are based on drug kinetics as discussed in Thompson and Boyle (1994a) and are assumed to be non-cumulative. The value of p is assumed to be small. Other formulas based upon alternative assumptions are presented in Borack (1997).

Table B-1

Drug Use by Navy Personnel During Past 30 Days (in percent)

		Frequency (Days of Use)				
Drug	**Never**	**1-3**	**4-10**	**11-19**	**20-27**	**28-30**
Marijuana	98.22	1.29	0.18	0.22	0.08	0.00
PCP	99.93	0.07	0.00	0.00	0.00	0.00
LSD	98.69	0.82	0.49	0.00	0.00	0.00
Cocaine	98.95	1.03	0.02	0.00	0.00	0.00
Amphetamines	99.78	0.16	0.07	0.00	0.00	0.00
Tranquilizers	99.77	0.07	0.01	0.13	0.00	0.01
Barbiturates	99.84	0.07	0.08	0.01	0.00	0.01
Heroin	99.93	0.07	0.00	0.00	0.00	0.00
Analgesics	98.65	0.98	0.16	0.16	0.00	0.05
Inhalants	99.28	0.53	0.11	0.08	0.00	0.01
Designers	99.53	0.38	0.08	0.00	0.00	0.00
Steroids	99.93	0.00	0.07	0.00	0.00	0.00
Any Drug	96.00	1.81	0.87	1.09	0.07	0.17

Source: Worldwide Survey of Substance Abuse and Health Behaviors Among Military Personnel, 1992.

Detection of drug users via a testing program is also affected by gaming strategy. The 1992 Worldwide Survey indicated that 59.6 percent of self-reported Navy drug users either agreed or strongly agreed with the statement: "Some drug users curtail use when they think they'll be selected for urinalysis." Responses to this question were cross-tabulated with frequency of drug use. Individuals who used more than one drug were categorized by the drug used most frequently. In cases where two or more drugs were used with the same frequency, the individual was categorized by the drug used most infrequently within the Navy. This technique results in the proportion of users with a specific frequency of use of 'any drug' to equal the sum of the proportions with that frequency of use of specific drugs. Table B-2 presents these results. Using the algorithms discussed above, both the probability of detection during the month and the expected number of months until detection for an inventory of users with this profile can be estimated.[2]

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[2] If f_c represents the proportion of users with profile c (frequency and type (gaming vs. non-gaming)), and $P(DET_p^c)$ represents the probability of detecting such a user during the month, then the expected probability of detection, $E(P(DET_p))$, can be estimated as:

$$E(P(\hat{DET}_p)) = \sum_c f_c P(DET_p^c) \quad \text{(A)}$$

From (1) the expected time until detection, E(TTD_p), can then be estimated as:

$$E(\hat{TTD}_p) = \sum_c f_c \left(\frac{1 - P(TTD_p^c)}{P(TTD_p^c)} + .5 \right) \quad \text{(B)}$$

Table B-2

Drug User Frequencies by Type and Gaming Strategy

	Frequency of Use (Days During Month)									
	Gaming User					Non-Gaming User				
Drug	**1-3**	**4-10**	**11-19**	**20-27**	**28-30**	**1-3**	**4-10**	**11-19**	**20-27**	**28-30**
Marijuana	16.20	1.41	2.15	2.35	0.00	1.27	0.00	3.04	0.00	0.00
LSD	4.52	13.57	0.00	0.00	0.00	0.55	0.00	0.00	0.00	0.00
Cocaine	12.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Analgesics	4.17	4.07	1.41	0.00	0.00	18.39	0.00	3.12	0.00	1.43
Inhalants	3.97	1.82	0.00	0.13	0.00	0.60	1.13	2.15	0.00	0.17
Designers	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.00
Any Drug	40.93	20.86	3.56	2.48	0.00	21.13	1.13	8.31	0.00	1.60

Source: Worldwide Survey of Substance Abuse and Health Behaviors Among Military Personnel, 1992.

Such estimates can be obtained from data for specific drugs. A simplified overall estimate can be computed from the frequency of use of any drug data. Using data from Table B-2, the expected probability of detection and the number of months until detection were computed for various monthly testing rates.[3] Table B-3 presents the probability of detection and the expected number of months until detection. Using the data in Table B-3 the following quadratic regression equation through the origin ($1 \geq p \geq 0$) was estimated:

$$P(D\hat{E}T_p) = .244p - .0417p^2 \qquad (2)$$

[3] The following average drug wear off patterns (in days) were assumed: marijuana, 2; LSD, 2; cocaine, 3; analgesics, 2; inhalants are typically not tested, but will serve as a proxy for steroids, PCP, barbiturates and other drugs which are tested but for which the positive rate is very small, 2; designers, 2 ; any drug, 2.

Table B-3

Impact of Monthly Test Rate on Detection

Monthly Test Rate (p)	Probability of Detection	Expected Months Until Detection
0.00	0.0000	Infinite
0.05	0.0123	134.65
0.10	0.0242	67.28
0.15	0.0360	44.83
0.20	0.0474	33.60
0.25	0.0587	26.86
0.30	0.0697	22.37
0.40	0.0910	16.67
0.50	0.1115	13.40
0.60	0.1312	11.15
0.70	0.1502	9.55
0.80	0.1684	8.35
0.90	0.1859	7.42
1.00	0.2029	6.67

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