Applied Information Economics (AIE) Analysis
Of The

Desktop Replacement Policy

For
The Environmental Protection Agency

August 2003

Decision Research
Hubbard
The Applied Information Economics Company

CONTENTS

Executive Summary

This report summarizes the results of the risk/return analysis of the proposed desktop replacement policy investment for The Environmental Protection Agency (EPA). The proposed investment is to accelerate the desktop replacement schedule from the status quo of once every five or more years to every three or four-years.

The method used to analyze this investment is the "Applied Information Economics" (AIE) approach developed by Doug Hubbard of Hubbard Decision Research (HDR).

Expected Benefits

A standard replacement cycle would enable us to stay current with the technology and not have the hardware (and corresponding OS) restrict the implementation of new technologies. Productivity is slightly improved with faster boot-up and processing times on desktops. A three year replacement cycle would take advantage of the warranty included with the equipment. Beyond that time frame either extended warranties would need to be purchased, or staffing and parts would be needed to establish a PC repair capability.

Required Investment

In addition to continuing with the current status quo replacement schedule, three investment options were considered. Over seven years the cost of implementing a four year replacement policy, including a catch-up in the first year to eliminate all machines older than four years will be $18,736,000.

Key Risks

In each of the accelerated replacement options, there is uncertainty about the extent of the productivity improvement (if any) and how many operating systems would actually be eliminated.

Recommendations

1) Implement a four year replacement schedule after catch-up.
2) Upgrade some remaining machines to minimize number of operating systems.
3) Reassess investment model again next year to reflect major environmental changes including whether the next year's replacement should be lease or purchase.
4) Implement the performance metrics on productivity improvements as shown in this report.

Value of This Information

Applied Information Economics can be used to compute the value of this analysis with standard, proven methods. The most conservative application of this approach assumes that only the decision to change the desktop replacement policy was a direct function of the AIE analysis. The expected Nept Present Value (NPV) of the recommended policy changes is $12.8 million over 7 years. Since this AIE analysis project cost was under $100,000 including EPA staff time, then the payback is *at least* 128:1. This also excludes the potential benefits of the improved metrics and risk mitigation strategies resulting from the AIE analysis. The cost of the AIE analysis was less than 1% of the investment analyzed, well within typical AIE cost guidelines.

1. Overview of the AIE Methodology

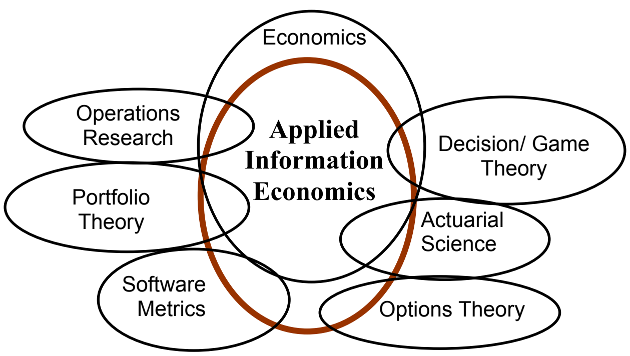
Applied Information Economics (AIE) is the practical application of scientific and mathematical methods to the IT and business decision process.

1.1 Key Principles

Several characteristics distinguish Applied Information Economics (AIE) from alternative decision-making methods.

- Everything is measurable
- Risk can be measured in an actuarially sound way
- The value of information can be computed in an economically sound way

AIE is a unique methodology to rigorously apply a specialized economic theory to the problems confronting the executive in charge of the "IT portfolio."



AIE is a synthesis of techniques from a variety of scientific and mathematical fields. The tools of economics, financial theory, and statistics are all major contributors to AIE. But in addition to these more familiar fields, AIE includes Decision Theory - the formulation of decisions into a mathematical framework - and Information Theory - the mathematical modeling of transmitting and receiving information. It is important to emphasize, however, that even though AIE is a theoretically well-founded set of techniques, it is a very practical approach. Every proper application of AIE keeps the bottom line squarely in mind. All output from the AIE project is in support of specific practical business objectives.

The powerful techniques of AIE clarify, measure, and provide optimal recommendations for a variety of situations. AIE applies across the enterprise to solve some of its most perplexing problems, including the following:

- Using mathematical models to improve cost/benefit analysis (CBA) for better decisions at all levels of IT;
- Developing financially-based quality assurance measurements to insure that the implementation of IT decisions are effective; and
- Developing a strategic plan for information systems based on identifying the best opportunities for economic contribution by information systems

Understanding the AIE methodology often requires a significant change in thinking. Principles and methods familiar to those in the scientific and mathematical fields that are used in AIE are often foreign to those in the information technology field. Consequently, many people experience the paradigm shifts listed the box below when first encountering AIE.

Paradigm shifts in AIE

- Everything is measurable
- The purpose of measurements is to provide information to make better future decisions not merely to justify past decisions
- Using range estimates for costs and benefits to estimate the value of IT is better than using averages or best guesses as estimates
- The value of information needed to make decisions can be computed
- Uncertainty and risk can be quantified
- Scientific methods of measurement are practical for IT investment

1.2 Key Methods of AIE

Some of the basic techniques that make AIE a powerful set of tools are "unit of measure" definitions, calculation methods for the value of information, methods for modeling uncertainty in estimates, and treating the IT investment as a type of investment portfolio. These methods are used also by financial services firms to create financial products and they are used also by the insurance companies to calculate premiums.

1.2.1 "Unit Of Measure" Definitions

Most IT investment arguments include some costs or benefits, which are treated as "intangibles" or factors that cannot be measured. Some common examples include "Strategic Alignment," "Customer Satisfaction" or "Employee Empowerment." In most of these cases, the factors only seem to be immeasurable because they are ambiguously defined. AIE removes this type of ambiguity by focusing on definitions that can be expressed in units of measure.

For example, an argument for a new Intrusion Detection System may claim that, among other things, it reduces "data exposure". Does this mean that legal exposure from unauthorized distribution of personal data is reduced? If so, how frequently do situations arise that result in legal costs and what is the cost per incident? Does reduced "data exposure" mean that the cost of fixing corrupted data is reduced? Does it mean that there will be less fraud resulting in monetary losses? Does this mean all of the above?

1.2.2. Analyzing Uncertainty Systematically

All investments have a measurable amount of uncertainty or risk. Rational investment decisions must always take both the risk and return of a given project into account. The ability to quantify the risk of a given IT investment, and compare its risk/return with other non-IT investments, is one of the many things that set AIE apart.

AIE quantifies uncertainties with ranges of values and probabilities. In reality, there is uncertainty about any number that we would apply to just about any cost/benefit variable. Instead of choosing a single point estimate, AIE focuses on determining the range of possible values for a given variable and ascribing probabilities to them. It is almost never the case that we will need exact numbers before we can make an economically rational decision. The ranges of values assigned to variables in a decision model can be used to determine a "probability distribution" of the net benefit of a particular IT investment.

AIE uses the "Monte Carlo" method - the generating of thousands of random scenarios on a computer (also used in statistics, actuarial science and game theory) - to develop a graph of the likelihood of each possible net benefit. Since part of this graph will usually show that there is some chance of losing the investment or not making the desired return, the risk of the investment can be quantified and assessed against its expected return.

1.2.3 The Calculation of The Economic Value of Information

Contrary to popular belief, the value of information can be calculated as a dollar value. Although the term "information" is often used in an ambiguous manner, an unambiguous unit of measure has been defined which can be used in an economic value calculation. This mathematical procedure can be paraphrased as follows:

- ✓ Information Reduces Uncertainty
- ✓ Less Uncertainty Improves Decisions
- ✓ Better Decisions Result In More Effective Actions
- ✓ Effective Actions Improve Profit or Mission Results

These four steps can be stated in unambiguous mathematical terms. The mathematical model for this has been around since the late 1940's. From this the "elusive" value of information can be determined precisely. If you were going to make a decision about implementing a new information system, you would find that you are uncertain of the cost and duration of the investment as well as the various benefits. If you had less uncertainty about these quantities then you would be more likely to make the right decision about whether to proceed with the investment.

A decision to proceed with a major IT investment is risky because of uncertain costs, benefits, learning curves, etc. The wrong decision will result in lost opportunities if a good investment is rejected or misallocated resources if a bad investment is accepted. If the decision-maker had more information (i.e., less uncertainty) about ongoing maintenance costs, for example, she would have a higher chance of making the right decision. Reducing uncertainty on more variables would bring an even higher chance that the right decision will be made. The wrong decision will cost money and the right decision will make (or save) money. The formula for this simply computes the likely economic advantage from having less uncertainty.

1.2.4 IT Investments As An Investment Portfolio

AIE uses the methods of Modern Portfolio Theory (MPT) and treats the set of an organization's IT investments as another type of investment portfolio. By using techniques from MPT, we can determine whether the uncertainties inherent in a given IT investment decision are acceptable given the risk/return position for the firm. MPT also isolates or identifies the contribution or impact of multiple investments separately and together. This allows AIE to find the optimum combination of investments.

1.3 Procedure

The next five sections of this report follow the major milestones of the AIE analysis method.

1.3.1 Scope The Decision Model

The objectives of this first step of the assessment are to:

- Provide a brief description of the investment decision
- List the benefit elements
- List the cost elements
- Identify the risk factors

This initial step takes the form of a workgroup comprised of the project sponsor, the estimators, the auditor, the assessment coordinators and the AIE facilitators. The intention is to arrive at a consensus concerning the scope of the project. At this stage, the different cost, benefit and risk elements can be expressed in fairly vague terms.

1.3.2 Build Decision Model

This step involves converting the intangible costs and benefits into tangibles, and constructing the cost/benefits model.

During this step, we conducted a series of workshops that focused on translating the "intangibles" step into well-defined measurable variables. The methods for doing this are based on the use of proven AIE methods in a "Clarification Workshop". These methods coach the people who originally identified the intangibles so that they can articulate the benefits in more precise terms. Once ambiguity is removed and more precisely defined variables are identified, then a spreadsheet is constructed to insert these new variables into a cost/benefit analysis.

1.3.3 Conduct Measurements

The objective of this step is to provide a estimate of the probable values for each parameter in the cost/benefit model. Specifically, this estimate will be expressed as a "Probability Distribution" that represents the uncertainty of each variable.

To conduct the measurements, a two-stage approach was used. The initial stage provided conservatively wide and rapidly developed ranges for the entire spreadsheet model. The majority of these initial measurements come from "Calibrated Probability Assessments.

Calibrated Probability Assessments are subjective - yet scientifically based - probability assessments of individuals. A series of training exercises are conducted to make the estimators aware of the optimistic nature of their estimates. These skills are independent of the subject. Therefore, even though the training is done with general trivia questions, the skill transfers to other subjects. For each subject matter expert, we were able to determine statistically how "over-confident" or "under-confident" they were when providing estimates. See the inset box below for explanations of these terms.

Definitions

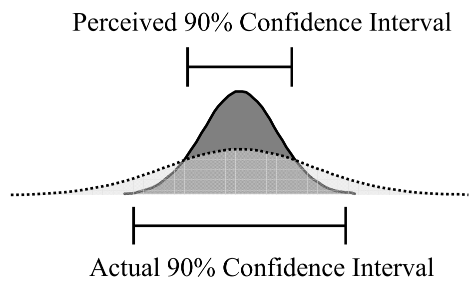
<u>Over-confidence:</u> The individual routinely puts too small of an "uncertainty" on estimated quantities and they are wrong much more often then they think. For example, when asked to make estimates with a 90% confidence interval much fewer than 90% of the true answers fall within the estimated ranges.

<u>Under-confidence:</u> The individual routinely puts too large of an "uncertainty" on estimated quantities and they are correct much more often then they think. For example, when asked to make estimates with a 90% confidence interval much more than 90% of the true answers fall within the estimated ranges.

The calibrated subject matter experts are then asked to apply their new calibration skills to estimate the uncertain variables in the decision model. The estimates are represented by a confidence interval and a probability distribution for this interval. The calibrated estimator has a 90% confidence level that the estimate he gives is within that range. The probability distribution demonstrates the shape of the curve of the range. Once the measurements received from the calibrated estimators are put into the spreadsheet, a Value of Information Analysis (VIA) is conducted.

Calibrated Probability Assessments

When asked to provide a subjective 90% confidence interval, most managers provide a range that only has about a 40%-50% chance of being right



The VIA is used to identify those variables for which it is economically justified to reduce uncertainty by searching for additional information. All measurements that have a value result in the reduction of uncertainty of some quantity that affects a decision. The variables vary by how uncertain they are and by how much they impact the final decision. The measurements with the highest VIA are chosen for further measurement.

Further measurement can consist of random samples, more background research, controlled experiments or simply breaking down the spreadsheet into more detail in a certain area. Once these measurements are conducted, the model is updated to reflect the new information.

1.3.4 Conduct Risk/Return Analysis

The objective of this step is to identify whether the expected return is enough to justify the risk according to the organization's investment criteria. This approach is inspired from applied financial portfolio management methods. The tools used in this step are the Excel spreadsheet and an Excel macro for generating the "Monte Carlo" simulation. AIE compares the "Expected Return" (the probability-weighted average of all possible returns) against the probability that the return will be negative. Finally, the results are used to determine if the investment is acceptable to the investors. This is done by plotting the investment on a chart that shows how much risk the investor is willing to accept for a given return.

1.3.5 Provide Recommendations

At this point we summarize the results of the AIE assessment and provide clear recommendations to support the decision-making process. The recommendations will be based on the results obtained during the previous steps. Careful attention is paid to the "residual VIA's" (high-impact uncertainty that could not feasibly be reduced prior to proposing the investment decision). This information tells us how to mitigate risks if the investment is actually approved and possible methods for accelerating benefits.

2. The Decision Scope

EPA currently replaces its desktop computers on an approximate five year cycle. The investment will replace that with a three or four-year desktop replacement policy. This is an analysis of the value of a policy for faster PC replacement, not the value of PC's in general.

2.1 Objectives

The objectives of this first step of the assessment are to:
- Provide a brief description of the investment decision
- List the benefit elements
- List the cost elements
- Identify the risk factors

2.2 Approach

This initial step takes the form of a workgroup comprised of the project sponsor, the estimators, the auditor, the assessment coordinators and the AIE facilitators. The intention is to arrive at a consensus concerning the scope of the project. At this stage, the different cost, benefit and risk elements can be expressed in fairly vague terms.

2.3 Description of Proposed Investment

All EPA staff and most on-site contractor personnel use EPA provided desktop computers to support their activities. The proposed investment is to accelerate the desktop replacement schedule from the status quo five year replacement schedule to either a three year or a four-year replacement policy.

As part of the analysis of the alternatives another option was developed that would take advantage of several critical benefits identified during the development of the model. That option is a four-year replacement policy with "catch-up" by replacing all desktops older than four-years in the first year. This alternative would enhance user productivity and reduce support costs by reducing the number of operating systems that need to be supported.

2.4 Decisions & Decision Criteria

The investment consists of changing the Agency's de facto five year (or higher) desktop replacement cycle to one of the following:

1. A three year replacement policy
2. A four-year replacement policy
3. A four-year replacement policy with "catch-up" replacement.

The "catch-up" in the third option is the immediate replacement of all desktops older than four years in the first year before falling into a regular four year replacement strategy. This is a faster replacement cycle than simply replacing 25% of desktops each year since such a schedule would not get rid of all machines older than four years in the first year.

2.5 Expected Benefits

The benefits of the investment include the following.

1. Enhanced user productivity composed of reduction of machine processing time required to support staff activities.
2. Reduction of wasted staff time due to machine failures.
3. Avoidance of older desktop upgrade requirements driven by introduction of new versions of Agency standard software (Office automation and Network) as well as the ability to adopt a new technology.
4. Reduction of maintenance costs for machines no longer covered by maintenance contracts.
5. Reduction in the Agency support staffing requirements due to the reduction in the number of operating systems that need to be supported because of the age of the machines.

2.6 Expected Cost Elements

The costs of investment include the marginal cost of the additional desktops to be acquired each year under the new policy as compared to the status quo policy. The cost of acquiring new desktops includes a manufacture's three year warranty.

See Appendix 3 for more details on all costs and benefits.

2.7 Risk Factors

The key risks vary somewhat depending on which of the three investment options is taken.

1. With the option to simply continue with the existing status quo replacement policy, key risks are mostly uncertainty about continuing to provide the processing power required to support Agency standard infrastructure and software standards. With the current policy, significant upgrades are required to allow existing machines to meet basic minimum requirements.
2. There is also some uncertainty about the trends in costs of desktop machines. Recent manufacturers' prices have actually accelerated the desktop performance/dollar growth trend, which is about 140% a year.
3. For all the faster replacement options, there is uncertainty about how much the faster replacement schedule will improve productivity or how many operating systems can be eliminated.

3. The Decision Model

A spreadsheet was constructed to capture all categories of benefits, costs and risks. The expected number of additional desktops was estimated, and then the costs of acquiring that equipment were estimated. The increased benefits due to acquisition of the additional new machines were also identified and estimated.

3.1 Objectives

This step involves converting the intangible costs and benefits into tangibles, and constructing the cost/benefits model.

3.2 Approach

During this step, we conducted a series of workshops that focused on translating the "intangibles" identified in the Describe & Classify step into well-defined measurable variables. The methods for doing this are based on the use of proven AIE methods in a "Clarification Workshop". These methods coach the people who originally identified the intangibles so that they can articulate the benefits in more precise terms.

Once ambiguity is removed and more precisely defined variables are identified, then a spreadsheet is constructed to insert these new variables into a cost/benefit analysis.

3.3 Structure of the Spreadsheet

The diagram on the following page shows an overview of the structure of the spreadsheet model. The spreadsheet can be broken down into the following sections:

1. Business Environment: This part of the model estimates items related to the business processes such as the number of users, the current machine infrastructure and their age. This provides a baseline for the investment to be analyzed.
2. Investment Alternatives: This section describes each alternative in terms of Implementation, benefits, and costs. The effect of each desktop replacement schedule alternative is determined based on the implementing a replacement policy. Given the users and machine age generated in the "Business Environment" section, the benefits and costs of the additional desktop and LAN printer purchases are estimated.

3.4 Financial Decision Criteria

The investment will be analyzed by Return on Investment (ROI) over seven years starting in FY 2004.

The requested desktop replacement budget is assumed to reflect anticipated changes in the number of users for the period. Likewise, the labor cost per person is assumed to be known for the next seven years and the cost of money is fixed at 4.5% annually. Any figures reported as exact quantities (as opposed to ranges) are due to mandates from specific sources such as EPA financial standards or OMB.

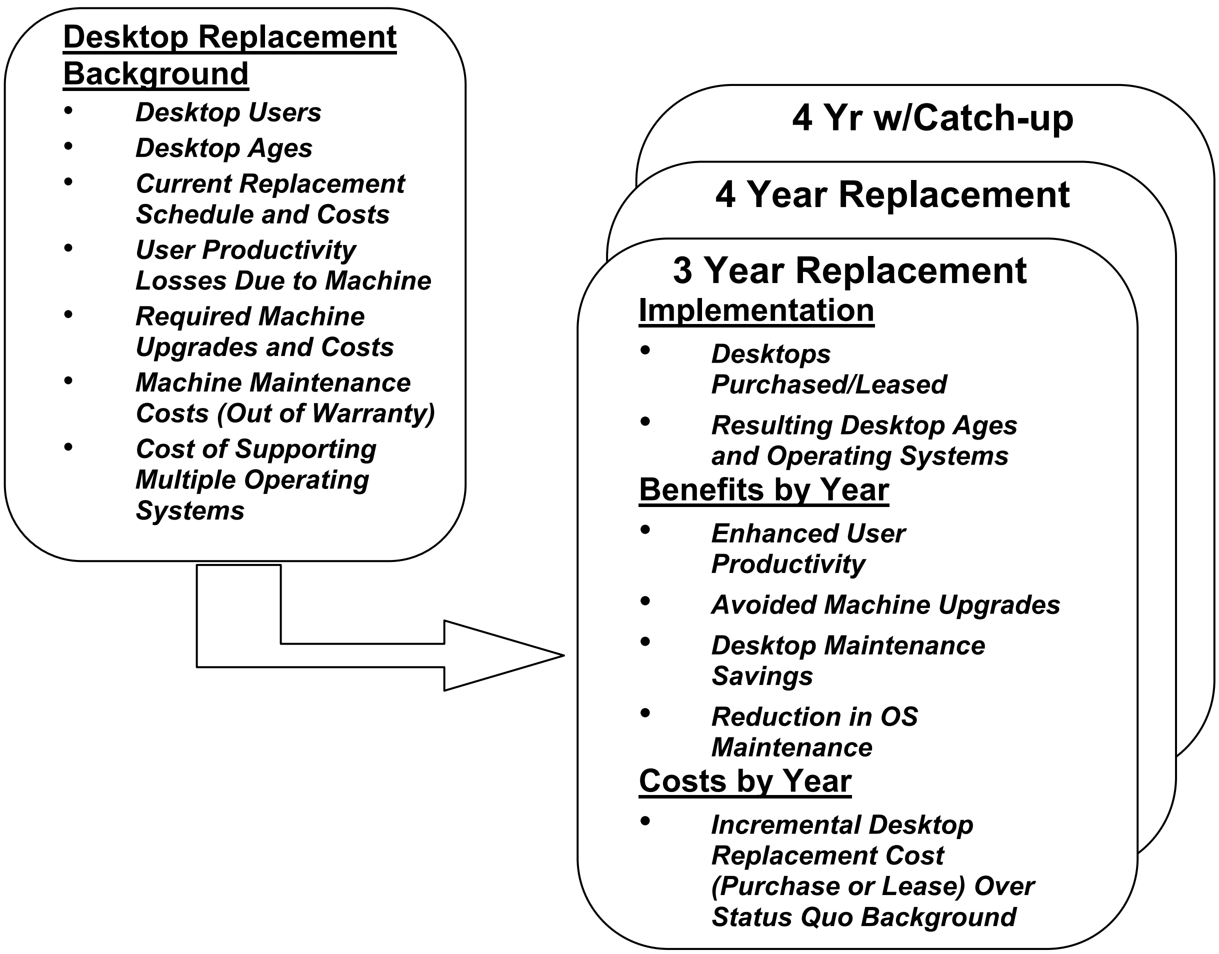
3.5 Decision Scope

The investment should be considered the *marginal* investment due to the change in the PC replacement policy. This is not a cost-benefit justification for PC's in general. Therefore it does not include the total costs of PC's in the EPA. This analysis focuses on the additional costs incurred specifically due to the change in policy itself. In other words, if a policy requires an increase in the number of PC's purchased in a given year, the cost of the policy is only the increase in PC purchases – not the total PC purchases.

One of the early determinations made during analysis of the status quo and alternatives was that inclusion of LAN printers in this analysis of desktop replacement policy was not appropriate. Because of the different life cycle of LAN printers, their presence in the model only served to hide the actual impacts of the replacement policy options.

Overview of the Spreadsheet model

The spreadsheet models the projected costs and benefits of implementing a faster desktop replacement process to maintain basic computer support capabilities for the EPA user community. See the spreadsheet in Appendix 3 for more details.



4. Measurements & VIA

Calibrated estimates were made for 47 variables. A value of information analysis (VIA) indicated that additional measurements were needed for the some of the estimates.

4.1 Objective

The objective of this quantification step is to provide a numerical estimate of the probable values for each parameter in the cost/benefit model. Specifically, this estimate will be expressed as a "Probability Distribution" that represents the uncertainty of each variable.

4.2 Approach

Since the variables in the cost-benefit model are clearly identified and organized and the formula to calculate the contribution of the variables has been indicated, the variables can now be measured. To conduct the measurements, a two-stage approach was used. The initial stage provided conservatively wide and rapidly developed ranges for the entire spreadsheet model. The majority of these initial measurements come from Standard Metrics and Calibrated Probability Assessments. Standard Metrics are simply quantities that are provided as "givens" in order to standardize cost/benefit analysis. Examples are loaded cost of labor and cost of capital.

Calibrated Probability Assessments are subjective - yet scientifically based - probability assessments of individuals. A series of training exercises (calibration) is conducted to make the estimators aware of the optimistic nature of their estimates. These exercises then develop the estimators' skills in representing uncertainty concerning quantities, or in determining a correction coefficient for their estimates.

The estimates are represented by a confidence interval and a probability distribution for this interval. The calibrated estimator has a 90% confidence level that the estimate he gives is within that range. The probability distribution demonstrates the shape of the curve of the range. Once the measurements received from the calibrated estimators are put into the spreadsheet, a Value of Information Analysis (VIA) is conducted.

The VIA is used to identify those variables for which it is economically justified to reduce uncertainty by searching for additional information.

4.3 Calibrated Probability Assessments

As expected, most of the initial quantities came from Calibrated Probability Assessments. The other source of data was Standard Metrics in the form of a Dell lease proposal. All remaining variables were computed from other inputs.

Initial Measurement Source Summary	
Source of Measurement	Number of variables
Calibrated Probability Assessments - probability distributions gathered from Estimators who have been through calibration workshops	**47**
Standard Metrics – Dell proposed four year lease price, provided by Bill Beaver.	**1**
Total	**48**

The calibration training showed that most of the estimators were able to adequately represent their uncertainties with probability distributions. Some estimates came from un-calibrated individuals but calibrated persons always confirmed the estimates.

4.4 Value of Information Analysis

The results of the first Value of Information Analysis (VIA) indicated that additional measurements were justified in the areas shown in the table on the following page.

Expected Value of Perfect Information (EVPI) shows the maximum value of additional information even if that information were perfect. This gives us a good idea of an extreme upper bound for effort required for additional measurements. As a rule of thumb, 2% to 20% of the VIA of each variable could be spent in further measurements. Also, the cost and feasibility of additional information gathering are considered when identifying measurement priorities.

Summary of Results of Value of Information Analysis (VIA)			
First VIA:			
Variable Name	Expected Value of Perfect Information (EVPI)	Justified measurement effort	Measurement Approach
Probability of eliminating one OS in 3-year cycle	$509,734	2 weeks (all the time remaining in the project)	A survey of 3,600 HQ desktops was conducted to better estimate the age and OS of machines.
Probability of eliminating one OS in 4-year cycle	$1,918,088	2 weeks (all the time remaining in the project)	Same as above
Percent of productivity loss due to >4yr machine	$115,951	2 weeks (all the time remaining in the project)	A controlled experiment measuring boot up time for 9 desktops of varying ages and OSs on the same network was completed
All other variables	**Under $1,000**	No time justified	

4.5 Measurement Round

The measurements focused on three variables:

- ✓ Probability of eliminating one OS in 3-year cycle,
- ✓ Probability of eliminating one OS In 4-year cycle,
- ✓ Percent of productivity loss due to >4yr machine.

The probability of eliminating one operating system used by the Agency impacts desktop support costs associated with operating system maintenance and roll-out of new applications or new releases of existing applications. If one operating system is eliminated significant cost savings will result.

To reduce the level of uncertainty concerning these variables two measurement efforts were undertaken.

4.5.1 Desktop Survey

To obtain a better understanding of the age, particularly to identify those older than four years and those currently three years old, and their operating systems, Computer Sciences Corporation (CSC) completed a survey of 3,600 EPA headquarters desktop machines. This effort was directed at providing additional information concerning items 1 and 2 above.

Table 1 -EPA HQ Desktop OS Survey

Office	Win 95 >4 yrs (%)	Win 98 3-4 yrs (%)	Win 2000 <3 yrs (%)	Total Machines
OAR	32 10.0%	230 71.9%	58 18%	320
OA	4 0.5%	237 30.4%	539 69%	780
OGC	12 6.0%	131 65.5%	57 29%	200
OPP	223 22.3%	741 74.1%	36 4%	1,000
OCFO/PMO	6 3.0%	170 85.0%	24 12%	200
OECA	20 2.2%	750 83.3%	130 14%	900
OW/OWM	7 3.5%	110 55.0%	83 42%	200
TOTAL	**304** **8.4%**	**2,369** **65.8%**	**927** **25.8%**	**3,600**

The survey was completed over a two-week period by the CSC technical support personnel that provide technical support to each of these EPA offices. They completed the survey in part for this task, but also to prepare for new software rollout that requires different processes for different operating systems.

The survey showed that the age of EPA desktops was different than that originally estimated by the calibrated estimators, leading to changes in the model ranges. This information about the ages and operating systems of a large percentage of EPA desktops also provided us with an empirical basis for making the claim that at least 1 operating system would be eliminated by implementing either the three or four year replacement policy. Bill Beaver (CE) confirmed the change in probability of eliminating 1 operating system if a three year replacement schedule were implemented from 70% to 100%. He also confirmed the change of the probability of eliminating 1 operating system if a four year replacement schedule were implemented from 50% to 100%.

4.5.2 Performance Experiment

The second effort was a controlled experiment designed to isolate the productivity loss of desktops due to age from losses that might be due to the network. For this experiment CSC technical staff selected 9 machines from the same manufacturer and basic model of various ages and operating systems were identified on a single 10 MHz network in a single office (OECA - Ariel Rios Building). Machines of the same model from a single manufacturer were selected to eliminate variances due to different manufacturer's design.

All the machines had approximately the same application suite installed, and each had been optimized for startup. Each machine was taken through a "cold boot" process and the startup time measured. The results are shown in Table 2.

Table 2 – Desktop Cold Boot Times (Single Network) July 3, 2003

Dell Model	Mhz	Operating System	Boot Time (Sec)
GXa	233	Windows 95	240
GXi	166	Windows 95	250
GX1	350	Windows 95	220
GX1	450	Windows 98	120
GX110	733	Windows 98	110
GX150	866	Windows 2000	75
GX240	1.7Ghz	Windows XP	32
GX240	1.7Ghz	Windows 2000	70
GX260	2.2Ghz	Windows 2000	50

Even with the small sample of 9 machines we were able to reduce uncertainty significantly. The performance times for desktops with the same operating system were fairly consistent. Comparing those desktops that were Windows 95 to more recent models allowed for a reduction in the original estimated range for "Percent of productivity loss due to >4yr machine" from 15%-70% to 45%-67%.

4.6 Summary of Final Measurements

A final Value of Information Analysis was conducted after the model was updated with the latest measurements. No information values were significant enough to merit further analysis.

Since no further measurements are justified, the information currently available should be the basis of the risk return analysis and identification of any specific recommendations.

5. Risk/Return Analysis

Implementing a four Year Desktop Replacement Policy with "Catch-Up" in the first year has a highly favorable return over the current replacement rates. The key risk for the this option is the likelihood of eliminating more than 1 operating system.

5.1 Objective

The objective is to identify whether the ratio of expected return to the risk of loss is compatible with the EPA's investment criteria.

5.2 Approach

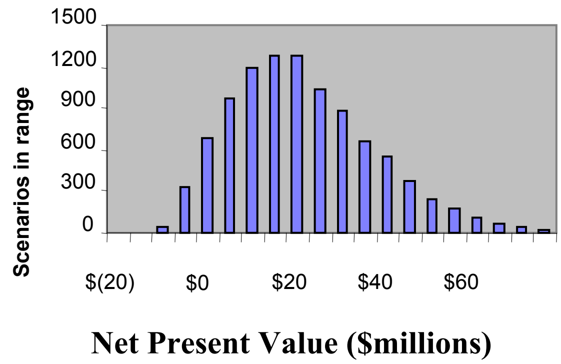
This approach is inspired from applied financial portfolio management methods. The tools used in this step are the Excel spreadsheet and an Excel macro for generating the "Monte Carlo" simulation. AIE compares the "Expected Return" (the probability-weighted average of all possible returns) against the probability that the return will be negative. Finally, the above results are used to plot the position the project's risk/return profile.

5.3 Distribution of Returns

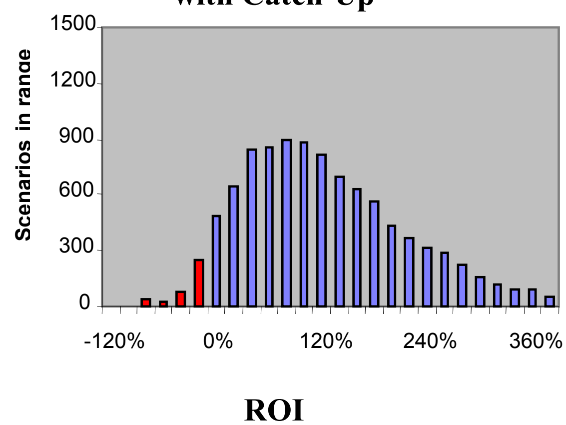
The Monte Carlo model ran 10,000 simulations on three different options to generate distributions of possible Net Present Value (NPV) and Return on Investment (ROI) values. The height of each bar shows the relative likelihood of different returns. The horizontal axis shows the possible range of returns generated in the simulations.

The value of establishing a four Year Desktop Replacement policy with a first year "catch-up" is very positive with an expected $18.9 NPV. This return is due to significant savings in operating system maintenance costs and added user productivity due to reduction in time spent "waiting" for the computer to boot and process daily transactions.

NPV Distribution for 10,000 Scenarios for a four Year Replacement Policy with Catch-Up



ROI Distribution for 10,000 Scenarios For a four Year Replacement Policy, with Catch-Up



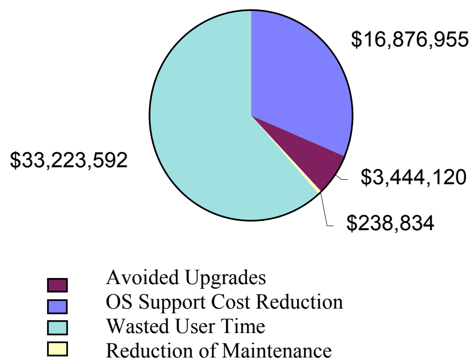
The second graph shows the distribution of ROI's for a four Year Replacement Policy with first year "catch-up. It considers only those additional costs and benefits unique to the proposed policy change and not the cost and benefits of simply continuing purchasing desktops on an approximately 5 year replacement schedule.

The average ROI of all the possibilities shown is 116%. There is also a 9% chance of a negative ROI with the proposed new policy. Most of this risk is due to the possibility that not all old machines are upgraded to allow additional operating systems to be eliminated.

5.4 Benefit Distribution

The sources of the $53.8M NPV benefits of the four Year Replacement Policy with "Catch-Up" over seven years are shown in the following pie chart.

4 Year Replacement Policy – with Catch-Up
Sources of $53.8 M Benefits



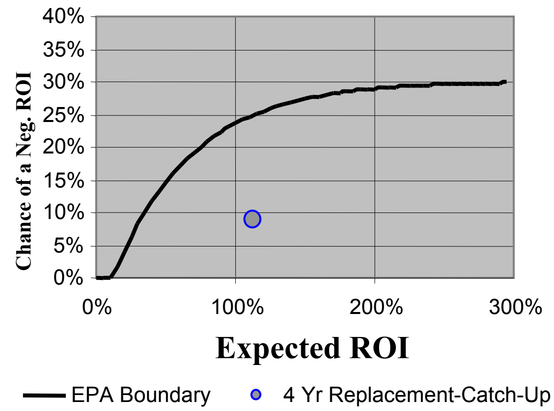
5.5 Risk/Return Position

The information from the ROI Distribution is used to plot the position of the investment in the "Risk/Return Plot" chart. In the Risk/Return Plot, the bold curve represents the required risk/return boundary for an investment the size of the four Year Desktop Replacement policy with first year "catch-up" investment.

The risk/return "boundary" was created in a meeting with Mark Day and Mark Luttner. They were asked how much risk they were willing to accept for various potential returns. Boundaries were identified for a $1,000,000, $10 million and a $100 million investment. The boundary shown is actually an interpolation of these boundaries appropriate for a four -year replacement policy with catch-up investment size of $18.7M. The dot represents where this investment plots relative to the risk boundary.

The "expected" ROI for the four -year Replacement Policy – with "Catch-Up" was computed by taking the average of 10,000 scenarios generated by a Monte Carlo simulation. There is a 9% chance that the policy will produce a negative ROI on the marginal investment alone. Therefore, while there are some manageable risks on parts of the investment, they are acceptable and the ROI on the investment is easily favorable.

Risk/Return Position for four Year Replacement Policy - with Catch-Up



The current 5 year replacement schedule and the proposed three and four year replacement policies are not shown on this plot. This boundary is considered unique for the Desktop Replacement policy investment and is not meant to be a general risk/return limit for EPA. This means that the boundary will be used only for evaluating this investment decision and will not be used as a standard for future projects.

6. Recommendations

Implement a four-year desktop replacement policy with "catch-up" in the first year to eliminate all machines older than four-years. Minimize the number of operating systems supported by upgrading remaining desktops to the new operating system.

6.1 Objectives

Summarize the results of the AIE assessment and provide clear recommendations to support the decision-making process.

6.2 Approach

The recommendations will be based on the results obtained during the previous steps. Careful attention is paid to the "residual VIA's" (high-impact uncertainty that could not feasibly be reduced prior to proposing the investment decision)

6.3 Recommendation

The recommendations result from the risk/return analysis and the value of information analysis:

6.3.1 Implement a four- year replacement schedule after catch-up

Establish a four year desktop replacement policy and "catch-up" in the first year to replace all machines older than four years. This replacement schedule will enhance the productivity of many thousands of EPA personnel, providing faster processing and reducing time waiting for machine repair. This policy can also be stated as "replace all desktops older than four years."

6.3.2 Upgrade some remaining machines to minimize number of operating systems

An additional operational recommendation is for remaining machines to be upgraded to the same operating system acquired with the catch-up. Whenever this completely eliminates an operating system major support cost savings will be achieved.

We recognize that new operating systems are introduced about once every one or two years and it will be impossible to eliminate all but one operating system. However, upgrading machines to the latest operating system whenever an opportunity of eliminating one is identified can minimize the support costs associated with multiple operating systems.

6.3.3 Reassess investment model each year

This investment decision applies only to the purchases for this year. Even though the costs and benefits of the business case are calculated for 7 years, EPA can reassess its position each year to incorporate changes in technology, major price changes, and availability of funding. The model data can be refreshed to reflect the new information and appropriate decisions should be made each year to reflect those realities.

6.3.4 Lease vs. Buy

A fixed lease vs. buy policy does not need to be part of the proposed policy. Lease and buy options will change significantly from one year to the next and can be evaluated on a year-by-year basis. On a present value basis, lease and buy options are nearly identical most of the time.

6.3.5 Eventually develop more sophisticated, individualized policy

The advantage of a uniform policy is that it simplifies what could be a large number of special decisions. The disadvantage of a uniform policy is that, sometimes, it can lead to irrational actions on an individual basis. We propose that the ongoing performance metrics eventually be used to allow for more individualized applications of a policy. Ideally, the policy would become a decision rule that tells the EPA whether a specific individual should have their PC replaced in a given year.

<u>Decision Rule</u>: If upgrading machines less than four years old to a new OS will eliminate an operating system to be supported complete the new OS installation.

6.4 Performance Metrics

One of the critical variables for this business case was the elimination of one or more operating systems. The costs of supporting many operating systems are large simply because of the number of machines managed and the complexity of the EPA IT infrastructure.

We recommend establishing certain on-going performance measurements to both document actual enhancements and to support future decision making.

- ✓ Assess time spent on waiting on PC boot-up or processing time. A periodic survey of a sample of 30-50 individuals for specific days could determine how much time they actually spend booting up, opening applications, or running other processor intensive tasks.
- ✓ Measure on-going OS support costs. Periodic surveys of support staff could determine how they share their time supporting problems related to different OS support tasks.
- ✓ Regular benchmarking of desktop performance for new purchases
- ✓ Develop a process to measure desktop maintenance costs (non-warranty).

Appendix 1: Auditor's Note

The Auditor has verified the cost/benefit analysis. The Auditor has also determined that estimator bias has no impact on the outcome of this analysis for the following reasons.

App. 1.1 Objectives

The Auditor's Note section is an objective review of the analysis of this investment. It is written by an objective observer who is qualified in AIE methods and it is meant to identify possible conflicts of interest in the analysis and to QA the results.

App. 1.2 Approach

The auditor is an objective observer of the AIE procedure who reports to the decision-makers of the investment. The auditor's role is to QA the analysis and to identify any possible lack of objectivity in the process (conflicts of interest, etc.). The ultimate tool of this auditor - as with any auditor - is disclosure. In the event that any shortcomings in the procedure were noted, it will be up to the Judge to interpret the effect on the desirability of the investment.

App. 1.3 Findings

- ✓ The RRA method itself was correctly applied during this analysis. After multiple audits, the auditor has determined that no modeling errors exist and the spreadsheet is a reasonable representation of the decision problem.
- ✓ The estimators for most of the benefits are also the champions of the investment. However, the estimates provided by the team are consistent with independently verifiable numbers and are consistent with previous models in the Hubbard Decision Research database. Therefore, a potentially over-optimistic bias does not seem to have affected this analysis.
- ✓ Not all estimators demonstrated an adequate level of calibration prior to providing estimates. An adjustment factor was applied to all calibrated estimates to adjust for some remaining "statistical overconfidence" that persisted after calibration training.

Summary of Assigned Roles

Role	Name, Company
Judge(s)	Mark Day, EPA
Auditor(s)	Doug Hubbard, Hubbard Decision Research
Sponsor/Promoter of the investment	Bill Beaver, EPA
Estimator(s)	Laurie Ford, EPA Kathy Barton, EPA Joanne Martin, EPA Wendy Bartel, EPA Lisa Hearns, EPA Paula Smith, EPA Louise Planet, EPA Bill Beaver, EPA Robert Lewis, EPA Hsiang Shyu, EPA Phil Paparodis, EPA Pam Shenefiel, EPA Art Koines, EPA
Facilitator(s)	Doug Hubbard, Hubbard Decision Research
Analyst(s)	Doug Hubbard, Hubbard Decision Research Wayne Savage, DynCorp

Appendix 2: Acronym Glossary

AIE	Applied Information Economics
CE	Calibrated Estimate
CSC	Computer Sciences Corporation
EPA	Environmental Protection Agency
EVPI	Expected Value of Perfect Information
FY	Fiscal Year
HQ	Headquarters
IT	Information Technology
LAN	Local Area Network
NPV	Net Present Value
OECA	Office of Enforcement and Compliance Assurance
OMB	Office of Management and Budget
OS	Operating System
PC	Personal Computer
ROI	Return on Investment
RRA	Risk Return Analysis
VIA	Value Of Information Analysis

	A	B	C	D	E	F
1		Lower	Formulas &	Upper	Dist.	Source
2	Variable Name	Bound	Best Estimate	Bound	Type*	References
3						
4	**Financial Assumptions**					
5	First year of cash flow (fiscal)		2004			
6	Horizon (last year of cash flow, fiscal)		2010			
7	Cost of capital		4.5%			OMB Circular A-11
8						
9						
10	**Desktop Refresh Background**					
11						
12	*Desktop Users*					
13	Current Population of EPA users	18,000.0	22,000.0	26,000.0	1	lower than ERDMS, CE WS
14	Average annual growth rate	-5%	-1%	3%	1	CE WS 5/22/03 Kevin CE
15	Number of EPA users by year					
16	2004		21,780			=C13*(1+C14)
17	2005		21,562			=C16*(1+C$14)
18	2006		21,347			=C17*(1+C$14)
19	2007		21,133			=C18*(1+C$14)
20	2008		20,922			=C19*(1+C$14)
21	2009		20,713			=C20*(1+C$14)
22	2010		20,505			=C21*(1+C$14)
23						
24	Desktops Retired by Year due to reduction of users					
25	2004		220			=MAX(C13-C16,0)
26	2005		218			=MAX(C16-C17,0)
27	2006		216			=MAX(C17-C18,0)
28	2007		213			=MAX(C18-C19,0)
29	2008		211			=MAX(C19-C20,0)
30	2009		209			=MAX(C20-C21,0)
31	2010		207			=MAX(C21-C22,0)
32						
33	*Current Population of Desktops*					
34	Share of Existing Std Desktop Ages - Standard Config		105%			=+SUM(C35:C39)
35	0-1 Year	10%	15%	20%	3	CE Bill Beaver given CSC sample of 3600 as benchmark
36	1-2 Years	10%	15%	20%	3	CE Bill Beaver given CSC sample of 3600 as benchmark
37	2-3 Years	10%	15%	20%	3	CE Bill Beaver given CSC sample of 3600 as benchmark
38	3-4 Years	30%	45%	60%	3	CE Bill Beaver given CSC sample of 3600 as benchmark
39	4 Years and over	10%	15%	20%	3	Upper bound CE WS 5/26; Lower Bound CSC sample of 3600 desktops
40						

* 1=Normal, 2=Lognormal, 3=Uniform, 4=Beta, 5=Binary

	A	B	C	D	E	F
1		Lower	Formulas &	Upper	Dist.	Source
2	Variable Name	Bound	Best Estimate	Bound	Type*	References
41	Adjusted Share of Std Desktop Ages - Standard Configuration					
42	0-1 Year		14%			=C35/C$34
43	1-2 Years		14%			=C36/C$34
44	2-3 Years		14%			=C37/C$34
45	3-4 Years		43%			=C38/C$34
46	4 Years and over		14%			=C39/C$34
47						
48	Number of Existing Std Desktop Ages - Standard Config					
49	0-1 Year		3,143			=+C42*C$13
50	1-2 Years		3,143			=+C43*C$13
51	2-3 Years		3,143			=+C44*C$13
52	3-4 Years		9,429			=+C45*C$13
53	Over 4 Years		3,143			=+C46*C$13
54						
55	***Desktop Purchase Schedule***					
56	Percent of Desktops Purchased each year	18%	20%	22%	1	CE JM 6/4
57	New desktop purchases under status quo by year					
58	2004		4,356			=+C$56*C16
59	2005		4,312			=+C$56*C17
60	2006		4,269			=+C$56*C18
61	2007		4,227			=+C$56*C19
62	2008		4,184			=+C$56*C20
63	2009		4,143			=+C$56*C21
64	2010		4,101			=+C$56*C22
65						
66	Desktops 3.0 years old by year					
67	2004		3,143			=C51
68	2005		3,143			=C50
69	2006		3,143			=C49
70	2007		4,356			=C58
71	2008		4,312			=C59
72	2009		4,269			=C60
73	2010		4,227			=C61
74						
75	Desktops 4.0 years old by year					
76	2004		7,995			=SUM(C52:C53)-C58-C25
77	2005		6,608			=C76+C67-C59-C26
78	2006		5,266			=C77+C68-C60-C27
79	2007		3,969			=C78+C69-C61-C28
80	2008		3,929			=C79+C70-C62-C29
81	2009		3,890			=C80+C71-C63-C30
82	2010		3,851			=C81+C72-C64-C31
83						

* 1=Normal, 2=Lognormal, 3=Uniform, 4=Beta, 5=Binary

	A	B	C	D	E	F
1		Lower	Formulas &	Upper	Dist.	Source
2	Variable Name	Bound	Best Estimate	Bound	Type*	References
84	Desktops >3 years old by year					
85	2004		11,138			=C67+C76
86	2005		9,751			=C68+C77
87	2006		8,409			=C69+C78
88	2007		8,325			=C70+C79
89	2008		8,241			=C71+C80
90	2009		8,159			=C72+C81
91	2010		8,077			=C73+C82
92						
93	***Warranty Distribution***					
106	***User Productivity***					
107	Performance losses due to machine > 4 yr in minutes per day	2	16	30	3	CE WS 5/29
108	Work days per year	230	245	260	3	CE ERDMS WS 5/28
109	Performance losses due to machine > 4 yr in hours per year		65			=C107/60*C108
110	Percent of actual loss due to desktop > 4 yr	45%	56%	67%	3	Based on sample of 9 machines of different ages on the same network
111						
112	Average user hourly salary (loaded)	$ 40	$ 60	$ 80	3	Benchmark ave salary = $91,100 with 1.2 multiplier - CE WS 5/29
113	Productivity Realization rate-EPA	0%	25%	50%	3	CE WS 5/29
114	Duration of average downtime - hours	0.25	3.00	6.00	3	CE JM 6/5
115	Productivity costs per user per year		$ 551			=(C$109*C$110+C$114*C$185)*(C$112*C$113)
116						
117	***Cost of Desktops***					
118	Current Desktop Unit Cost	$ 1,000	$ 1,300	$ 1,600	3	CE WS 5/29 BB adjusted for price of Standard Desktop definition currently priced at $1300
119	Desktop Purchase Costs by Year					
120	2004		$ 5,662,800			=C$118*C58
121	2005		$ 5,606,172			=C$118*C59
122	2006		$ 5,550,110			=C$118*C60
123	2007		$ 5,494,609			=C$118*C61
124	2008		$ 5,439,663			=C$118*C62
125	2009		$ 5,385,266			=C$118*C63
126	2010		$ 5,331,414			=C$118*C64
127						
128	***Machines Upgraded***					
129	Required annual upgrade cost for machines >3 yrs to meet tech requirements	$ 100	$ 150	$ 200	1	CE WS 5/29
130	Performance improvement due to upgrade compared to new machine	20%	30%	40%	1	CE WS 5/29
131						
132	Events requiring upgrade of 4 year old machines					

* 1=Normal, 2=Lognormal, 3=Uniform, 4=Beta, 5=Binary

	A	B	C	D	E	F
1		Lower	Formulas &	Upper	Dist.	Source
2	Variable Name	Bound	Best Estimate	Bound	Type*	References
133	2004		75%		5	CE WS 5/29
134	2005		75%		5	CE WS 5/29
135	2006		75%		5	CE WS 5/29
136	2007		75%		5	CE WS 5/29
137	2008		75%		5	CE WS 5/29
138	2009		75%		5	CE WS 5/29
139	2010		75%		5	CE WS 5/29
140						
141	Events requiring upgrade of 3 year old machines if 4 yr old machines are upgraded					Conditional probability given that 4 yr old machines are upgraded computed from independent probability of 45% per year of upgrading 3 yr old machines from CE WS 5/29
142	2004		60%		5	see note above
143	2005		60%		5	see note above
144	2006		60%		5	see note above
145	2007		60%		5	see note above
146	2008		60%		5	see note above
147	2009		60%		5	see note above
148	2010		60%		5	see note above
149						
150	Events requiring upgrade of 3 year old machines if 4 yr old machines are upgraded					
151	2004		45%			=C142*C133
152	2005		45%			=C143*C134
153	2006		45%			=C144*C135
154	2007		45%			=C145*C136
155	2008		45%			=C146*C137
156	2009		45%			=C147*C138
157	2010		45%			=C148*C139
158						
159	Cost of upgrading Machines > 3 yrs per year					
160	2004		$ 1,111,629			=(C151*C67+C133*C76)*C$129
161	2005		$ 955,548			=(C152*C68+C134*C77)*C$129
162	2006		$ 804,564			=(C153*C69+C135*C78)*C$129
163	2007		$ 740,513			=(C154*C70+C136*C79)*C$129
164	2008		$ 733,107			=(C155*C71+C137*C80)*C$129
165	2009		$ 725,776			=(C156*C72+C138*C81)*C$129
166	2010		$ 718,519			=(C157*C73+C139*C82)*C$129
167						
168	Cost of upgrading Machines > 4 yrs per year					
169	2004		$ 899,486			=C133*C76*C$129
170	2005		$ 743,405			=C134*C77*C$129
171	2006		$ 592,421			=C135*C78*C$129
172	2007		$ 446,483			=C136*C79*C$129
173	2008		$ 442,018			=C137*C80*C$129
174	2009		$ 437,598			=C138*C81*C$129

* 1=Normal, 2=Lognormal, 3=Uniform, 4=Beta, 5=Binary

	A	B	C	D	E	F
1		Lower	Formulas &	Upper	Dist.	Source
2	Variable Name	Bound	Best Estimate	Bound	Type*	References
175	2010		$ 433,222			=C139*C82*C$129
176						
177						
178						
179						
180	***Desktop > 3 yrs Maintenance Costs***					
181	**Parts**	$ 20	$ 85	$ 150	3	CE WS 5/29
182	**Average labor rate for technicians**	$ 60	$ 65	$ 70	1	CE JM 6/4-Revised 6/5
183	**Labor - Purchase and install parts/software - min**	10	15	20	1	CE WS 5/29
184	**Cost of labor per machine**		$ 16.25			=C183/60*C182
185	**Probability of failure of machines out of warrantee**	1%	5.5%	10%	3	CE WS 5/29
186	**Current Desktop Maintenance/Service Annual Costs/Per Machine > 3 yrs old No longer under warrantee**		$ 5.57			=+(C181+C184)*(C185)
187						
188	**Desktop Maintenance/Service Costs by year**					
189	2004		60,706			=C$186*C99
190	2005		53,057			=C$186*C100
191	2006		45,658			=C$186*C101
192	2007		44,924			=C$186*C102
193	2008		44,475			=C$186*C103
194	2009		44,030			=C$186*C104
195	2010		43,590			=C$186*C105
196						
197	***Support of Multiple OSs***					
198	**Probability of reducing 1 OS by replacing machines in a 3 yr cycle**		100%		5	CE - WS 5/29/03
199	**Probability of reducing 1 OS by replacing machines in a 4 year cycle**		100%		5	Research - Effort to support OS's, cost reduction due to eliminating number of OSs (Al-Bill Beaver-Wayne) MS-Windows Desktop Operating Systems Illustrated History (6/8/03) - Average introduction rate of .923 new Windows OSs per year.
200	**Support FTE**	369.00	419	484.00	3	CE Bill B. 6/6/03 benchnmarked on Agency Standard 1 FTE/52 machines
201	**Support FTE dealing with old OS Issues**	2%	6%	10%	3	CE JM 6/4/03
202	**Cost for support of a old OS**		3,202,836			=C201*C200*C182*8*C108
203	**Productivity Realization rate-Contractors**	50%	75%	100%	3	CE - WS 5/29/03
204						
205	***TOTAL Desktop COSTS by year***					
206	2004		$ 6,835,135			=C189+C160+C120
207	2005		$ 6,614,777			=C190+C161+C121
208	2006		$ 6,400,333			=C191+C162+C122
209	2007		$ 6,280,046			=C192+C163+C123

* 1=Normal, 2=Lognormal, 3=Uniform, 4=Beta, 5=Binary

	A	B	C	D	E	F
1		Lower	Formulas &	Upper	Dist.	Source
2	Variable Name	Bound	Best Estimate	Bound	Type*	References
210	2008		$ 6,217,246			=C193+C164+C124
211	2009		$ 6,155,073			=C194+C165+C125
212	2010		$ 6,093,523			=C195+C166+C126
213						
214	**Option 1: 3 Year Replacement**					
215						
216	***Implementation***					
217	Desktops					
218	Percentage of Desktops purchased per year		33%			Three year replacement policy, regardless of PC age
219	Std. Desktop Purchases by year					
220	2004		7,253			=+C$218*C16
221	2005		7,180			=+C$218*C17
222	2006		7,108			=+C$218*C18
223	2007		7,037			=+C$218*C19
224	2008		6,967			=+C$218*C20
225	2009		6,897			=+C$218*C21
226	2010		6,828			=+C$218*C22
227						
228	Desktops 4.0+ years old by year					
229	2004		5,099			=C52+C53-C25-C220
230	2005		841			=MAX(C229+C238-C221-C25,0)
231	2006		-			=MAX(C230+C239-C222-C26,0)
232	2007		-			=MAX(C231+C240-C223-C27,0)
233	2008		-			=MAX(C232+C241-C224-C28,0)
234	2009		-			=MAX(C233+C242-C225-C29,0)
235	2010		-			=MAX(C234+C243-C226-C30,0)
236						.
237	Desktops 3.0-4.0 years old by year					
238	2004		3,143			=C51
239	2005		-			=IF(C238+C229-C221-C27<0,C49+C238+C229-C221-C27,0)
240	2006		-			=IF(C239+C230-C222-C28<0,0,C48+C239+C230-C222-C28)
241	2007		-			=IF(C240+C231-C223-C29<0,0,C49+C240+C231-C223-C29)
242	2008		-			=IF(C241+C232-C224-C30<0,0,C220+C241+C232-C224-C30)
243	2009		-			=IF(C242+C233-C225-C31<0,0,C221+C242+C233-C225-C31)
244	2010		-			=IF(C243+C234-C226-C32<0,0,C222+C243+C234-C226-C32)
245						
246	Desktops >3 years old by year					
247	2004		8,242			=C238+C229
248	2005		841			=C239+C230
249	2006		-			=C240+C231
250	2007		-			=C241+C232
251	2008		-			=C242+C233

* 1=Normal, 2=Lognormal, 3=Uniform, 4=Beta, 5=Binary

	A	B	C	D	E	F
1		Lower	Formulas &	Upper	Dist.	Source
2	Variable Name	Bound	Best Estimate	Bound	Type*	References
252	2009		-			=C243+C234
253	2010		-			=C244+C235
254						
255						
256	**Desktops Not on Warranty**					
257	2004		8,033			=C238*(1-C$95)+C229*(1-C$96)
258	2005		833			=C239*(1-C$95)+C230*(1-C$96)
259	2006		-			=C240*(1-C$95)+C231*(1-C$96)
260	2007		-			=C241*(1-C$95)+C232*(1-C$96)
261	2008		-			=C242*(1-C$95)+C233*(1-C$96)
262	2009		-			=C243*(1-C$95)+C234*(1-C$96)
263	2010		-			=C244*(1-C$95)+C235*(1-C$96)
264						
265	***Benefits***					
266						
267	**Enhanced productivity**					
268	Avoided waste of user time by replacing computers >3 yrs by year (for both faster processing and elimination of waiting time while computer is being fixed)					
269	2004		$ 1,596,900			=C$115*(C85-C247)
270	2005		$ 4,911,623			=C$115*(C86-C248)
271	2006		$ 4,635,574			=C$115*(C87-C249)
272	2007		$ 4,589,218			=C$115*(C88-C250)
273	2008		$ 4,543,326			=C$115*(C89-C251)
274	2009		$ 4,497,892			=C$115*(C90-C252)
275	2010		$ 4,452,913			=C$115*(C91-C253)
276						
277	**Avoided Machine Upgrade Cost per year**					
278	2004		$ 325,883			=C160-(C151*C238+C133*C229)*C$129
279	2005		$ 860,898			=C161-(C152*C239+C134*C230)*C$129
280	2006		$ 804,564			=C162-(C153*C240+C135*C231)*C$129
281	2007		$ 740,513			=C163-(C154*C241+C136*C232)*C$129
282	2008		$ 733,107			=C164-(C155*C242+C137*C233)*C$129
283	2009		$ 725,776			=C165-(C156*C243+C138*C234)*C$129
284	2010		$ 718,519			=C166-(C157*C244+C139*C235)*C$129
285						
286	**Desktop Maintenance Cost Savings by Year**					
287	2004		$ 15,970			=(C99-C257)*C$186
288	2005		$ 48,419			=(C100-C258)*C$186
289	2006		$ 45,658			=(C101-C259)*C$186
290	2007		$ 44,924			=(C102-C260)*C$186
291	2008		$ 44,475			=(C103-C261)*C$186
292	2009		$ 44,030			=(C104-C262)*C$186
293	2010		$ 43,590			=(C105-C263)*C$186

* 1=Normal, 2=Lognormal, 3=Uniform, 4=Beta, 5=Binary

	A	B	C	D	E	F
1		Lower	Formulas &	Upper	Dist.	Source
2	Variable Name	Bound	Best Estimate	Bound	Type*	References
294						
295	Streamlining number of different OS					
296	Avoided OS Maintenance Cost by year					
297	2004		$ -			=IF(C238+C229=0,C$202*C$198*C$203,0)
298	2005		$ -			=IF(C239+C230=0,C$202*C$198*C$203,0)
299	2006		$ 2,402,127			=IF(C240+C231=0,C$202*C$198*C$203,0)
300	2007		$ 2,402,127			=IF(C241+C232=0,C$202*C$198*C$203,0)
301	2008		$ 2,402,127			=IF(C242+C233=0,C$202*C$198*C$203,0)
302	2009		$ 2,402,127			=IF(C243+C234=0,C$202*C$198*C$203,0)
303	2010		$ 2,402,127			=IF(C244+C235=0,C$202*C$198*C$203,0)
304						
305	***Total Option 1 Benefits***					
306	2004		$ 1,938,754			=C297+C287+C278+C269
307	2005		$ 5,820,940			=C298+C288+C279+C270
308	2006		$ 7,887,923			=C299+C289+C280+C271
309	2007		$ 7,776,782			=C300+C290+C281+C272
310	2008		$ 7,723,035			=C301+C291+C282+C273
311	2009		$ 7,669,826			=C302+C292+C283+C274
312	2010		$ 7,617,149			=C303+C293+C284+C275
313						
314	***Costs***					
315	Additional (Over current) Desktop Purchase Costs by year					
316	2004		$ 3,765,762			=(C220-C58)*C$118
317	2005		$ 3,728,104			=(C221-C59)*C$118
318	2006		$ 3,690,823			=(C222-C60)*C$118
319	2007		$ 3,653,915			=(C223-C61)*C$118
320	2008		$ 3,617,376			=(C224-C62)*C$118
321	2009		$ 3,581,202			=(C225-C63)*C$118
322	2010		$ 3,545,390			=(C226-C64)*C$118
323						
324	***TOTAL OPTION 1 COSTS***					
325	2004		$ 3,765,762			=C316
326	2005		$ 3,728,104			=C317
327	2006		$ 3,690,823			=C318
328	2007		$ 3,653,915			=C319
329	2008		$ 3,617,376			=C320
330	2009		$ 3,581,202			=C321
331	2010		$ 3,545,390			=C322
332						
333	**Summary Option 1 Cash Flow**					
334						
335	2004		$ (3,765,762)			=+C305-C325
336	2005		$ (1,789,351)			=+C306-C326
337	2006		$ 2,130,117			=+C307-C327

* 1=Normal, 2=Lognormal, 3=Uniform, 4=Beta, 5=Binary

	A	B	C	D	E	F
1		Lower	Formulas &	Upper	Dist.	Source
2	Variable Name	Bound	Best Estimate	Bound	Type*	References
338	2007		$ 4,234,008			=+C308-C328
339	2008		$ 4,159,406			=+C309-C329
340	2009		$ 4,141,833			=+C310-C330
341	2010		$ 4,124,436			=+C311-C331
342						
343	**<u>Option 2: 4 Year Replacement</u>**					
344						
345	***Implementation***					
346	Desktops					
347	Percentage of Desktops purchased per year		25%			Four year replacement policy, regardless of PC age
348	Std. Desktop Purchases by year					
349	2004		5,445			=+C$347*C16
350	2005		5,391			=+C$347*C17
351	2006		5,337			=+C$347*C18
352	2007		5,283			=+C$347*C19
353	2008		5,230			=+C$347*C20
354	2009		5,178			=+C$347*C21
355	2010		5,126			=+C$347*C22
356						
357	Desktops 4.0+ years old by year					
358	2004		6,906			=C52+C53-C25-C349
359	2005		4,441			=SUM(C51:C$53)-SUM(C$349:C350)-SUM(C$25:C26)
360	2006		2,032			=SUM(C50:C$53)-SUM(C$349:C351)-SUM(C$25:C27)
361	2007		-			=IF(SUM(C49:C53)-SUM(C25:C28)-SUM(C349:C352)>0,SUM(C49:C53)-SUM(C25:C28)-SUM(C349:C352),0)
362	2008		-			=IF(SUM(C50:C54)-SUM(C26:C29)-SUM(C350:C353)>0,SUM(C50:C54)-SUM(C26:C29)-SUM(C350:C353),0)
363	2009		-			=IF(SUM(C51:C55)-SUM(C27:C30)-SUM(C351:C354)>0,SUM(C51:C55)-SUM(C27:C30)-SUM(C351:C354),0)
364	2010		-			=IF(SUM(C52:C56)-SUM(C28:C31)-SUM(C352:C355)>0,SUM(C52:C56)-SUM(C28:C31)-SUM(C352:C355),0)
365						.
366	Desktops 3.0-4.0 years old by year					
367	2004		3,143			=C51
368	2005		3,143			=C50
369	2006		3,143			=C49
370	2007		5,123			=C349-(SUM(C349:C352)-C19)
371	2008		5,071			=C350-(SUM(C350:C353)-C20)
372	2009		5,021			=C351-(SUM(C351:C354)-C21)
373	2010		4,970			=C352-(SUM(C352:C355)-C22)
374						

* 1=Normal, 2=Lognormal, 3=Uniform, 4=Beta, 5=Binary

	A	B	C	D	E	F
1		Lower	Formulas &	Upper	Dist.	Source
2	Variable Name	Bound	Best Estimate	Bound	Type*	References
375	Desktops >3 years old by year					
376	2004		10,049			=C367+C358
377	2005		7,584			=C368+C359
378	2006		5,174			=C369+C360
379	2007		5,123			=C370+C361
380	2008		5,071			=C371+C362
381	2009		5,021			=C372+C363
382	2010		4,970			=C373+C364
383						
384						
385	Desktops Not on Warranty					
386	2004		9,823			=C367*(1-C$95)+C358*(1-C$96)
387	2005		7,382			=C368*(1-C$95)+C359*(1-C$96)
388	2006		4,997			=C369*(1-C$95)+C360*(1-C$96)
389	2007		4,867			=C370*(1-C$95)+C361*(1-C$96)
390	2008		4,818			=C371*(1-C$95)+C362*(1-C$96)
391	2009		4,770			=C372*(1-C$95)+C363*(1-C$96)
392	2010		4,722			=C373*(1-C$95)+C364*(1-C$96)
393						
394	***Benefits***					
395						
396	Enhanced productivity					
397	Avoided waste of user time by replacing computers >4 yrs by year (for both faster processing and elimination of waiting time while computer is being fixed)					
398	2004		$ 600,338			=C$115*(C76-C358)
399	2005		$ 1,194,674			=C$115*(C77-C359)
400	2006		$ 1,783,065			=C$115*(C78-C360)
401	2007		$ 2,187,864			=C$115*(C79-C361)
402	2008		$ 2,165,985			=C$115*(C80-C362)
403	2009		$ 2,144,325			=C$115*(C81-C363)
404	2010		$ 2,122,882			=C$115*(C82-C364)
405						
406	Avoided Machine Upgrade Cost per year					
407	2004		$ 122,513			=C160-(C151*C367+C133*C358)*C$129
408	2005		$ 243,800			=C161-(C152*C368+C134*C359)*C$129
409	2006		$ 363,874			=C162-(C153*C369+C135*C360)*C$129
410	2007		$ 394,734			=C163-(C154*C370+C136*C361)*C$129
411	2008		$ 390,787			=C164-(C155*C371+C137*C362)*C$129
412	2009		$ 386,879			=C165-(C156*C372+C138*C363)*C$129
413	2010		$ 383,010			=C166-(C157*C373+C139*C364)*C$129
414						
415	Desktop Maintenance Cost Savings by Year					
416	2004		$ 6,004			=(C99-C386)*C$186

	A	B	C	D	E	F
1		Lower	Formulas &	Upper	Dist.	Source
2	Variable Name	Bound	Best Estimate	Bound	Type*	References
417	2005		$ 11,947			=(C100-C387)*C$186
418	2006		$ 17,832			=(C101-C388)*C$186
419	2007		$ 17,824			=(C102-C389)*C$186
420	2008		$ 17,646			=(C103-C390)*C$186
421	2009		$ 17,469			=(C104-C391)*C$186
422	2010		$ 17,295			=(C105-C392)*C$186
423						
424						
425	Streamlining number of different OS					
426	Avoided OS Maintenance Cost by year					
427	2004		$ -			=IF(C358=0,C$202*C$199*C$203,0)
428	2005		$ -			=IF(C359=0,C$202*C$199*C$203,0)
429	2006		$ -			=IF(C360=0,C$202*C$199*C$203,0)
430	2007		$ 2,402,127			=IF(C361=0,C$202*C$199*C$203,0)
431	2008		$ 2,402,127			=IF(C362=0,C$202*C$199*C$203,0)
432	2009		$ 2,402,127			=IF(C363=0,C$202*C$199*C$203,0)
433	2010		$ 2,402,127			=IF(C364=0,C$202*C$199*C$203,0)
434						
435	***Total Option 2 Benefits***					
436	2004		$ 728,855			=C427+C416+C407+C398
437	2005		$ 1,450,421			=C428+C417+C408+C399
438	2006		$ 2,164,771			=C429+C418+C409+C400
439	2007		$ 5,002,549			=C430+C419+C410+C401
440	2008		$ 4,976,545			=C431+C420+C411+C402
441	2009		$ 4,950,801			=C432+C421+C412+C403
442	2010		$ 4,925,314			=C433+C422+C413+C404
443						
444	***Costs***					
445	Additional (Over current) Desktop Purchase Costs by year					
446	2004		$ 1,415,700			=(C349-C58)*C$118
447	2005		$ 1,401,543			=(C350-C59)*C$118
448	2006		$ 1,387,528			=(C351-C60)*C$118
449	2007		$ 1,373,652			=(C352-C61)*C$118
450	2008		$ 1,359,916			=(C353-C62)*C$118
451	2009		$ 1,346,317			=(C354-C63)*C$118
452	2010		$ 1,332,853			=(C355-C64)*C$118
453						
454	***TOTAL OPTION 2 COSTS***					
455	2004		$ 1,415,700			=C446
456	2005		$ 1,401,543			=C447
457	2006		$ 1,387,528			=C448
458	2007		$ 1,373,652			=C449
459	2008		$ 1,359,916			=C450
460	2009		$ 1,346,317			=C451

* 1=Normal, 2=Lognormal, 3=Uniform, 4=Beta, 5=Binary

	A	B	C	D	E	F
1		Lower	Formulas &	Upper	Dist.	Source
2	Variable Name	Bound	Best Estimate	Bound	Type*	References
461	2010		$ 1,332,853			=C452
462						
463	**Summary Option 2 Cash Flow**					
464						
465	2004		$ (1,415,700)			=+C435-C455
466	2005		$ (672,688)			=+C436-C456
467	2006		$ 62,893			=+C437-C457
468	2007		$ 791,119			=+C438-C458
469	2008		$ 3,642,634			=+C439-C459
470	2009		$ 3,630,229			=+C440-C460
471	2010		$ 3,617,948			=+C441-C461
472						
473	**Option 3: 4 Year Leased Replacement with "Catch-Up"**					
474						
475	***Implementation***					
476	Desktops					
477	Long term replacement schedule (after initial catch up) Std. Desktop Replacements by year		25%			Replace all desktops 4+ years and older the first year, then instituting a 25% replacement policy. This option is only the marginal difference between the Status Quo and the 25% replacement schedule.
478						
479	2004		12,571			=C52+C53
480	2005		5,391			=C17*C$477
481	2006		5,337			=C18*C$477
482	2007		5,283			=C19*C$477
483	2008		5,230			=C20*C$477
484	2009		5,178			=C21*C$477
485	2010		5,126			=C22*C$477
486						
487						
488	Desktops Acquired in addition to Status Quo					
489	2004		7,995			=C479-C58-C25
490	2005		1,078			=C480-C59
491	2006		1,067			=C481-C60
492	2007		1,057			=C482-C61
493	2008		1,046			=C483-C62
494	2009		1,036			=C484-C63
495	2010		1,025			=C485-C64
496						
497	***Benefits***					
498						
499	Enhanced productivity					

* 1=Normal, 2=Lognormal, 3=Uniform, 4=Beta, 5=Binary

	A	B	C	D	E	F
1		Lower	Formulas &	Upper	Dist.	Source
2	Variable Name	Bound	Best Estimate	Bound	Type*	References
500	Avoided waste of user time by replacing computers >4 yrs by year (for both faster processing and elimination of waiting time while computer is being fixed)					
501	2004		$ 4,407,680			=C$115*C76
502	2005		$ 3,642,850			=C$115*C77
503	2006		$ 2,902,995			=C$115*C78
504	2007		$ 2,187,864			=C$115*C79
505	2008		$ 2,165,985			=C$115*C80
506	2009		$ 2,144,325			=C$115*C81
507	2010		$ 2,122,882			=C$115*C82
508						
509	Avoided Machine Upgrade Cost per year					
510	2004		$ 899,486			=C169
511	2005		$ 743,405			=C170
512	2006		$ 592,421			=C171
513	2007		$ 446,483			=C172
514	2008		$ 442,018			=C173
515	2009		$ 437,598			=C174
516	2010		$ 433,222			=C175
517						
518	Desktop Maintenance Cost Savings by Year					
519	2004		$ 15,970			=C287
520	2005		$ 48,419			=C288
521	2006		$ 45,658			=C289
522	2007		$ 44,924			=C290
523	2008		$ 44,475			=C291
524	2009		$ 44,030			=C292
525	2010		$ 43,590			=C293
526						
527						
528	Streamlining number of different OS					
529	Number of OS elliminated	2	2.5	3	3	CE Hubbard and Savage based on OS distribution in EPA, monte carlo takes integer value so actual range is 3 to 5, further refined by discussion with Louise Planet to 2 to 4
530						7/25 - Louise Planet - Region 9 - minimum of 3 OS
531	Additional savings per OS elliminated over initial OS	50%	65%	80%	3	CE Bill Beaver 6/26/03
532	Marginal savings per OS elliminated compared to first OS ellimination					
533	1		100%			
534	2		65%			=C$531^1
535	3		42%			=C$531^2
536	4		27%			=C$531^3
537	5		18%			=C$531^4

* 1=Normal, 2=Lognormal, 3=Uniform, 4=Beta, 5=Binary

	A	B	C	D	E	F
1		Lower	Formulas &	Upper	Dist.	Source
2	Variable Name	Bound	Best Estimate	Bound	Type*	References
538				0.5		
539	Cumulative savings per OS elliminated					
540	1		6%			=SUM(C$533:C533)*C$201
541	2		10%			=SUM(C$533:C534)*C$201
542	3		12%			=SUM(C$533:C535)*C$201
543	4		14%			=SUM(C$533:C536)*C$201
544	5		15%			=SUM(C$533:C537)*C$201
545						
546	Percent reduction in support costs		12%			=CHOOSE(INT(C529+0.5),C540,C541,C542,C543,C544)
547	Total support cost reduction		$ 4,978,408			=C546*C200*C182*8*C108*C203
548						
549	***Total Option 3 Benefits***					
550	2004		$ 10,301,544			=C$547+C519+C510+C501
551	2005		$ 9,413,083			=C$547+C520+C511+C502
552	2006		$ 8,519,483			=C$547+C521+C512+C503
553	2007		$ 7,657,679			=C$547+C522+C513+C504
554	2008		$ 7,630,887			=C$547+C523+C514+C505
555	2009		$ 7,604,362			=C$547+C524+C515+C506
556	2010		$ 7,578,102			=C$547+C525+C516+C507
557			$ 4,978,408			=C$547+C526+C517+C508
558	***Costs***					
559	Upgrade existing desktops to Windows XP per desktop	$ 120	$ 150	$ 180	1	CE Hubbard 7/1/03 benchmark is $180 per desktop license retail, probably lower for EPA
560	Labor cost per desktop upgrade to XP	$ 65	$ 80	$ 95	1	CE Hubbard 7/1/03 with $80 per desktop benchmark from previous XP ungrade study
561	Number of desktops requiring XP and memory upgrade		3,143			=C67
562	Number of desktops requiring XP upgrade only		6,286			=C49+C50
563	Probability of upgrading machines to eliminate OS	0.4	0.6	0.8	1	CE Louise Planet 7/27
564	Cost of upgrading existing desktops		$ 1,584,000			=((C561+C562)*(C559+C560)+(C129*C561))*C563
565						
566	Annual lease cost per machine		$ 394.70			
567	Additional (Over current) Desktop Purchase Costs by year					
568	2004		$ 3,155,796			=C$566*C489
569	2005		$ 3,581,326			=C566*(C490+C489)
570	2006		$ 4,002,600			=C$566*(C491+C490+C489)
571	2007		$ 6,083,697			=C$566*(C492+C482+C490+C489)
572	2008		$ 1,676,758			=C$566*(C493+C492+C491+C490)
573	2009		$ 1,659,990			=C$566*(C494+C493+C492+C491)
574	2010		$ 1,643,391			=C$566*(C495+C494+C493+C492)
575						
576						
577	***TOTAL OPTION 3 COSTS***					

* 1=Normal, 2=Lognormal, 3=Uniform, 4=Beta, 5=Binary

	A	B	C	D	E	F
1		Lower	Formulas &	Upper	Dist.	Source
2	Variable Name	Bound	Best Estimate	Bound	Type*	References
578	2004		$ 4,739,796			=C568+C$564
579	2005		$ 3,581,326			=C569
580	2006		$ 4,002,600			=C570
581	2007		$ 6,083,697			=C571
582	2008		$ 1,676,758			=C572
583	2009		$ 1,659,990			=C573
584	2010		$ 1,643,391			=C574
585						
586	**Summary Option 3 Cash Flow**					
587						
588	2004		$ (4,739,796)			=+C549-C578
589	2005		$ 6,720,218			=+C550-C579
590	2006		$ 5,410,482			=+C551-C580
591	2007		$ 2,435,785			=+C552-C581
592	2008		$ 5,980,921			=+C553-C582
593	2009		$ 5,970,896			=+C554-C583
594	2010		$ 5,960,971			=+C555-C584
595						
596	**Summary Cash flow**					
597	Option		2			
598	2004		$ (1,415,700)			=CHOOSE(C$597,C335,C465,C588)
599	2005		$ (672,688)			=CHOOSE(C$597,C336,C466,C589)
600	2006		$ 62,893			=CHOOSE(C$597,C337,C467,C590)
601	2007		$ 791,119			=CHOOSE(C$597,C338,C468,C591)
602	2008		$ 3,642,634			=CHOOSE(C$597,C339,C469,C592)
603	2009		$ 3,630,229			=CHOOSE(C$597,C340,C470,C593)
604	2010		$ 3,617,948			=CHOOSE(C$597,C341,C471,C594)
605						
606	**Financial Results**					
607	Net Present Value		$ 7,117,021			=NPV(C7,C598:C604)
608	IRR Guess		462%			=SUM(C598:C604)/-SUMIF(C598:C604,"<0")
609	Return On Investment		48%			=IRR(C598:C604,C608)
610	Filtered IRR		48%			=IF(ISERR(C609),C608,C609)
611						

* 1=Normal, 2=Lognormal, 3=Uniform, 4=Beta, 5=Binary