OptFolio™
Project Portfolio Optimization Software
For Capital Budgeting and Finance

On January 1, 2003 OptTek Systems, Inc. won a Phase I Small Business Innovative Research (SBIR) grant* from the National Science Foundation (NSF). Considered by many to be one of the most prestigious United States Federal Government awards to a small business, SBIR's have had a profound impact on the growth and prosperity of a vital sector of the US economy since their inception over twenty years ago.

This SBIR is being used to support OptTek's development of OptFolio, new software to significantly enhance capital budgeting and finance decisions. By the end of June 2003, OptTek developed a pilot system to demonstrate the unique approach that underlies the software.

The approach is based on a new paradigm that OptTek expects will be intuitively appealing to senior executives. It incorporates risk and uncertainty directly into the representation of the decision-making process. It enables a virtually infinite number of what-if questions to be asked and their answers sorted and prioritized with accuracy and speed. By incorporating the software into their capital budgeting and finance procedures, executives can expect to realize greater returns and gain superior confidence in managing risk.

To obtain more details, please send us an email with a suggested time to contact you.

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* Since 1982, the Small Business Innovation Research (SBIR) Program has directed over 30,000 awards worth several billion dollars in R&D support to thousands of qualified small high-tech companies on a competitive basis. To obtain funding, a company applies for a Phase I SBIR grant. The proposed project must meet an agency's research need and have commercial potential. If approved, grants of up to $100,000 are made to allow the scientific and technical merit and feasibility of an idea to be evaluated. If the concept shows potential, the company can receive a Phase II grant of up to $750,000 to develop the idea further. In Phase III, the innovation must be brought to market with private sector investment and support.

Project Brief

This Small Business Innovation Research Phase I project supported the design of an algorithmic approach and the development of pilot software for optimizing the returns and associated risks of project portfolios to significantly improve the performance of capital finance and budgeting.

This project achieved the following objectives:

- Design an algorithmic approach for intelligently achieving significantly improved solutions (near-optimal) for project portfolios in industries such as oil and gas, pharmaceuticals, bioengineering, heavy manufacturing, etc.
- Develop pilot software that incorporates this approach when integrated with simulation.
- Establish key performance indicators to test the software.
- Establish and confirm a value proposition to assess satisfaction of customer requirements.
- Collect examples of real company data to populate the software trials.
- Identify additional benefits revealed during implementation of research plan.
- Determine additional business plan and technical elements required for commercialization.

OptTek's new approach, called the LEVER method, which we proposed to implement and test by the creation of commercial grade pilot software, provides a way to generate a model representation that is far more exploitable than those produced by past efforts. Coupled with other software that we specialize for this model type, the results will provide a major advance in the ability to solve problems of project portfolio management effectively.

The commercial applications anticipated for the ultimate software system are to enhance the performance of capital budgeting and project portfolio management. Those staff members and executives in commercial organizations responsible for analyzing, recommending, and making capital investments are the intended customers for the proposed technology. Current methods have been in place for many years and have not shown significant improvement in generating acceptable returns for some time. While recognition of the limitations of current approaches is universal, none of the alternatives to these approaches has proved attractive enough to become widely embraced as a viable method of choice.

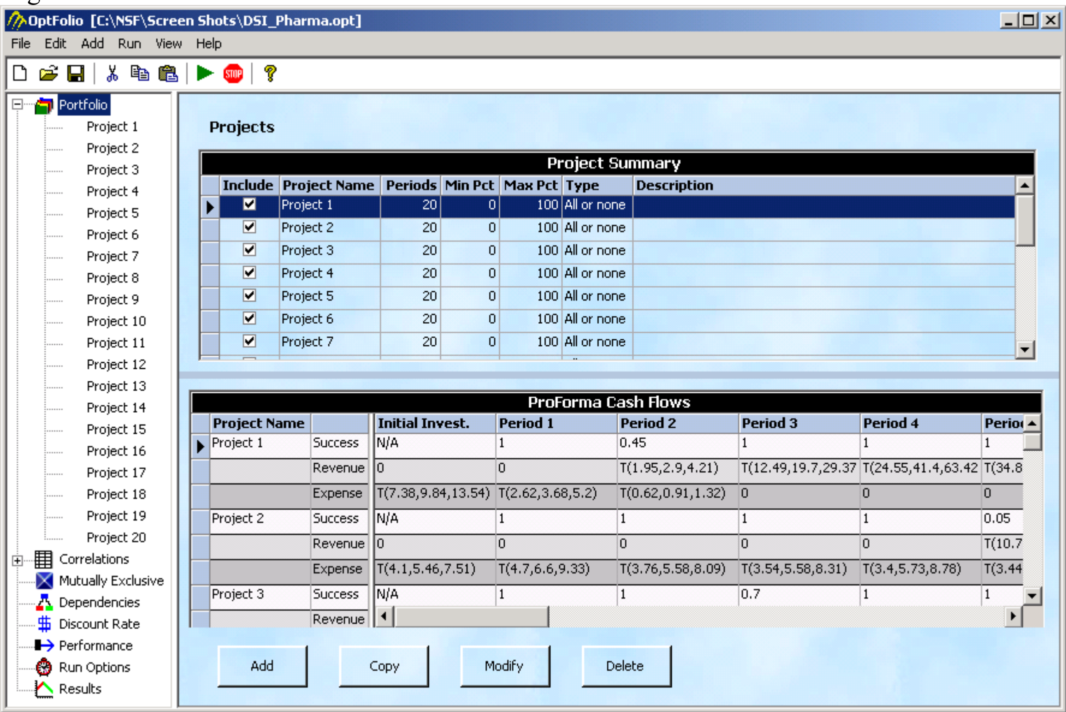
Project Results

Real data was collected from intended customers in the oil and gas, pharmaceutical, information technology, and communication industries resulting in four project portfolio simulations. Key performance indicators have been established through interactions with the companies and include several portfolio performance metrics (Net Present Value, Internal Rate of Return, and Payback Period) and system constraints (budget, dependencies, and exclusivities). Additionally, customers voiced a need for efficient procedures capable of solving their problems in a few minutes.

A pilot system was created for OptFolio, which is a windows-based software prototype that permits users to enter project data and determine optimal portfolios that optimize their performance metrics while controlling risk. The system contains many features to facilitate the process. The following screen shots capture a subset of the system capabilities.

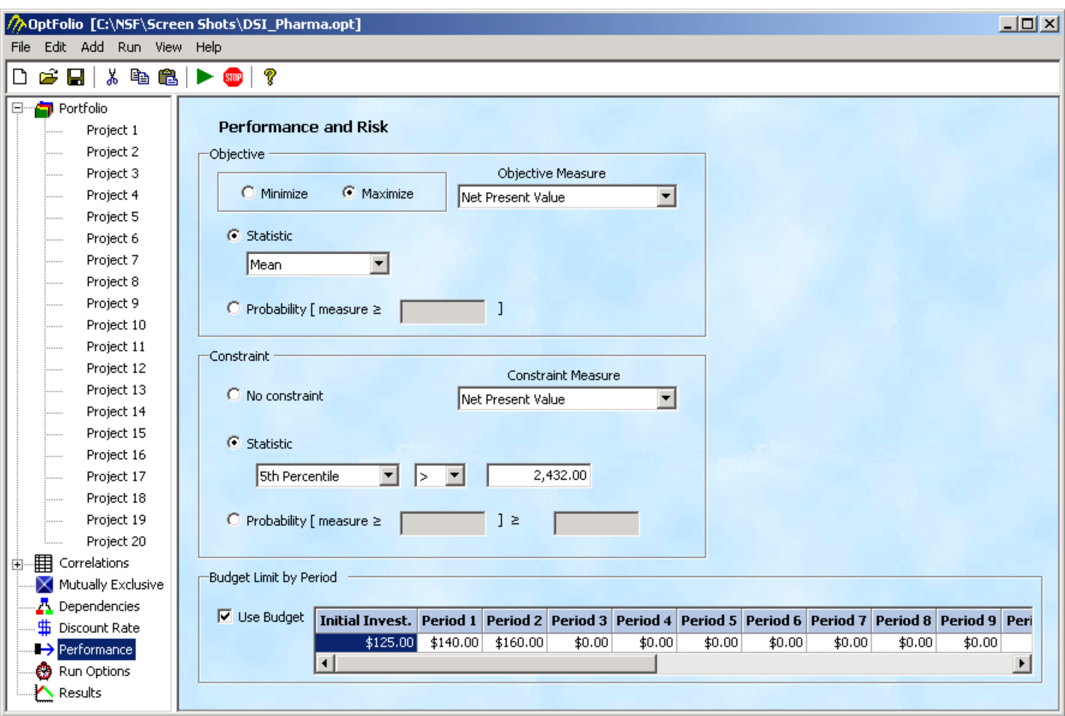
A problem in OptFolio consists of a set of projects that a firm is considering. Due to budget constraints, the firm cannot fund all projects. Therefore, the objective is to select the best combination of projects to optimize some predefined performance criteria. Projects are defined by the range of participation that the firm can have in each project, and by the project's pro-forma cash flow for each period in the life of the project.

The project summary displays information for all projects in the portfolio. The upper grid summarizes the number of periods, the range of participation, and the type of participation for each project. The bottom grid displays the summary of the pro-forma cash flows for each project.



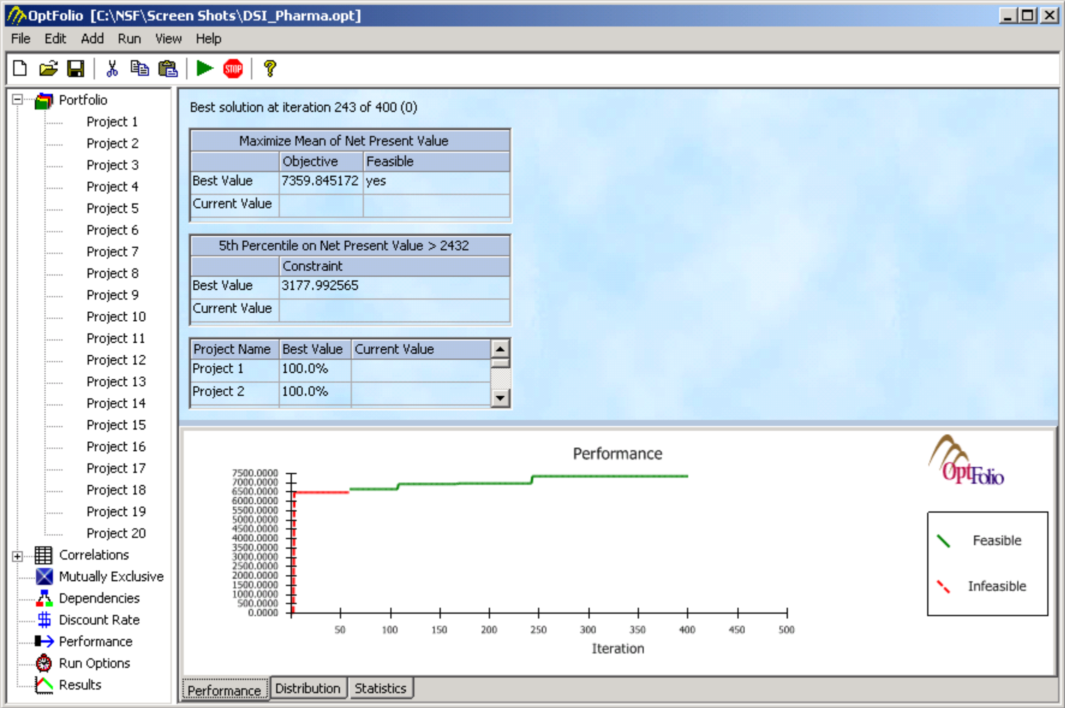
Project Summary Display

In the performance and risk dialog, the user defines the portfolio goal. Optionally the user may define a constraint that imposes a limit on a statistic for a selected measure. For example, it may be desired to maximize the mean of the Net Present Value while keeping the 5th Percentile above a certain value. The dialog also allows a budget limit to be defined for each period.



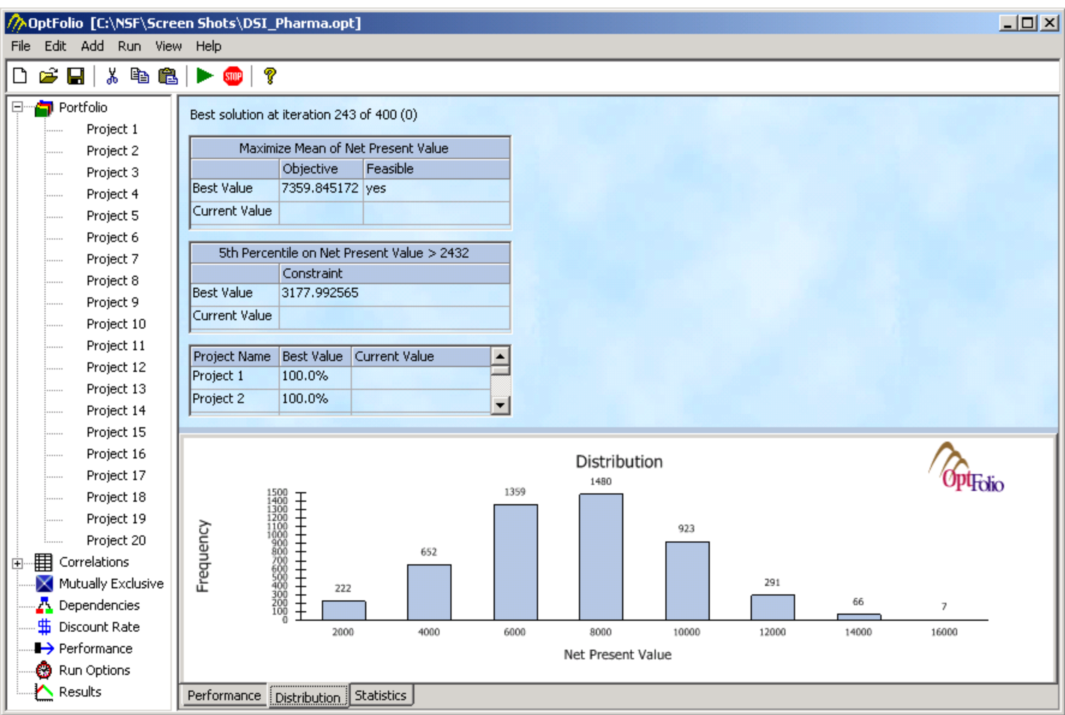
Performance and Risk Display

While the optimization is running, the performance graph and the grids on the results dialog show the progress of the optimization. The grids on the upper half show the best solution found and the current solution being tested. The performance graph on the bottom plots the best performance as a function of the number of simulations. If the user has defined a constraint, it is possible that a solution violates the constraint. In that case, the value is plotted as a red, dashed line. Solutions that satisfy the constraint are plotted by a green, solid line.



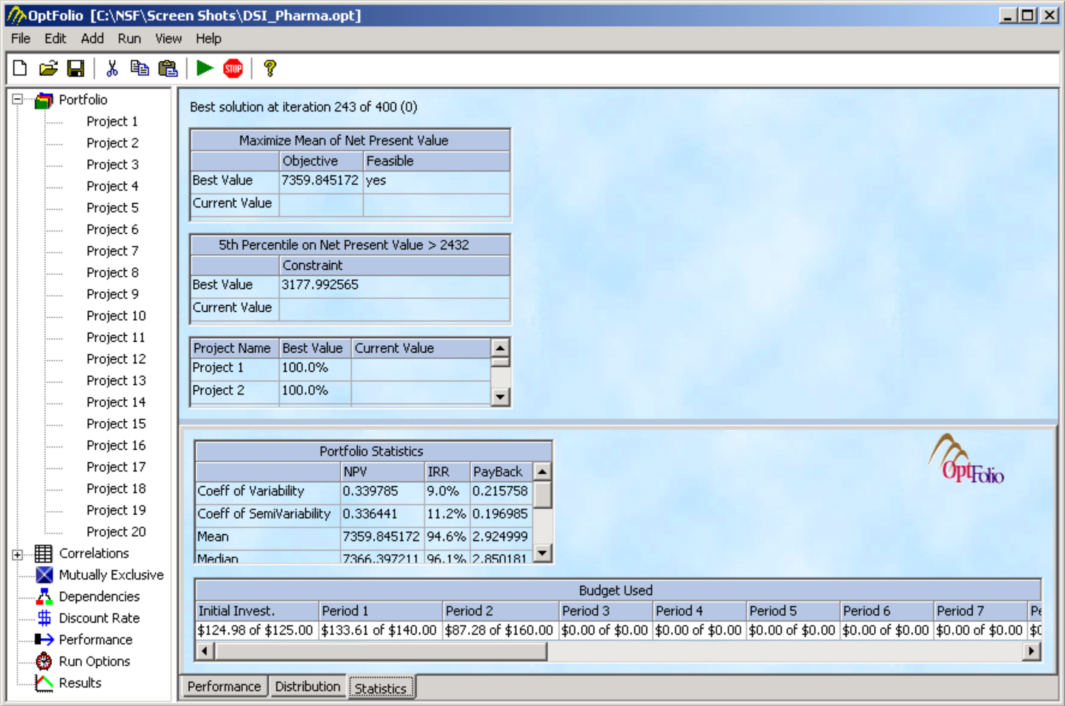
Performance Display

When the optimization completes, a histogram is created showing the distribution of the performance measure defined in the objective. The horizontal axis represents the values of the performance measure, while the frequencies are represented on the vertical axis.



Distribution Display

The statistics tab displays all of the statistics for each of the measures, which include Net Present Value (NPV), Internal Rate of Return (IRR) and Payback Period.



Statistics Display

The following examples clearly demonstrate the utility of the approach.

Example 1: The Petroleum and Energy Industry

The Petroleum and Energy (P&E) industry uses project portfolio optimization to manage investments in oil and gas exploration and production. Each project's cash flow pro-forma is modeled as a Monte Carlo simulation capturing the uncertainties of expenses and revenues. The following example involves models of fifteen potential projects with multiple types of uncertainty in drilling, production, and market conditions. The data were provided by Landmark Graphics using their TERAS Portfolio system. The OptFolio system requires pro-forma information for each project, as well as budget information. The cash flows are entered as constants or statistical distributions depending upon the user's knowledge of system uncertainty. The revenues and expenses can be correlated between projects. A cost of capital rate is used to compute discounted cash flows (the system allows this rate to also be specified by a constant or a distribution). We used a 10% cost of capital rate for all of our analyses. The user specifies performance metrics and constraints to tailor the portfolio for his needs. We examined multiple cases to demonstrate the flexibility of OptFolio to enable a variety of decision alternatives that significantly improve upon traditional mean variance portfolio optimization.

Case 1: Traditional Markowitz Approach

In case 1, the decision is to determine participation levels [0,1] in each project with the objective of maximizing the expected NPV of the portfolio while keeping the standard deviation of the NPV below a specified threshold. An initial investment budget was also imposed on the portfolio.

$$\text{Maximize } \mu_{NPV}$$
$$\text{s.t.}$$
$$\sigma_{NPV} < 5000$$
$$\text{Budget} \leq 10{,}000$$

This formulation resulted in a portfolio with the following statistics:

$$\mu_{NPV} = 11478$$

$\sigma_{NPV} = 5000$
5^{th} Percentile = 3989

We generated this traditional mean variance case to provide a basis for comparison for the subsequent cases. An empirical histogram for the optimal portfolio is shown in Figure 1.1.

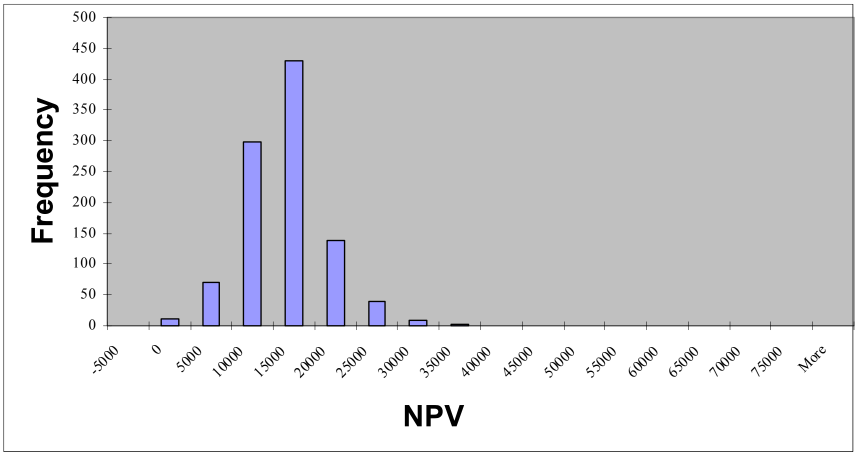


Figure 1.1 – Mean Variance Portfolio

Case 2: Risk controlled by 5^{th} Percentile
In case 2, the decision is to determine participation levels [0,1] in each project with the objective of maximizing the expected NPV of the portfolio while keeping the 5^{th} percentile of NPV above the value determined in case 1. An investment budget was also imposed on the portfolio.

Maximize μ_{NPV}
s.t.
5th Percentile $\geq$ 3,989
Budget $\leq$ 10,000

This case has replaced standard deviation with the 5^{th} percentile for risk containment. The resulting portfolio has the following attributes:

$\mu_{NPV} = 26{,}793$
$\sigma_{NPV} = 15{,}332$
5^{th} Percentile = 4,037

By using the 5^{th} percentile as a measure of risk, we were able to more than double the expected return compared to the solution found in case 1. Additionally, one could argue that the 5^{th} percentile provides a better understood measure of risk, i.e., there is a 95% chance that the portfolio will achieve a NPV of 4,037 or higher. The NPV distribution is shown in Figure 1.2.

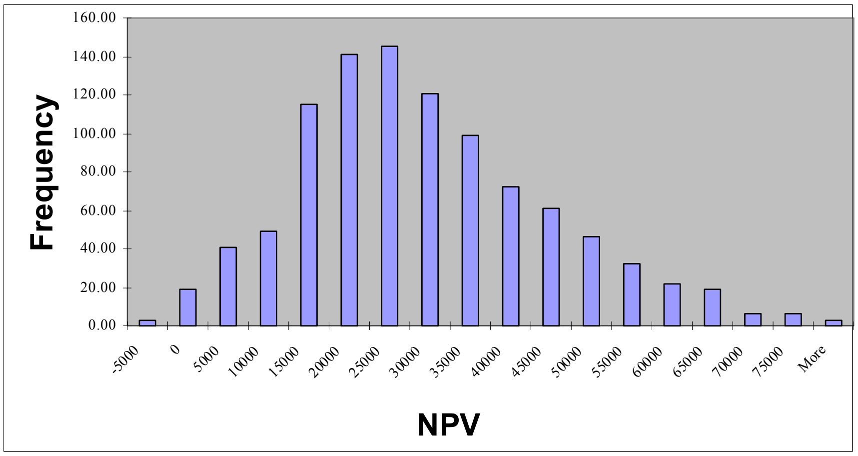


Figure 1.2 – 5th Percentile Portfolio

Case 3: Maximizing Probability of Success

In case 3, the decision is to determine participation levels [0,1] in each project with the objective of maximizing the probability of meeting or exceeding the mean NPV found in case 1. An investment budget was also imposed on the portfolio.

Maximize Probability ($NPV \geq 11{,}478$)
s.t.
$\text{Budget} \leq 10{,}000$

This case focuses on maximizing the chance of obtaining a goal and essentially combines performance and risk containment into one metric. The resulting portfolio has the following attributes:

Probability ($NPV \geq 11{,}478$) = 0.88
$\mu_{NPV} = 27{,}980$
$\sigma_{NPV} = 16{,}109$
5^{th} Percentile = 3,242

This portfolio has an 88% chance of achieving the NPV goal of 11,478. This represents a significant improvement over the case 1 portfolio considering that the probability of meeting or exceeding 11,478 in case 1 was only 50%. The NPV distribution is shown in Figure 1.3.

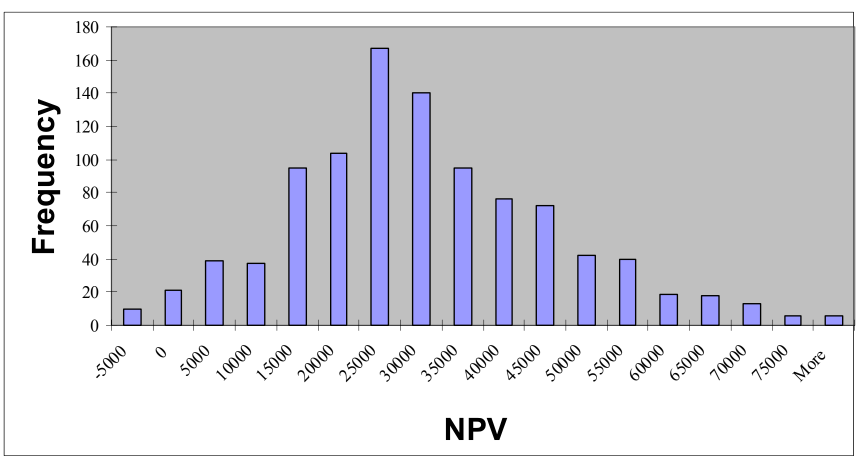


Figure 1.3 – Probability Portfolio

Case 4: Minimum Participation

An examination of the optimal participation levels found in case 3 revealed that several of the participation levels were less than 0.1. In many cases, these low levels of participation may be unacceptable. In case 4, we modified the case 3 constraints to prohibit participation levels in the range (0,0.25). In other words, if a project is selected, it must utilize at least a 25% participation or be excluded from the portfolio. An investment budget was also imposed on the portfolio.

Maximize Probability (NPV $\geq$ 11,478)
s.t.
Budget $\leq$ 10,000
Participations = 0 or [0.25,1]

The resulting portfolio has the following attributes:

Probability (NPV $\geq$ 11,478) = 0.88
μ_{NPV} = 24,149
σ_{NPV} = 13,252
5^{th} Percentile = 3,664

In spite of the participation restriction, this portfolio also has an 88% chance of exceeding an NPV of 11,478.

Case 5: All or Nothing
Case 5 extends the participation restriction to the all or nothing case.

Maximize Probability (NPV $\geq$ 11,478)
s.t.
Budget $\leq$ 10,000
Participations = 0 or 1.

The resulting portfolio has the following attributes:

Probability (NPV $\geq$ 11,478) = 0.83
μ_{NPV} = 29,283
σ_{NPV} = 19,046
5^{th} Percentile = 42

Although the probability measure for this portfolio is still quite high, we can see that the 5^{th} percentile measure has dropped precipitously from the previous cases.

Case 6: Exclusivity
In many situations it is desirable to select a single project from a group of projects. In case 6, we limit the portfolio to select a single development project form the set of four development projects considered in this analysis. The other, non-development projects can be selected without restriction. We utilize the case 2 approach.

Maximize μ_{NPV}
s.t.
5th Percentile $\geq$ 3,989
Budget $\leq$ 10,000
At most, select one development project.

The resulting portfolio has the following attributes:

μ_{NPV} = 19,861
σ_{NPV} = 10,453
5^{th} Percentile = 4,038

Compared to case 2, the mean NPV is reduced. However, the standard deviation of the NPV is substantially lower.

Example 2: The Pharmaceutical Industry

Among many other types of initiatives, the Pharmaceutical Industry uses project portfolio optimization to manage investments in new drug development. A pharmaceutical company that is developing a new breakthrough drug is faced with the possibility that the drug may not do what it was intended to do, or have serious side effects that make it commercially infeasible. Thus, these projects have a considerable degree of uncertainty related to the probability of success. Relatively recently, an options-pricing approach, called "real options" has been proposed to model such uncertainties. Although this approach is receiving some attention and may gain a presence in the marketplace, initial feedback has indicated that it faces an obstacle to achieving market penetration, due to the fact that it is difficult to understand and use. Furthermore, there are no empirical research results that indicate the "real option" approach can compete with the algorithmic approach we are developing.

The following example is based on data provided by Decision Strategies, Inc., a consulting firm that works with numerous clients in the Pharmaceutical Industry. The data consists of twenty potential projects in drug development. These projects have rather long horizons – 15 to 20 years – and the pro-forma information is given as triangular distributions for both per-period net contribution and investment. The models use a probability of success index – from 0% to 100%. The probability of success index is used in such a way that, if the project fails during a simulation trial, then the investments are realized, but the net contribution of the project is not. In this way, the system can be used to model premature project terminations providing a simple, understandable alternative to real options. In this example, we examined five cases. Table 2 shows a summary of the results for these cases.

Case 1: Simple Ranking of Projects
In Case 1, we ranked the projects according to a specific objective criterion. This is an approach often taken by currently available Project Portfolio Management tools in order to select projects under a budgetary constraint. In this case we chose the following objective measure:

$$R = \frac{PV(\text{Revenues})}{PV(\text{Expenses})}$$

All 20 projects were ranked in descending order according to this measure, and projects were added to the final portfolio as long as the budget constraint was not violated. This procedure resulted in a portfolio with the following statistics:

$\mu_{NPV} = 7{,}342$
$\sigma_{NPV} = 2{,}472$
5^{th} Percentile = 3,216

In this case, 15 projects were selected in the final portfolio. What follows is a discussion of how using OptFolio can help improve these results.

Case 2: Traditional Markowitz Approach
In Case 2, the decision criterion is to determine participation levels [0,1] in each project with the objective of maximizing the expected NPV of the portfolio while keeping the standard deviation of the NPV below a specified threshold of 1000. An investment budget was also imposed on the portfolio.

Maximize μ_{NPV}
s.t.
$\sigma_{NPV} \leq 1{,}000$
Budget Period 1 $\leq$ 125
Budget Period 2 $\leq$ 140
Budget Period 3 $\leq$ 160

This formulation resulted in a portfolio with the following statistics:

$\mu_{NPV} = 4{,}140$
$\sigma_{NPV} = 1{,}000$
5^{th} Percentile = 2,432

We included this traditional mean variance case to provide a basis for comparison for the subsequent cases. An empirical histogram for the optimal portfolio is shown in Figure 2.1.

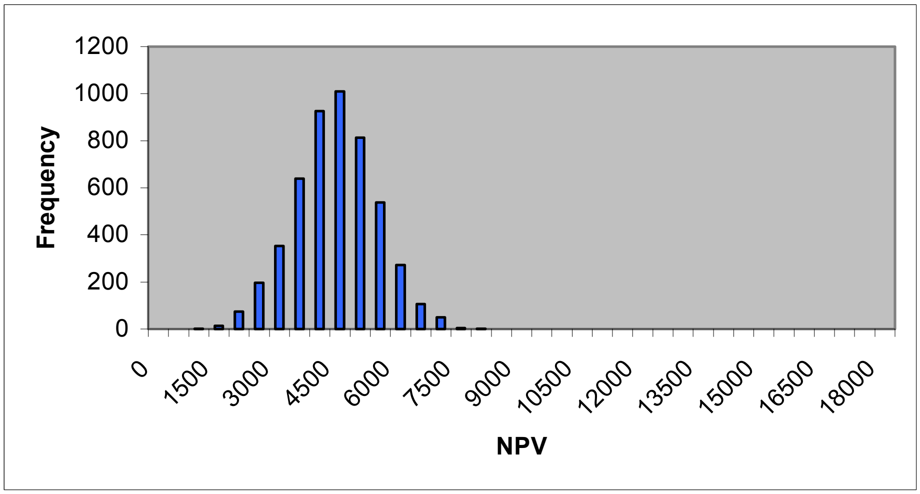


Figure 2.1 – Mean Variance Portfolio

Case 3: Risk controlled by 5th Percentile

In case 3, the decision criterion is to determine participation levels [0,1] in each project with the objective of maximizing the expected NPV of the portfolio while keeping the 5th percentile of NPV above the value determined in case 2 (2,432). The same investment budget was also imposed on the portfolio.

Maximize μ_{NPV}
s.t.
5th Percentile $\geq$ 2,432
Budget Period 1 $\leq$ 125
Budget Period 2 $\leq$ 140
Budget Period 3 $\leq$ 160

This case has replaced standard deviation with the 5th percentile for risk containment, which is an intuitive way to control catastrophic risk. The resulting portfolio has the following attributes:

μ_{NPV} = 7,520
σ_{NPV} = 2,550
5th Percentile = 3,294

By using the 5th percentile as a measure of risk, we were able to almost double the expected return compared to the solution found in case 2, and improved on the simple ranking solution. Additionally, as previously discussed the 5th percentile provides a more intuitive measure of risk, i.e., there is a 95% chance that the portfolio will achieve a NPV of 3,294 or higher. The NPV distribution is shown in Figure 2.2. It is interesting to note that this solution has more variability but is focused on the upside of the distribution. By focusing on the 5th percentile rather than standard deviation, a superior solution was created.

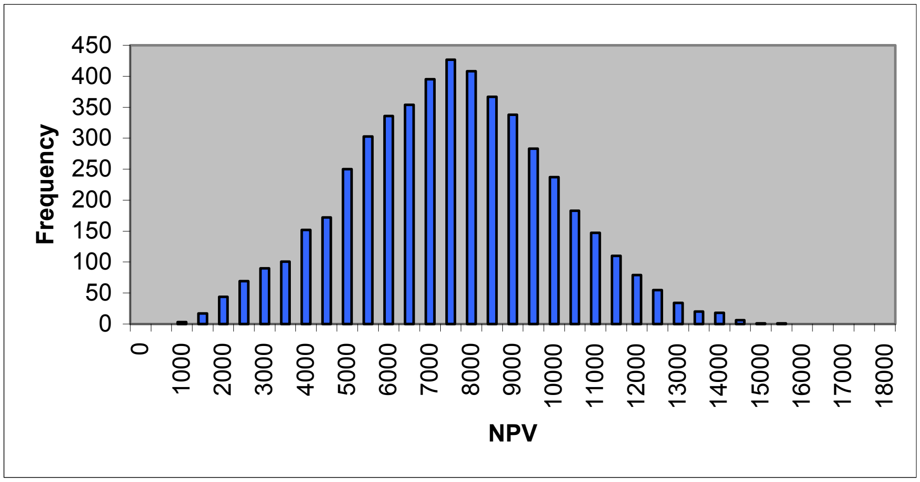


Figure 2.2 – 5th Percentile Portfolio

Case 4: Maximizing Probability of Success

In case 4, the decision criterion is to determine participation levels [0,1] in each project with the objective of maximizing the probability of meeting or exceeding the mean NPV found in case 2. An investment budget was also imposed on the portfolio.

Maximize Probability (NPV $\geq$ 4,140)
s.t.
Budget Period 1 $\leq$ 125
Budget Period 2 $\leq$ 140
Budget Period 3 $\leq$ 160

This case focuses on maximizing the chance of obtaining a goal and essentially combines performance and risk containment into one metric. The resulting portfolio has the following attributes:

μ_{NPV} = 7,461
σ_{NPV} = 2,430
5^{th} Percentile = 3,366

This portfolio has a 91% chance of achieving or exceeding the NPV goal of 4,140. This represents a significant improvement over the case 2 portfolio considering that the probability of meeting or exceeding 4,140 in case 2 was only 50%. The NPV distribution is shown in Figure 2.3.

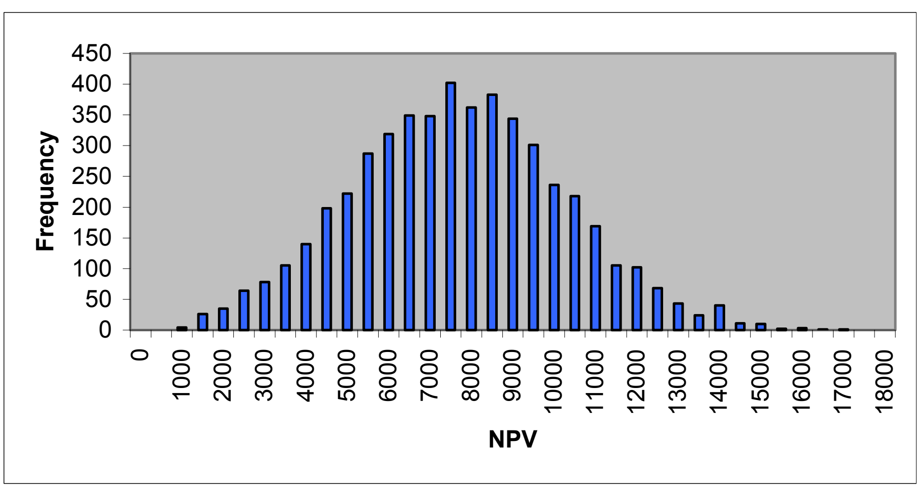


Figure 2.3 – Probability Portfolio

Case 5: All-or-nothing

In many real-world cases, these types of projects have all-or-nothing participation levels. However, in case 4 most of the optimal participation levels found were fractional. In case 5, we modified the case 4 constraints to allow only 0 or 1 participation levels. In other words, a project must utilize 100% participation or be excluded from the portfolio. An investment budget was also imposed on the portfolio.

Maximize Probability (NPV $\geq$ 4,140)
s.t.
Budget Period 1 $\leq$ 125
Budget Period 2 $\leq$ 140
Budget Period 3 $\leq$ 160
Participations = 0 or 1

The resulting portfolio has the following attributes:

μ_{NPV} = 7,472
σ_{NPV} = 2,503
5^{th} Percentile = 3,323

In spite of the participation restriction, this portfolio also has a 91% chance of exceeding an NPV of 4,140, and has a high expected return. In this case, as in Case 1, 15 out of the 20 projects were selected in the final portfolio. However, the expected returns are significantly higher than in case 1.

These cases illustrate the benefits of using alternative measures for risk. Not only are percentiles and probabilities more intuitive for the decision-maker, but, more importantly, they also produce solutions with better financial metrics.

The OptFolio system can also be used to optimize performance metrics such as Internal Rate of Return (IRR) and Payback Period. The following examples address these cases.

Example 3: Information Technology Projects

One of the fastest growing areas of application for Project Portfolio Management is Information Technology (IT). Traditionally, firms have not had a systematic approach for tracking the returns on investment projects. Also, it is estimated that more than 30% of IT projects ultimately fail, after a considerable amount of money and resources has been invested (AMR Research, October 2002). Therefore, there is a trend across all industries to improve the ways in which decisions are made whether to undertake specific projects. The following example involves models of five potential IT projects. These projects involve data processing, network integration and enterprise management solutions. Data for these projects were provided by Decision Strategies, Inc. As in our previous examples, we used OptFolio for our analysis. In all cases, we considered budgetary restrictions.

Case 1: Traditional Markowitz Approach

In this case, we maximize mean NPV, while limiting the standard deviation to at most 3.0. The resulting statistics for the final portfolio are:

μ_{NPV}	= 12.15
σ_{NPV}	= 0.50
5^{th} Percentile	= 11.36
μ_{IRR}	= 95.90%

The NPV distribution for this portfolio is shown in figure 3.1.

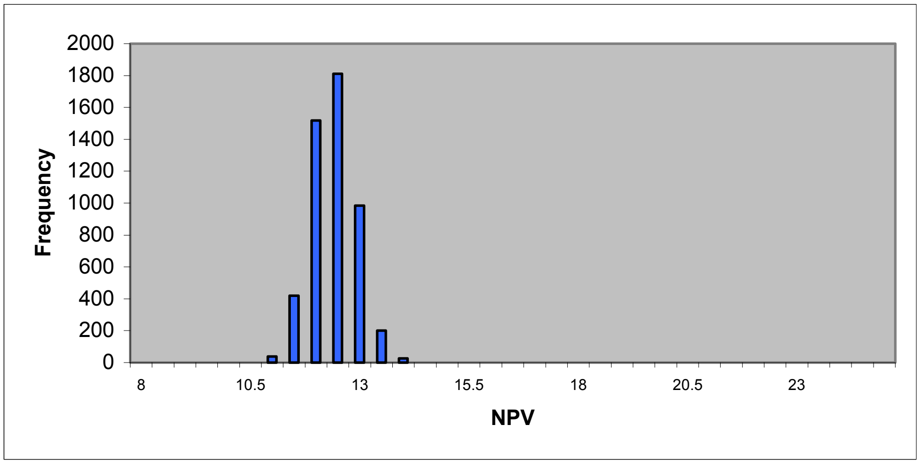


Figure 3.1 – Traditional Markowitz Approach

Case 2: Risk Controlled by the 5th Percentile

In case 2, we maximize mean NPV, while holding the 5th percentile to at least 11.36. The statistics for the final portfolio are:

μ_{NPV}	= 19.42
σ_{NPV}	= 1.26
5th Percentile	= 17.33
μ_{IRR}	= 45.80%

The NPV distribution for case 2 is shown in Figure 3.2.

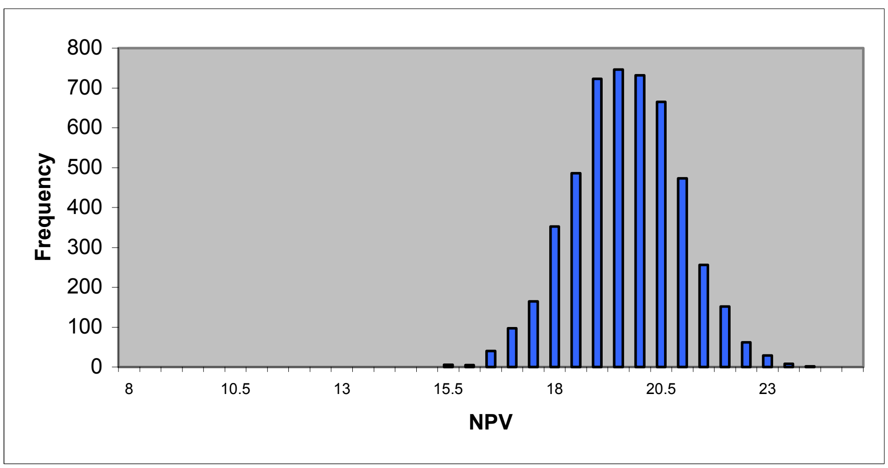


Figure 3.2 – Risk Controlled by 5th Percentile

Case 3: Maximize Probability of Success

In case 3, we maximize the probability that the NPV is greater than 12.15. The resulting portfolio is the same as in case 2.

Case 4: All-or-nothing

Case 4 is the same as case 3, but we restrict participation levels to the all-or-nothing case. Since the results are the same as cases 2 and 3, we conclude that in all three cases the solution only involved all-or-nothing participation levels.

Cases 5 and 6: Maximizing IRR

In some cases, the user may decide that NPV is not the best measure for selecting projects. Cases 5 and 6 seek to maximize Internal Rate of Return (IRR) in order to obtain a better portfolio; however, a NPV smaller than 12.15 (obtained in Case 1) is considered unacceptable.

In case 5, we maximize the mean IRR while holding the mean NPV to at least 12.15. The resulting portfolio outperforms the case 1 portfolio in terms of NPV.

In case 6, we maximize the probability that the IRR is greater than 60.8%, the mean IRR value obtained in case 5. We also keep the constraint on the mean NPV, as in the last case. In the resulting portfolio, although the NPV values are lower than in case 5, the IRR has a 100% probability of exceeding 60.8%, with a mean IRR of 101.8%, which is the highest of all the cases analyzed. Table 1 summarizes the results from our analysis.

	Mean NPV ($)	5th Percentile	Std. Dev.	Coeff. of Var.	Mean IRR	Mean DPO
Case 1	12.15	11.36	0.50	0.04	95.9%	1.98
Case 2	19.42	17.33	1.26	0.07	45.8%	3.32
Case 3	19.42	17.33	1.26	0.07	45.8%	3.32
Case 4	19.42	17.33	1.26	0.07	45.8%	3.32
Case 5	14.47	13.37	0.69	0.05	60.8%	1.94
Case 6	13.32	11.84	0.89	0.07	101.8%	2.01

Table 1. Summary Results for Information Management Project Portfolios

Example 4: The Telecommunications Industry

The Telecommunications Industry uses project portfolio optimization for several different types of projects. This industry is undergoing an extended period of slow growth, consolidation, and re-focusing of core competencies. Therefore, mergers and acquisitions, infrastructure projects and capacity redeployment projects are ubiquitous throughout the industry.

In our example, we analyzed models for five projects with a ten-year horizon. The data, supplied by Level3, corresponds to projects being considered for Q3 2003 deployment. A requirement of Level3 was that Project 1 be included in all final portfolios, at a 100% participation level.

The results obtained from this study are summarized in Table 2.

	Mean NPV ($)	5th Percentile	Std. Dev.	Coeff. of Var.	Mean IRR	Mean DPO
Case 1	45.77	40.75	3.00	0.07	35.7%	4.92
Case 2	45.56	40.81	2.83	0.06	36.2%	0.04
Case 3	46.15	39.74	3.88	0.08	33.9%	5.28
Case 4	45.14	41.25	2.29	0.05	39.8%	4.69
Case 5	45.14	41.25	2.29	0.05	39.8%	4.69
Case 6	45.14	41.25	2.29	0.05	39.8%	4.69

Table 2. Summary Results for Telecommunications Project Portfolios

All cases tested considered the requirement that the first project be included, as well as the budget constraints. The cases tested are as follows:

Case 1: Maximize Mean NPV subject to Std. Dev. NPV 3.00
Case 2: Maximize Mean NPV subject to 5^{th} Percentile $\geq$ 40.75
Case 3: Maximize P(NPV $\geq$ 45.77)
Case 4: Maximize P(NPV $\geq$ 45.77) subject to all-or-nothing projects
Case 5: Maximize Mean NPV subject to Std. Dev. NPV $\leq$ 3.00 and all-or-nothing projects
Case 5: Maximize Mean IRR subject to all-or-nothing projects

Here, we can see that the best portfolio, in terms of NPV, is found in case 3, where we maximize the probability that the mean NPV is greater than 45.77.

We see that cases 4, 5 and 6, where the participation levels are all-or-nothing, yield the same results. In this case, maximizing some measure of NPV or IRR results in the same portfolio, due to the simplicity of the data. These are 5 projects with relatively short horizons. Furthermore, project 1 was always included at 100%, simplifying the search even more.

We can conclude from these examples that the application is very effective for complex, as well as simple sets of projects, where different measures of risk and return can produce improvements over the traditional Markowitz (mean-variance) approach, as well as over simple project ranking approaches.

OptFolio as developed under this Phase 1 SBIR offers the user the flexibility to choose various measures and statistics, both as objective performance measures as well as constraints. This enables the user to select better ways of modeling and controlling risk, while aligning the outcomes to specific corporate goals.

OptFolio also provides ways to define special relationships that often arise between and among projects. Correlations can be defined between the revenues and/or expenses of two projects. In addition, the user can define projects that are mutually exclusive, or dependent. For example, in some cases, selecting Project A *implies* selecting Project B; such a definition can easily be done in OptFolio.

Portfolio analysis tools are designed to aid senior management in the development and analysis of project portfolio strategies, by giving them the capability to assess the impact on the corporation of various investment decisions. To date, commercial portfolio optimization packages are relatively inflexible and are often not able to answer the key questions asked by senior management. With OptFolio, we present new techniques that increase the flexibility of portfolio optimization tools and deepen the types of portfolio analysis that can be carried out.

Example 5 – Large Portfolio

The final test of the system was performed to assess the system's ability to process a large portfolio of projects. The portfolios provided by potential customers were modest in size having no more than ten projects. To stress the system, we created a simulated portfolio with fifty projects. This set of projects was constructed by combining and varying the data from the previous examples. Four tests similar to those undertaken on the previous data sets were performed on this large portfolio. A description of the tests and the results (Table 3) are shown below.

Test 1: Maximize μ_{NPV} while $\sigma_{NPV} \leq 10000$
Test 2: Maximize μ_{NPV} while 5th percentile ≥ 176818
Test 3: Maximize $P(NPV \geq 193022) \rightarrow 0.83$
Test 4: Maximize $P(NPV \geq 193033)$ and all-or-nothing participations $\rightarrow 0.69$

	Mean NPV	5th Percentile	Standard Deviation	Coefficient of Variation.	Mean IRR	Mean Payback Period	Optimization Time (min)
Test 1	193022	176817	9986	0.052	34.3%	5.25	4.0
Test 2	206365	184257	13445	0.065	34.4%	5.26	0.5
Test 3	206364	184249	13444	0.065	34.4%	5.26	1.0
Test 4	199844	177289	13007	0.065	39.2%	4.50	7.0

Table 3. - Stress Test Results

It is important to note that each run of the system required less than seven minutes, thereby satisfying the customer' request for a speedy solution. This set of tests provides a demonstration of scalability, which we anticipate to be critical in the next phase of this project.

Performance Comparison

The following figures demonstrate OptFolio's performance compared to the system prior to this research. The LEVER method has had significant impact on the efficiency of our approach. In all the cases below, OptFolio was run with and without the LEVER method. We provide examples from the four data sets tested in the previous section.

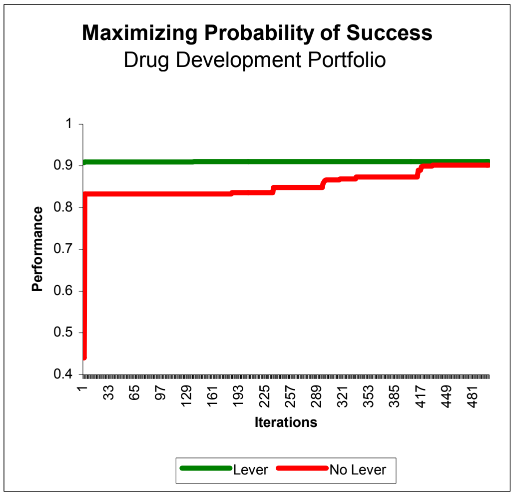


Figure 6.1 - Maximizing Probability of Success

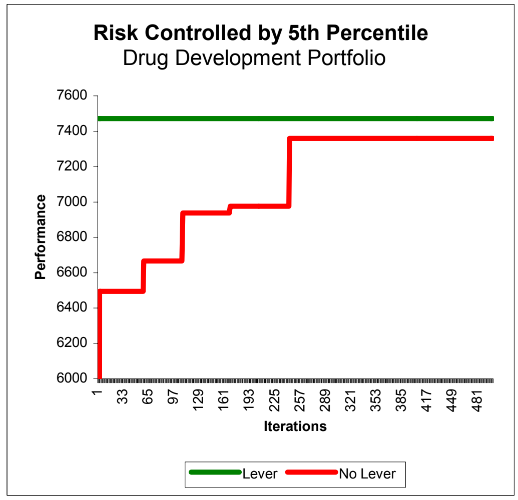


Figure 6.2 - Controlling Risk by 5th Percentile

For these cases, we let both applications run for the same number of iterations. The total number of iterations was the same used for our test trials described in the previous section, to ensure we obtained the solutions reported above for OptFolio. In figures 6.1, 6.2 and 6.3, not only does OptFolio with the LEVER method find the best portfolio significantly sooner, but also, given the total number of iterations allotted, the non-enhanced system never finds a solution of equal or higher quality.

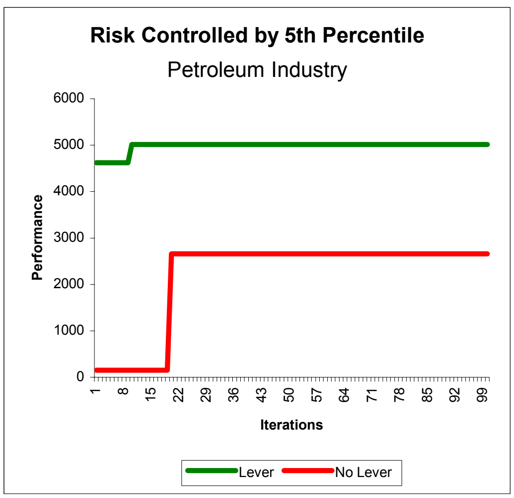


Figure 6.3 - Controlling Risk by 5th Percentile

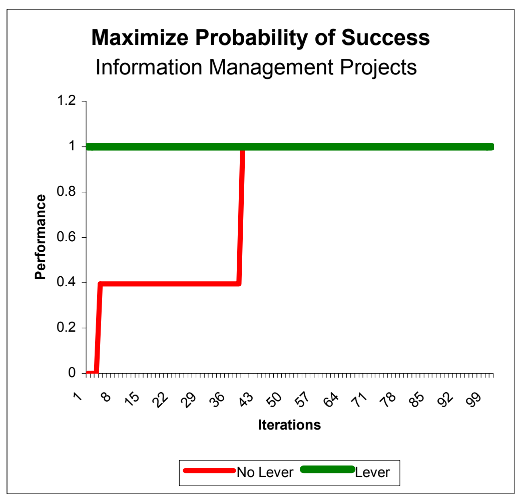


Figure 6.4 - Maximizing Probability of Success

In figure 6.4, where the objective is to maximize the probability that the NPV is greater than a specific value, although both applications ultimately find the best solution (100% probability), OptFolio with LEVER does it immediately (iteration 2). These performance results show that OptFolio with the LEVER method is more than 1000% more efficient than our previous system.

Based on reviewing research reports, journal articles and commercial marketing literature, and after summarizing interviews with executives from potential customer companies and alliance firms, we have formulated a value proposition as follows:

OptFolio enables:
- significantly enhanced capital budgeting and finance decisions
- greater returns and superior confidence in managing risk
- a virtually infinite number of what-if questions to be asked and their answers sorted and prioritized with accuracy and speed
- simultaneously achieving higher returns while reducing the probabilities of selecting projects destined to either fail or exhibit poor performance
- increasing the potential for investments in more projects

Each one of these statements reflects the benefits associated with satisfying requirements identified during the project and illustrated in the examples and cases that demonstrate the feasibility of the approach. For instance, the examples show that when the new approach is compared to the alternatives of traditional ranking and Markowitz methods, either returns increase, or the probability of realizing returns increases, or a combination of both. Furthermore, the new approach exhibits the capability of providing more flexibility in the ways projects can be evaluated as well as a more intuitive way to measure risk.