*Decision Making in a Non-Profit
Engineering Environment*

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*Decision Making in a Non-Profit
Engineering Environment*

Dana Carl Christensen

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NOMENCLATURE

AHP: The Analytic Hierarchy Process, a mathematical technique designed to integrate subjective and objective information in assisting in decision making.

DOE: Department of Energy, a cabinet-level department of the executive branch of the United States government.

DOE/EM: DOE Office of Environmental Remediation and Waste Management, an office within the Department of Energy.

DOE/MD: DOE Office of Material Disposition, an office within the Department of Energy.

DNFSB: Defense Nuclear Facility Safety Board, a board established by congress for the express purpose of ESH oversight of DOE Nuclear Facilities.

ESH: Environmental Safety and Health.

Expert Choice: A computer-based AHP implementation.

IAEA: International Atomic Energy Agency, an international agency that oversees domestic nuclear power generation and spent nuclear fuel management.

Mat Liab: [Material Liabilities] The management of activities involving the cleanup of excess cold war facilities and inventories.

Non Prol: [NonProliferation] The management of activities involving the international safeguarding of nuclear materials.

Oprtnl: [Operational] The management of nuclear facility operations consistent with national cleanup facility standards.

OSHA: Occupational Safety and Health Administration, an office of the United States government focused on industrial workplace safety.

SNM: Special Nuclear Material, which is defined as plutonium, enriched uranium, and tritium.

START: Strategic Arms Reduction Treaty, a treaty between the United States and the former Soviet Union on the reduction of nuclear weapons.

Stk Mngt: [Stock Management] The management of activities involving nuclear weapon stockpile security.

Stockpile: The inventory of nuclear weapons remaining in the national defense arsenal as well as those existing in the undeployed reserve.

TA-55: Technical Area 55, the technical area at Los Alamos National Laboratory that contains the Laboratory's plutonium facility.

DECISION MAKING IN A NON-PROFIT ENGINEERING ENVIRONMENT

BY

DANA CARL CHRISTENSEN

ABSTRACT

A conceptual management framework is developed and applied in a science and engineering organization located within a non-profit, public institution. The goal of this research is to select a set of projects whose combined contributions to the organization's strategic interests satisfy sponsor desires and can be completed within existing time and resource constraints. The development of the rationale for project selection and implementation within the plutonium facility at Los Alamos National Laboratory is studied. This includes the integration of prioritization decision tools, optimization techniques, and advanced planning and scheduling tools. The Nuclear Materials Technology Division is the custodian of the plutonium facility, whose mission is to develop, demonstrate, and deploy technologies necessary to address the nation's and world's plutonium problems. This includes management of nuclear weapon stockpile components, stabilization of plutonium residues, clean-up of contaminated soils and facilities, support to non-proliferation and arms control initiatives, and the eventual disposition of surplus plutonium.

Selection of projects is a decision problem of vital importance in the facility's long-range strategy, particularly in view of limited budgets being allocated to address these issues. The challenge is compounded by the fact that the Laboratory is non-profit and therefore does not have a financial basis for comparing investment options.

In this study, projects are evaluated against selection criteria deemed to be of critical program importance. The Analytic Hierarchy Process is used to evaluate and rank the importance of the suite of candidate projects. Because individual projects may be of interest to a number of business sectors and sponsors, the approach must be capable of using funding sources in an integrated manner in order to meet overall facility and program strategies. The prioritization is followed by optimization of an objective function involving constrained resources in order to balance resources within the facility, which include equipment design, configuration management, the availability of installation labor, and funding. A unique feature of this work is establishing the relative "priority" measures as the common basis for evaluating the optimization of constrained resources. Finally, project planning and scheduling tools are integrated into the decision network in order to ensure that appropriate resource leveling occurs and that the actual project selection takes into account the temporal relationships among available resources. The significant contribution of this work is the coupling of three existing quantitatively-based tools in an integrated manner to support informed strategic and tactical decision making in a non-profit science and engineering organization.

Chapter 1

INTRODUCTION

1.1 Purpose of This Project

The common approach to solving engineering problems usually involves the optimization of critical operating features in an engineering process. Differential methods, linear and non-linear programming, and numerical optimization methods are examples of approaches often used in reaching optimum operating conditions.

However, in industrial applications, most decisions involve multiple objectives that are almost always in conflict. For instance, in a production plant, maximizing output while minimizing waste are often in conflict. In another example, minimizing worker idle time while maximizing project output are often in conflict. The challenge in making the "best" decision in an actual engineering situation includes simultaneously evaluating objective parameters (e.g., process yield, quantity of waste generated) as well as even more numerous subjective parameters (e.g., sponsor interest, work crew scheduling). Today's society is placing higher priorities on non-economic objectives such as social responsibility, corporate and organizational image, environmental protection, and strict compliance with various orders, regulations, laws, and good industrial practices; often, these parameters cannot be directly compared by a common factor, such as dollars.

The concept of optimizing an engineering operation now has become one of being able to *satisfy* numerous desires without formally optimizing any one. This concept means that compromise must be reached in balancing various tradeoffs, but, reaching a satisfactory solution is not sufficient within the reality of operating a facility until the dimension of time and budget cycles are taken into account. Real constraints are encountered in arriving at the appropriate solution. The problem therefore requires integrating the prioritization of projects with optimization of constrained resources against facility and operational constraints and, finally, evaluating the temporal dependencies of resource usage in the pragmatic implementation of a set of interrelated decisions. The practical consideration will identify conflicts in scheduling and resource utilization, and force a rebalancing of activities. The final selection of activities cannot be fully made until all three major steps are completed in an integrated manner.

The approach employed in this research involves using project management tools for prioritizing projects followed by the use of binary integer optimization to take into account real facility and operating constraints and finally taking the time relationship of tasks into account. The purpose is to establish a rationally based methodology that can be easily used by decision makers in an organization having multiple objectives. Although a number of project prioritization techniques exist, the Analytical Hierarchy Process (AHP) is used in this research project. There are also a number of software systems that have been developed using AHP, such as *Criterion*

and *Expert Choice*. These techniques incorporate informed judgments that use comparative assessments instead of absolute assessments of parameters. Key parameters of interest will be identified together with analytical approaches for assessing values. The results of the prioritization will then be evaluated against operating constraints. A set of candidate projects that result from the optimization of an objective function subject to constraints will be selected using binary integer programming. In addition, a sequence of work can be identified on the basis of the optimum use of limited resources. Finally, the projects will be scheduled, using the Gantt Chart approach, to help identify and resolve resource and schedule conflicts that could disrupt effective project implementation. This final step incorporates the time dependency of internal resources, such as the availability of designers or craftsmen, for installing critical equipment. It also incorporates resource leveling necessary for completing a set of projects in a cost-effective, timely manner. Feedback must be used along each step of the analysis to update and adjust decisions along the path to achieve an effectively managed organization.

1.2 Background and Literature Review

The end of the Cold War has dramatically changed the role of the nuclear weapon stockpile and, simultaneously, the disposition of the various nuclear weapon manufacturing facilities across the Department of Energy (DOE) complex, including the national laboratories. A critical element of the national policy on defense has been

the nuclear deterrent. This deterrence was achieved by producing large quantities of nuclear weapons. The Strategic Arms Reduction Treaty (START) and START II called for significant reductions in nuclear weapons for both the United States and the former Soviet Union [1]. The result is a much reduced-scale manufacturing complex that will rely on a more sophisticated approach to manufacturing because of the small numbers of weapons to be fabricated. The streamlined weapons complex of the future will focus on long-term storage of nuclear material, weapons dismantlement, and a modest fabrication and rebuild capability of weapons components which are both hedges against aging or degrading weapons in the stockpile. The DOE has been tasked with ensuring the continued safety and reliability of the weapons stockpile during a period of rapidly decreasing budgets and has therefore begun to close the large-scale manufacturing facilities and to consolidate much of their production needs into small-scale facilities existing at the national laboratories. This strategy integrates production with research, design, development, and testing of weapon components.

The changing view of the threat for which nuclear weapons are designed and nuclear materials are managed has also resulted in a dramatically changed set of requirements for material management and facility operations. First, the Secretary of Energy began an initiative to increase the quality of Environmental Safety and Health (ESH) management within DOE facilities [2]. This step exposed the nuclear defense community to a broader range of oversight organizations, most of which are outside the DOE. At the same time, the United States Congress (Congress) established the

Defense Nuclear Facilities Safety Board (DNFSB) with the charter to evaluate the performance of the DOE in the execution of its safety and health obligations [3]. This board became a very public vehicle for bringing scrutiny on the DOE's nuclear operations. Congress and DOE established the Office of Environmental Remediation and Waste Management (DOE/EM) with the charter to clean up excess Cold War nuclear facilities and sites [4]. This decision resulted in the transfer of a significant amount of plutonium to the new DOE/EM in the form of residues, waste, and contaminated equipment and facilities. The DOE/EM is heavily involved in the privatization of facility clean-up functions, and most of the new contractors are unaware of the historical basis for nuclear material management.

The Secretary announced the "Openness Initiative" wherein previously classified information was released for public consumption. This initiative included the disclosure of quantities of plutonium that exist in the defense inventories [5]. Congress recognized that plutonium would become an inventory challenge and initiated the DOE Office of Material Disposition (DOE/MD) to evaluate permanent disposition options for excess weapons materials. An additional dimension to the charter of DOE/MD was opening relations with the Russian Federation and discussing plutonium stabilization and disposition [6]. In 1995, President Clinton announced that the United States would place 200 metric tons of special nuclear material (SNM), including plutonium and enriched uranium, under the International

Atomic Energy Agency (IAEA) safeguards program [7]. This action exposed the DOE facilities to the potential for international safeguard controls over material.

During 1994, two DOE complex-wide plutonium safety assessments were made; one was made by the DNFSB and the other by the DOE Assistant Secretary for Environmental Safety and Health [8,9]. The latter assessment resulted from a 1993 Presidential initiative on nuclear nonproliferation and DOE's effort to develop strategies for the eventual disposition of excess fissile materials [10,11]. Both of these assessments identified the imminent dangers to workers, environment, and the public associated with the ever-deteriorating state of nuclear material packages, infrastructure, and nuclear facilities. On January 14, 1997, the Secretary of Energy signed the record of decision designating Los Alamos National Laboratory (LANL) and the plutonium facility (TA-55) as the plutonium weapon component manufacturing center, thus directing the Laboratory to upgrade both its chemical and metallurgical processing technologies as well as its nuclear material and facility management functions [12]. This record of decision represented the product of the Final Programmatic Environmental Impact Statement, a detailed study performed by the DOE for evaluating the transfer of functions and mission between DOE facilities [13]. This list of significant changes and actions has generated an increasingly more complex list of requirements for material management and facility operations.

The plutonium facility (TA-55) at Los Alamos National Laboratory is currently the only operating facility in the nation with established plutonium handling

capabilities that can be upgraded to larger scale to provide production capability for the fabrication and chemical processing of plutonium. Included within the capability are support functions such as analytical chemistry, waste management, non-destructive assay, and radiography, as well as a full set of personnel support capabilities. The programs hosted within TA-55 include the processing of weapon grade plutonium and fabrication of weapon test components as well as the fabrication of ^{238}Pu heat sources for use in deep space research, the processing and fabrication of nuclear fuels, the development of stabilization technologies for long-term storage of excess plutonium, and the development of technologies for cleaning up the environment. Two issues are facing TA-55 in addressing the need to scale up operations in support of manufacturing, disposition, and management functions: 1) the facility is now almost 20 years old and is in need of a significant upgrade of its infrastructure, and 2) budgets and other resources are constrained. Balancing resources across all program elements while simultaneously upgrading aging infrastructure and operating systems and transitioning the fabrication functions into a full manufacturing capability introduces significant complexity into the decision processes. To further compound the challenge, financial support comes from a number of sponsors, each of which has parochial interests in their products and services. This dissertation presents an integrated approach to decision making, which takes into account the parochial interests of various sponsors, the realities of constrained budgets and facility resources, and the continuously changing set of operational conditions.

1.3 Overall Project Structure

The logic for project selection is demonstrated in Figure 1, which indicates both the strategic and tactical planning process for the project selection. This figure represents the overall path for the strategic management decision process together with the specific sequencing of steps necessary to demonstrate a logically-based thought process. The first step involves determining the strategic direction for the organization. The purpose is to define the organization-wide missions, directions, goals, and emerging strategic initiatives. It must define the businesses in which the organization intends to participate and address the scope and mix of specific projects that will bound the market segment that it intends to serve. In particular, it defines the business directions for the organization within which sponsorship is to be integrated and customers are to be served.

The second element of the process involves prioritization planning. Prioritization allows the planning process to become a total *systems* evaluation process as opposed to one that evaluates only accurately characterized and quantitative information related to component performance and management. It introduces a mechanism to integrate the parochial interests of various sponsors and regulators and to consider how each decision will contribute to those interests, and therefore prioritizes the various projects. It is the step in the process in which apples and oranges are compared, on the basis of expert opinion, and the value of each is resolved as opposed to solved. This element is essential at this point of the planning

Figure 1: Overall Logic for Decision Making Process

process because it places a boundary on the problem statement by identifying both the highest and lowest priority tasks, thus facilitating an understanding of the relative importance of the selected projects. As noted later in the literature review on prioritization (see section 3.1), many researchers and practitioners stop at this point and use the prioritization list as if it were adequate for defining the project selection hierarchy, but the process at this point has not yet taken into account the physical, financial, and time constraints existing within an organization and facility.

The third element in the process is optimization planning. Optimization specifically involves the use of mathematical techniques for solving problems in which one is attempting either to maximize benefits, while using limited resources, or to minimize cost, while meeting certain requirements. It involves the development of an objective function and requires the establishment of constraints that limit the value of the objective function. The objective function is a mathematical expression of the goal and is stated in terms of the decision variables. Each decision variable represents a controllable element in the set of decision options available. In terms of project selection, decision variables and constraints involve limited resources, primarily labor, but can also include limited facility space and equipment availability together with the available funding.

The fourth major element of the process is the planning and scheduling of tasks that comprise a project selected for implementation. This involves the development of a project network and includes specifically identifying the

relationship among the various tasks needed to complete the project. Planning involves identifying the activities to be performed, estimating the time required to perform each activity, and developing the predecessor/successor relationships between each. For multiple-project tasks, each task will have a unique plan with interrelating steps. Scheduling involves the preparation of a time chart showing the schedule for use of each resource as well as the expenditure of funds on each task. In evaluating the various relationships, conflicts are identified where the same resource is required at the same point in time for more than one task. Resolving these conflicts is the responsibility of management throughout the decision sequence.

Management evaluation and modification of planned decisions occurs along each step of the model sequence. As identified earlier, conflict often occurs when multiple tasks are planned and scheduled simultaneously. The manager must evaluate the significance of the conflict and develop an alternate path for project completion. The simplest form of a process modification is a direct resource releveling, focused on minimizing the impact on the integrated schedules. This releveling specifically involves moving the start and/or finish times for tasks so as to develop a relatively constant utilization profile for resources. In some cases, it may not be possible to directly relevel a resource simply because of a serious overcommitment of that resource. In this case, modifications to either the prioritization or optimization steps will be required. In extreme cases, modifications to the initial strategy may be

necessary. These steps are indicated on Figure 1 as the feedback arrows leaving each model element back to the various earlier elements.

Chapter 2

STRATEGIC ANALYSIS

2.1 Strategic Analysis Literature Review

The importance of basing the entire project selection process on a well-defined strategic analysis cannot be overstated. The actual selection, design, procurement, installation, and startup phase of a project can take many months, even years, and therefore, a significant amount of pre-planning is essential so as to not squander valuable resources. Indeed, assuring that a project contributes to the long-term strategy of an operation is essential.

There are numerous publications discussing the importance and application of strategic planning to technical management situations involving research and development (R&D), some of which are referenced here. Cory [14,15] discusses the importance of the strategic planning process and its relationship to technical management. Cory states that "technical management is the integrated practice, i.e., process, between business and the technical disciplines that are required to plan, develop, apply or install technological capabilities for products or services to form and achieve, successfully, the strategic and operational objectives in an enterprise." The strategic planning process is designed to develop and implement a course of action or direction that a company will pursue to achieve its objectives. Gottinger [16] further develops the statement of need by discussing the technical problems

confronted when R&D project managers try to select an optimal combination of related projects. The major goal of his work was to establish a decision-making tool for R&D strategic management that enables one to make choices on projects at a firm or industry level. He further points out that for large, multi-dimensional problems, heuristic techniques cannot be easily applied and a tool should be developed for a sequence of milestones that first establishes a quantitative decision-analytic model but results in a user-friendly intelligent decision support tool for selection.

A number of such tools exist and the Analytic Hierarchy Process (AHP) has been selected as a tool to facilitate the selection process. This tool is widely accepted as a decision support tool and is used in industrial R&D project selection. Liberatore [17,18] discusses a number of applications of decision making tools with emphasis on the use of AHP. Finally, Dyer [19] has performed a review of the literature and discusses the future use of decision support systems over the next decade. According to Dyer, a key feature of these works is a methodology which allows for a hierarchical structure that includes both subjective and uncertain information to be used to link the R&D project selection decision to strategic planning.

The purpose of strategic planning is to determine the actions to be taken in the immediate future to best prepare for the uncertain distant future. Obviously, maintaining flexibility and remaining uncommitted allows for greater freedom in responding to future changes. Conversely, definite plans and commitments provide the foundation for the efficient achievement of specific goals. Saaty and Kearns [20]

use this duality dilemma to provide a foundation for their approach to strategic planning. First, they believe that strategic planning is an ongoing process that involves both forward and backward thinking. The forward process begins with the consideration of current factors, influences, and objectives that together yield a set of potential sensible and logical future states. In contrast, the backward planning process starts with a desired future scenario and then works backwards to identify factors and intermediate outcomes that are necessary to produce the desired future. Iteration back and forth between the forward outcomes and the desired outcomes can then identify the actions needed to reach the desired future.

The primary challenge facing the Nuclear Material Technology Division is in establishing a basis for strategic direction. For private organizations, the basis for their strategy is the maximization of profits to shareholders, but for a non-profit institution, success is measured by how well it provides service to its sponsors and customers. The Division does not generate profits, nor does it measure success by return-on-investment. In a strategic management sense, establishing a clear vision of the future, which includes metrics of success, is extremely difficult because of the lack of a clear basis for assessment. This difficulty means that a non-profit institution can find it difficult to quickly respond to threats, opportunities, and changes in the business environment. The lack of a profit measure represents a constraint to effective distribution of resources. Koteen [21] states, "Experts with experience both in government and industry concede that differences between profit-oriented and not-

for-profit organizations exist.” He notes that the profit measures for business give managers a control far superior to the tools that exist in a non-profit organization. Managers can make decisions in terms of effect on profit and can measure performance on the basis of earned values. Service-based measures, such as those provided by not-for-profit organizations, are less tangible. It is difficult to know exactly how much service is rendered or to know precisely how much money needs to be spent to achieve a customer-specified goal. The most serious problem is in defining objectives, thus making it difficult to decide on the amount of resources required to achieve objectives. It then becomes almost impossible to measure the efficiency and effectiveness with which the organizations operate to meet their objectives.

2.2 Establishing Strategic Emphasis

Keeping this service-oriented focus in mind, it is imperative to establish a measurable mechanism for determining strategic emphasis. The mechanism must result in a product that integrates the desires of various sponsors and business areas with the core capabilities of the organization and can be used in a semi-quantitative fashion to make detailed decisions concerning the selection of projects to fund. The approach demonstrated here involves the use of a pair-wise comparison technique, coupled with the *Expert Judgments* approach, which results in a relative measure of importance for strategic alternatives. The relative measure can then be used for tactical decision making. The first step is to establish the areas of strategic emphasis and then to

formulate them into a framework from which importance-weighting can be derived. The approach used was to assemble together the senior managers within the plutonium facility as well as the program managers from around the Laboratory (a team of experts) and to discuss where plutonium facility operations are envisioned to be in the 10 year time frame. Included in this discussion was an evaluation of the status of the nation's plutonium inventory and how that inventory was to be used in the future. It also included a discussion of the public expectations for handling plutonium. Five key business interests were identified and are listed in Table 1.

It is important to note that the possible business interests discussed were reduced to the five categories. Indeed, each of these business interests involves unique products which are, for the most part, independent of each other. In addition, all of the nation's plutonium activities are included within these business interests; the entire national focus for plutonium management is included within these five categories. Finally, numerous sponsors contribute to the technologies necessary to succeed in each business interest, but the sponsor relationships are not unique to each business interest. In other words, an individual sponsor contributes to technologies that facilitate success in a number of business areas simultaneously. Investments in these technologies represent the core for future project selection.

Each of the business interests commands a different level of attention on the basis of the importance of the activities being performed within the area. Establishing

the level of preference is the first key task in identifying the strategic emphasis that each business sector contributes to the overall strategy for the plutonium facility.

Table 1: The Consensus Listing of Strategic Business Interests

	Business Interests	Activities Involved
1.	Nuclear Weapon Stockpile Management (Stk Mngt)	Surveillance of weapon components, fabrication and requalification of stockpile components, dynamic materials testing and science.
2.	Nuclear Materials Based Energy Futures (Energy)	Terrestrial and space based nuclear power generation.
3.	Management of Special Nuclear Material Liabilities Resulting From Cold War Activities (Mat Liab)	SNM stabilization, material disposition, environmental cleanup, excess facility decontamination and decommissioning.
4.	Support to Nuclear Non-Proliferation and Arms Control Initiatives (NonProl)	International safeguards, SNM identification and tracking.
5.	Maintaining High Quality and Legally Compliant Facility Operations (Oprtnl)	Conduct of operations, training and certification, waste management, health and safety, security, information and resource management.

Using AHP, this preference is established by having the team of senior managers perform pair-wise comparisons between the business sectors. Table 2 shows the matrix developed for the comparisons that are produced by the software program *Expert Choice*. *Expert Choice* is one of several software packages that implements AHP. (Note: A thorough discussion of AHP is not intended here as the details of the process are well documented elsewhere [22,23,24,25].) The goal of this high-level set of comparisons is to “identify the relative importance of business areas to the success of TA-55 in the 10 year time frame.”

The numbers in the matrix are to be read as follows: the row element is X times more important than the column element. For instance, Stockpile Management (Stk Mngt) is 2.0 times more important than Materials Liabilities (Mat Liab) in meeting

Table 2: Comparison of the Relative Importance of Business Areas

	Stk Mngt	Mat Liab	Opertnl	NonProl	Energy
Stk Mngt	1.0	2.0	5.0	7.0	9.0
Mat Liab		1.0	2.0	5.0	7.0
Opertnl			1.0	3.0	6.0
NonProl				1.0	5.0
Energy					1.0

the long-term goals of the plutonium facility. To determine the remaining entries in the pair-wise comparison matrix, the reciprocal values of the preference ratings for the existing assessments can be assumed. This means that if Stockpile Management is 2.0 times more important than Materials Liabilities, then Materials Liabilities is 0.5 times more important than Stockpile Management. Table 3 shows the completed matrix, including the reciprocal relationships.

Once the matrix of pair-wise comparisons has been developed, a synthesis of the matrix can be performed. This synthesis will result in a relative priority of each of the business sectors being compared. The synthesizing process is performed as follows:

Step 1: Sum the values in each column of the pair-wise comparison matrix.

- Step 2: Divide each element in the pair-wise comparison matrix by its column total; the resulting matrix is referred to as the normalized pair-wise comparison matrix.
- Step 3: Compute the average of the elements in each row of the normalized matrix; these averages provide an estimate of the relative priorities of the elements being compared. It is the Eigen Vector for the matrix.

Table 3: Comparison of the Relative Importance of Business Areas, Including Reciprocal Relationships

	Stk Mngt	Mat Liab	Opertnl	NonProl	Energy
Stk Mngt	1.0	2.0	5.0	7.0	9.0
Mat Liab	0.5	1.0	2.0	5.0	7.0
Opertnl	0.2	0.5	1.0	3.0	6.0
NonProl	0.14	0.2	0.33	1.0	5.0
Energy	0.11	0.14	0.17	0.2	1.0

Appendix A contains the detail of the Eigen Vector calculations for the synthesis previously described. Figure 2 displays the results of the synthesis and shows the computed priority values for the five business sectors together with a bar chart giving a visual assessment of the priorities.

Also noted in Figure 2 is a factor referred to as the *Consistency Ratio*. An important consideration in terms of the quality of the results relates to the consistency of the judgments. For example, consider the interpretation in Table 2 as follows. Stockpile Management is considered twice as important as Materials Liability and five times as important as Operations. Using this information, we would deduce that

Materials Liability would be 2.5 times as important as Operations. In fact, the expert judgments valued Materials Liability as being only 2.0 times as important as Operations. This fact introduces inconsistency into the synthesis step. Perfect consistency is very difficult to achieve when dealing with a large matrix (larger than a 3 X 3 matrix) using expert judgment as the source of input information. To handle the

Figure 2: Synthesis Results Showing Relative Importance of Each Business Area

consistency question, AHP provides a method for measuring the degree of consistency by computing a inconsistency ratio. The ratio is designed such that values of the ratio exceeding 0.10 are indicative of inconsistent judgments. If this is the case, a review of the decision results is warranted. Values of the inconsistency ratio of 0.10 or less are considered to indicate a reasonable level of consistency in the pair-wise comparisons. As noted here, the ratio of 0.07 is well below the 0.10 indicator and therefore, no further evaluation is necessary. The actual calculation of the inconsistency ratio can be seen in Appendix B.

2.3 Management Issues Involving Strategic Analysis

It is first important to recognize that an organization's senior managers are primarily responsible for formulating and implementing the strategic plans for the organization as a whole. However, managerial positions with strategic management responsibility are by no means restricted to a few senior managers. The strategic management function directly involves all managers with line authority across the organization. For successful implementation of strategy, managers must evaluate the impact of their strategic decisions on those aspects of the plan to be carried out in their area of responsibility. This reality means that strategic planning should not be a high-level function but rather needs to engage those managers responsible for implementing the strategic directions of the organization.

The issues to be evaluated, therefore, first involve the question of who is involved in the strategic analysis. The most important individuals include the senior executives, the functional line managers, and the managers of the liaison functions with the sponsors. Indeed, it may be appropriate to include key sponsors in assessing the impact of various business areas on the strategic decisions. In the example discussed earlier, the entire line management and marketing (program) management was fully involved in the evaluation.

Once this question has been adequately addressed, the next step is to evaluate the results of the strategic analysis. The analysis must be consistent with both the direction that environment/customer forces are moving the business and the direction

that management wishes to move the organization. In rare cases, organizations can create market direction/opportunity through strategic initiative. In this research, however, the first key question to be asked is if the plutonium facility's strategic direction is consistent with that of the DOE. The answer to this question is 'yes'. In particular, the department is de-emphasizing major production operations and downsizing to smaller and more flexible operations, which are consistent with those activities existing at the TA-55 plutonium facility. Moreover, there is clearly an emphasis on environmental remediation and waste management as a logical transition away from the Cold War production initiatives while there still remains a requirement to maintain the nuclear deterrent. Disposition of excess nuclear materials is an emerging initiative. Finally, the recent records of decision from the Secretary of Energy indicate that the TA-55 plutonium facility is a focus of future programmatic emphasis within the plutonium community.

The final question to be evaluated is whether the levels of importance arrived at for each business thrust are viewed to be appropriate. This question is a subjective one and must meet the "gut" test for those charged with implementation. There is no analytic test to evaluate the appropriateness of the levels. The distribution of importance must engender commitment to the strategic management process, provide guidance to the entire management hierarchy about strategic directions, and provide management with a rationale for evaluating competing requests for investments, whether they be for people, space, or new facilities. The initial answer to this

question comes from the managers involved. The ultimate answer comes from the degree of success associated with the implementation of initiatives within the selected strategic business areas.

Chapter 3

PRIORITIZATION: USING THE RESULTS OF STRATEGIC PLANNING TO PRIORITIZE PROJECTS

3.1 Prioritization Literature Review

Successful project management involves three major phases: planning, scheduling, and control. The initial step in the planning phase involves identifying the main activities to be performed, which includes prioritizing them in a sequence consistent with meeting the objectives of the organization, whether they be short or long term. Indeed, prioritizing activities is the necessary precursor to the actual selection of activities to be performed. Ruusunen and Hamalainen [26] point out that many companies use financial measures, e.g., payback period, return-on-investment, or cost/benefit analysis, to evaluate the benefits of a project, but scoring models using subjective criteria can be employed where cost-based criteria are not available or appropriate. Possible criteria can include technical risk, strategic importance, equipment availability, and manpower availability. Each project in question is evaluated against the criteria, and the resulting vector of scores is used to analyze the strengths and weaknesses of the project. An overall benefit measure is obtained from a synthesis of the scores, and the relative ranking of those scores, represents the priority of selection.

The project selection problem has been one of interest for many years and numerous publications have appeared in the literature. Overviews on project selection are compiled by Booker and Bryson [27,28], Steele [29], Danila [30], Sanchez [31], and Baker and Freeland [32]. The project selection techniques discussed include: 1) scoring and ranking, 2) mathematical programming, 3) economic evaluations such as net-present-value or return-on-investment, 4) decision analysis such as AHP, and 5) artificial intelligence such as expert systems and fuzzy logic. In spite of the potential usefulness of decision analysis in project selection shown in the literature, the citations of industrial applications are not evident. In fact, authors lament the lack of industrial application [33,35,36].

From an academic standpoint, the more recent trend has been to combine a number of different approaches into an integrated system, commonly referred to as a Decision Support System (DSS). For example, managers may combine scoring with Delphi to obtain a relevant ranking of priorities and evaluate information using net-present-value analysis. In combining a number of tools, sensitivity analysis can be performed analyze "what if" questions. However, engineering managers have made little use of the integrated methods appearing in the literature [31,33,34]. The basic reasons have to do with academic battles between rival decision analysis methods, complexity of application, and the intense demand for input data [31,33,34,35,36]. Consequently, to develop a method that will be usable in an industrial environment, it

is essential to devise a methodology that addresses these three issues and still provides the flexibility to be easily maintained and updated.

3.2 Establishing Project Priority Structure [37]

The challenge facing the TA-55 plutonium facility is to establish the priority of a large number of projects and to ensure that the selection is consistent with the strategic direction of the operations. The *Ratings* assessment approach, imbedded within *Expert Choice*, combines the flexibility of the hierarchy and the pair-wise comparison process with the capability to rate a large number of projects. The basis for the *Ratings* approach is to establish standards for the criteria and compare each alternative against those standards. The approach enables decision makers to evaluate a large number of options, prioritize them against a common set of criteria, and make decisions concerning selection. It is important that the individuals doing the ratings be very familiar with the standards and that they are comfortable comparing alternatives against them.

In the model being developed here, the first level of standards is represented as the area of strategic emphasis and is therefore the basic criterion being used to evaluate the project priorities. The projects must then be rated against their contribution to success in each strategic area by using the second level of standards of evaluation. The standards are referred to as the scale of intensity. The scale of intensity for each criterion appears as a group of nodes under the strategic emphasis

criterion nodes. The intensity categories are prioritized through the pair-wise comparison process discussed previously and are then used in conjunction with the *Ratings* spreadsheet to perform the prioritization. Table 4 identifies and defines the standards being used to perform the assessment together with the intensities which have resulted from the pair-wise comparison of standards. (See Appendix C for the calculations of intensities found in Table 4 and used in Table 5. The calculation procedure is defined in Appendix A.) Table 5 displays the hierarchy being used for the decision process, including the placement of the standards into the decision structure.

Table 4: Standards and Intensities Developed for Evaluating Project Prioritization

Standard	Intensity	Definition of Standard
High	1.00	Program will fail without the project.
Medium-High	0.52	Project results in money savings and/or project delays will result without selection.
Medium	0.27	Acceptable alternatives, routine upgrade to existing equipment, or moderate programmatic delays will occur.
Medium-Low	0.14	Project is desirable but only slight programmatic impact will occur.
Low	0.07	Project is desirable but no programmatic impact will occur.

Inconsistency Ratio = 0.05

The column in Table 4, referred to as "Intensity," identifies the standard weights for use in the evaluation. These weights are inserted into Table 5 as a set of nodes below each category of the strategic emphasis, as shown from Table 2.

Judgments are then entered by assigning to the alternatives the appropriate intensity for each criterion. Note that the inconsistency ratio found by calculating the intensities is 0.05. As mentioned earlier, an inconsistency ratio of 0.10 or less is considered acceptable and, therefore, a further evaluation of the pair-wise comparison matrix is not necessary.

Table 5: Decision Hierarchy Tree Showing the Relationship of Selection Standards

GOAL (1.000)				
Stk Mngt (0.483)	Energy (0.031)	Mat Liab (0.263)	NonProl (0.075)	Oprtnl (0.149)
High	High	High	High	High
Med-High	Med-High	Med-High	Med-High	Med-High
Medium	Medium	Medium	Medium	Medium
Med-Low	Med-Low	Med-Low	Med-Low	Med-Low
Low	Low	Low	Low	Low

The total of ratings across all of the criteria becomes the performance measure for the alternative. Appendix D lists the project alternatives to be considered in the prioritization and subsequent optimization. A subset of Appendix D is shown as Table 6. This table (and Appendix D) is generated using the "ranking" option of the AHP and demonstrates the application of the decision hierarchy tree shown in Table 5. The first column of the table indicates the titles of the alternatives. The second column (entitled "Total") indicates the mathematical synthesis of the evaluation arrived at by applying the scoring of intensities to the strategic weightings of each

Table 6: Project Alternatives Showing Rank Scoring Results (partial table)

	Alternatives	TOTAL	Stk Mngt	Energy	Mat Liab	Non Prol	Oprrtl
			4825	0310	2627	0749	1489
1	Replace Air Compressor	1.000	High	High	High	High	High
2	Replace TA-55 Fire Protection	1.000	High	High	High	High	High
3	Install Nitric Acid Tanks NMT-2	0.901	High	Low	High	Low	High
4	Replace Nitric Acid Supply Line	0.901	High	Low	High	Low	High
5	Install ARIES System, NMT-6	0.795	High	Low	High	Med-High	Low
6	Wet and Dry Vacuum Pumps	0.639	Med-High	Med-High	High	Med-High	Med-High
7	Upgrade ROBOCAL Phase I	0.612	Med-High	Medium	Med-High	High	High
8	In-line U Analyzer SRL, NMT-6	0.607	High	Low	Medium	Medium	Medium
9	Replace GB	0.586	Med-High	Low	High	Med-High	Medium
10	Server for Maintenance Management	0.583	Med-High	Med-High	Med-High	Med-High	High
11	Fire Alarm Control Panel Upgrade	0.583	Med-High	Med-High	Med-High	Med-High	High
12	Pit Surveillance Leak Detector	0.565	High	Low	Medium	Low	Low
13	Pit Rebuild Leak Detector	0.565	High	Low	Medium	Low	Low
14	Process Control System Upgrade	0.565	High	Medium	Low	Low	Low
15	Declass. Furnace for SRL	0.565	High	Medium	Low	Low	Low
16	Install Continuous Air Monitors	0.560	Medium	Medium	High	Medium	High
17	Install CLEAR GB line, NMT-2	0.553	Med-High	Low	High	Low	Medium
18	Procure GC Mass Spec., NMT-6	0.540	Medium	Low	High	Low	High
19	Install HCl Delivery Piping	0.534	Med-High	Low	High	Low	Med-Low
20	Mod HVAC	0.532	High	Low	Med-Low	Low	Low
21	Relocate Foundry GB	0.516	High	Low	Low	Low	Low
22	Install Services to 40mm, NMT-9	0.516	High	Low	Low	Low	Low
23	Inspection Area Trunk Line	0.516	High	Low	Low	Low	Low
24	NMT-5 Sheffield Rot. Cont. Gage	0.516	High	Low	Low	Low	Low
25	NMT-5 Ring-Rotocon GB	0.516	High	Low	Low	Low	Low
26	Install PIGMA welder, NMT-5	0.516	High	Low	Low	Low	Low
27	Install New Main T-Base Lath	0.516	High	Low	Low	Low	Low

See Appendix D, "Project Alternatives Showing Rank Scoring Results."

strategic area for each project alternative. The result, as indicated in Table 6 and Appendix D, is a rank ordered priority for projects on the basis of their importance in meeting the overall strategic emphasis for the operations. A sample calculation follows. For project number 3, "Install Nitric Acid Tanks," the total score of 0.901 is calculated this way:

$$\begin{aligned} \text{Total} = 0.901 = & 0.4825(1.00) + 0.0310(0.069) + 0.2627(1.00) + \\ & 0.0749(0.069) + 0.1489(1.00). \end{aligned}$$

Thus far, the ranking indicates only a subjective prioritization against overall facility strategies. The ranking does not yet take into account constraints within the operations, such as installation labor, and neither does it take into account budgetary limitations. Therefore, a further analysis is necessary to ensure that the projects selected are not only of high priority but can be satisfactorily accomplished within resource and financial constraints. Resource optimization is the approach selected for performing this analysis.

3.3 Management Issues Involving Project Prioritization

The AHP technique has several advantages. It is easy to use, it easily monitors the consistency of the expert's evaluations, and it easily quantifies qualitative information. These reasons make the technique directly suitable for evaluating projects against a set of criteria. The first management question is whether the strategic level hierarchy represents an independent set of criteria. In other words, a

high rating on one criteria (Energy) should not imply a high rating on another criteria (NonProl). Responses on each branch of the hierarchy must be as independent as possible of each other. Because of the selection of the *Ratings* approach, feedback cycles within the hierarchy are not allowed. Although this may be viewed as a possible problem, in a strategic hierarchy, feedback calculations should not be necessary.

The second issue of concern has to do with the relative weights of the scoring intensities, and the third issue has to do with the ranking results for the various projects. Because they are intimately linked, they should be evaluated together. In the example demonstrated here, the scoring intensities do not represent a linear set. Remember that the intensities are arrived at through a pair-wise comparison of the standards. The best approach for evaluating the intensities is to examine the scoring results of the various project alternatives. The question to be answered is whether the list indeed does represent a logical hierarchy of projects, given the experts' knowledge of the market place and sponsors' desires. No mathematical proof can be applied to determine if the rankings of the projects seems to represent an appropriate list.

In the event that the project ranking does not represent an acceptable list, either the intensity ratings or the strategic scores must be further examined. The AHP does not provide an easily applied sensitivity analysis approach in evaluating the impact of change of the strategic scores on the overall ranking of projects resulting from the use of the *Ratings* approach. As a result, either a re-assessment of the pair-

wise comparisons for the strategic analysis or a re-evaluation of the pair-wise comparison for the standards should be performed. Once performed, a re-synthesis of the ratings of projects can be performed. This set of steps is relatively straight forward and can be accomplished with no requirement to reenter individual project scores.

Chapter 4

OPTIMIZATION

4.1 Optimization Literature Review

The object of optimization is to select a portfolio of projects from the list of candidates that optimizes the objective function and yet still satisfies the priorities identified to meet overall facility strategies. The traditional methods for project selection tend to rank or rate projects individually, without taking into account the various interactions, dependencies, or interdependencies among projects. They also do not take into account alternative uses for constrained resources devoted to completing all projects. The optimization must take into account resource dependencies, budget constraints, technical interactions, and program considerations.

The optimization method used is mathematical programming. A number of authors discuss the key aspects of project interactions, with particular emphasis on using mathematical programming to overcome resource distribution questions in project selection. Martino [38] discusses project selection methods and demonstrates the use of mathematical optimization (linear optimization) coupled with spreadsheets. He also discusses the importance of evaluating the various interactions and constraints critical to making engineering decisions. Martino's example demonstrates spreadsheet optimization using a financial basis for optimization to include profit and return on investment. Madey and Dean [39] also discuss the use of linear optimization but

include the use of Multi-Attribute Utility theory as a basis for evaluating criteria before performing the optimization. In this work, Madey and Dean include financial criteria, such as return-on-investment, sales growth, and corporate profit, as the bases for decision of evaluation but concede that the modeling approach is academic in nature and difficult to implement in practice. Their reasons for this conclusion include inadequate treatment of risk and uncertainty in the criteria; inadequate treatment of multiple, often interrelated, criteria in the initial assumptions; and incomplete knowledge of the decision managers. They do go on to point out that the next generation of engineering management models may begin to use the technology and results of several developing areas such as microcomputers, user-friendly software, spreadsheet software, and the incorporation of decision making preference structures.

Ringuest and Graves [40] develop an approach they refer to as multi-objective linear programming, used to produce a set of R&D project selection problems as an alternative to the net present value approach. Their approach continues to use budget considerations for comparisons of R&D projects and is simplex-based. However, it still represents a complicated approach for decision making because it requires the use of "filtering and clustering algorithms" to simplify the decision matrices.

Two other authors, Schmidt [41] and Taylor et al. [42], both discuss the importance of evaluating resource interactions as constraints in mathematical programming. They point out the necessity that the project selection process be viewed as a multi-criteria decision-making problem. They also develop a probability

of success approach for resource utilization based on budget expended. Again, the basis for project selection is budget based. Finally, Ragsdale [43] introduces the use of spreadsheet modeling for decision analysis. He demonstrates the use of the EXCEL Solver add-in option. This reference develops the linear programming for optimizing constrained resources in project selection situations.

Overall, the current literature in this area is beginning to address the incorporation of computer-based systems with user-friendly software in an effort to make decision-support systems more available to practicing industrial managers. The need to couple multi-attribute prioritization with mathematical optimization is also beginning to be recognized.

4.2 Project Interactions [38]

Projects cannot be considered in isolation because there are many interactions that require considering the effects of one project on another. For instance, different projects will require using the same resource, such as designers, quality engineers, and skilled craftsmen. They may also include resources that can be saturated, such as analytical equipment and computer services. The object of taking resource dependencies into account is to ensure that adequate resources are available to complete each task. Operating budget is also considered a constraint in that the expenditures on projects must stay within the available funds. This constraint means that projects must be selected that do not exceed the funds available for any period

and that sufficient funds are available to satisfactorily complete the portfolio of selected projects. Technical interactions represent another category of concern that optimization can help address. More than one project may lead from the successful completion of a prior project. Failure of the prior project may lead to delays or cancellation of subsequent projects. Therefore, the selection criteria can be configured in such a way to avoid common-point failures in the chain of projects. Finally, program considerations may drive the selection of projects so as to violate the strategic prioritization. For instance, a project may be performed at the request of sponsors independent of how it contributes to organizational importance. This project will reduce the optimal use of resources but may be deemed important for programmatic considerations.

4.3 Structuring for Optimization

The first step in preparing for optimization is to identify which resources are being used by the projects, using the prioritization results as a basis for initial selection. Starting with those projects deemed to be of highest priority, a resource requirement profile for further evaluation is developed. Figure 3 is a functional flow block diagram which represents an expansion of Figure 1 and identifies points in the decision path where resource information is necessary to begin optimization of constrained resources.

Figure 3: Expanded Logic Diagram for Decision Process

After prioritization has taken place, each project must be evaluated for resource requirements to include an initial evaluation of time durations for each step. Figure 3 indicates this data gathering step, entitled "Resource and Time Duration Estimates," which is further broken down into fundamental steps for project estimating. Each of the fundamental steps represents a need for a different type of constrained resource. Table 7 indicates the types of resources necessary in completing each step.

Referring to Figure 3, the key steps in performing tasks are noted, and reasonably accurate resource and time durations are needed to perform the optimization. Initially, a project design is required and, if necessary, procurement of long-lead equipment items should take place. Therefore, estimates of the time required for performing these tasks for each project are necessary together with an assessment of the total design and procurement time that is available for all projects.

The second step is technical design review. This step is generally of short duration and involves the technical experts on the project in ascertaining if the design meets the intended technical goals. Generally these resources are dedicated to the project and are therefore not constrained in terms of optimization. If, on the other hand, they are constrained resources, an estimate of the time duration and numbers of people involved are necessary.

The third step in the estimating involves an independent design change package approval and generally requires the use of facility-wide engineering skills. The

main purpose of this independent review is to evaluate each new installation or facility modification in terms of its impact to existing facility configuration and safety standards. This is an especially important step in large complex operations where a number of changes are taking place simultaneously. Indeed, it is of critical importance to ensure that the impact of change in one area does not introduce deleterious effects to adjacent areas. Generally, the resources in this area are limited (constrained) and estimates of their need are essential.

Table 7: The Types of Resources Required to Complete a Project

Fundamental Step	Description of Activity and Resource Type Required
1. Experimental Design and Procurement Estimates	Engineering Design or Change of Equipment. Also included is the procurement of long lead time equipment. Key resources are design engineers, project engineers, design draftsmen, and procurement specialists.
2. Technical Design Review Estimates	Design review by both project leader and the organization to be responsible for operating the equipment. Design must be able to meet programmatic intentions.
3. Design Change Package Approval Estimates	Facility Engineering Review of design to confirm if design conforms with overall facility safety and operational standards and configuration. Key resources are facility system engineers.
4. ESH Review Estimates	ESH review to confirm if design conforms to operational safety standards. Key resources are facility safety engineers.
5. Skilled Labor, Type, Quantity, and Time Estimates	Estimating the types, amounts, and time durations of skilled labor necessary to complete the project (e.g., electricians, fitters). Key resources include skilled labor estimators and facility engineers.
6. Operational Readiness Review Estimates	Evaluation of "as-built" status of project to confirm if installation conforms with initial design and that all ESH provisions are fully addressed. Key personnel include facility engineers, project engineers, safety engineers, and line management.

The fourth step involves the performance of an ESH review that includes an evaluation of the use and control of hazardous chemicals, stored energy such as high pressure and electrical power, ergonomics, environmental emissions, and a variety of other requirements such as Occupational Safety and Health Administration (OSHA) policies.

In step 5, all of the various installation tasks must be identified and an estimate of the appropriate skilled labor categories must be made. Skilled labor includes electricians, fitters, ironworkers, teamsters, laborers, and others. In many large industrial operations, this group of employees is unionized and therefore there are often labor time guides that can be employed to gain accurate duration estimates. In addition, in unionized operations, labor rates are standardized so the cost of installation can be accurately estimated. When unionized labor is employed, all labor must be billed to specific projects which means that, in order to minimize costs, optimum use of skilled labor is important. As a result, this category is generally most constrained.

The final step in resource estimating requires identifying the personnel involved in performing the final readiness review of the project once installation is complete and ready to start-up. This step involves evaluating the as-built status of the project and comparing it to the intended design. Regularly, field modifications are made during project installation, and therefore, the final installation deviates from the original design. It is important to evaluate the modifications and determine if and

where deviations took place and then to evaluate the implications of those modifications in context with the other configuration and safety management programs.

Table 8 is a spreadsheet that takes the projects identified in Table 6 and adds to them the estimates indicated in Figure 3. The table is set up to identify the candidate projects, listed in priority order, to include:

- Column A: The title of each project.
- Column B: The Design and Procurement Cost. This cost is arrived at by multiplying the Design and Procurement Hours (columns G & H) by their respective labor rates.
- Column C: Procurement Capital. This is the funding required for large capital outlays for specific equipment.
- Column D: Procurement Operating. This is the funding required for small materials and supplies procurement.
- Column E: Installation Cost. This cost is arrived at by multiplying the Facility Engineering Hours, ESH Hours, and Skilled Labor Hours (columns I, J, K, L, M, and N) by their respective labor rates.
- Column F: Total Cost. This cost is arrived at by adding columns B, C, D and E.

Table 8: Resource Estimates Necessary to Complete Individual Projects (partial table)

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Project Title to include Design Change Packages for each Project	Design & Procure Cost (\$k)	Procure Capital (\$k)	Procure Operat (\$k)	Install Cost (\$k)	Total Cost (\$k)	Design Hours	Procure Hours	Fac Eng Hours	ESH Hours	Shtmtl Hours	Electrician Hours	Fitter Hours
2	TA-55 Compressors												
3	#9603031 (DCP 95-0-27)TA-55 Compressors R&A	7.1	0	700	42	749	100	20	40	4	0	240	480
4	TA-55 Replace Fire Protection Main												
5	#9603031 (DCP 95-0-27)TA-55 Compressors R&A	7.1	0	700	42	749	100	20	40	4	0	240	480
6	Replace Nitric Acid Supply Line												
7	#9710025 (97-005)Repl & Repair Nitric Supply Line R&A	7.1	700	0	5	712	100	20	40	4	0	0	80
8	#9711039 (97-015)Change Nitric Acid Supply Valve R&A	1.1	0	50	3	54	0	20	20	4	0	0	40
9	Acid Recycle Additional Tanks												
10	#9609036(95-0-12)NPDES Recycle	93.3	100	0	10	203	1500	60	40	4	80	16	80
11	#9407034 (DCP 95-002)Evaporator Removal R&A	0.0	0	0	16	16	0	0	20	4	160	40	80
12	ARIES												
13	#9601012B1 (96-026B1) ARIES Move	2.4	0	0	21	23	40	0	20	4	80	120	160
14	#9601012E1 (96-026E1)ARIES Move	2.4	0	0	22	24	40		20	4	80	120	180
15	#9601012F (DCP 96-026F) ARIES Move Raman	2.4	0	0	10	13	40	0	20	4	60	60	60
16	#9601012F1 (96-026F1)ARIES Move	2.4	0	0	48	51	40	0	20	4	120	240	480
17	#9601012G (DCP 96-026G) ARIES Move	2.4	0	0	48	51	40	0	20	4	120	240	480
18	#9601012G1 (96-026G1)ARIES Move	2.4	0	0	32	35	40	0	20	4	80	160	320
19	#9601012H (96-026H) ARIES Inst Conveyor	49.1	150	0	75	274	800	20	30	4	700	320	320
20	#9601012I (96-026I) ARIES Relocate	24.0	0	0	21	45	400	0	40	4	80	120	160
21	#9601012J (96-026J) ARIES D&D	24.0	0	0	32	56	400	0	40	4	80	160	320
22	#9601012K (96-026K) ARIES Trolley Supp Frame	37.1	150	0	9	196	600	20	30	4	160	0	0
23	#9601012L (96-026L) ARIES Inst TNC	25.1	150	0	32	207	400	20	40	4	80	160	320
24	#9601012M (96-026M) ARIES Inst NDA	50.8	300	0	32	383	800	50	30	4	80	160	320
25	#9601012N (96-026N) ARIES Inst Elec/Dec	49.1	150	0	48	247	800	20	40	4	120	240	480
26	#9601012O (96-026O) ARIES Inst H/D	49.1	150	0	48	247	800	20	40	4	120	240	480
27	#9601012P (96-026P) ARIES Inst Pit Bis	49.1	150	0	48	247	800	20	40	4	120	240	480
28	#9601012Q (96-026Q) ARIES Inst Cann'g	49.1	150	0	48	247	800	20	40	4	120	240	480
29	#9601012R (96-026R) ARIES Inst LLNL	49.1	150	0	48	247	800	20	40	4	120	240	480
30	Wet and Dry Vacuum Pumps												
31	Procure Replacement Pumps	2.3	150	0	25	177	20	20	20	4	150	40	240
32	Upgrade ROBOCAL Phase I												
33	DCPs for Robocal	3.5	250	0	6	259	40	20	20	4	0	100	0

See Appendix E, "Resource Estimates Necessary to Complete Individual Projects."

The body of the table includes labor hours under the appropriate columns and estimated costs under the various cost columns. In column A, each project is noted in bold letters, and sub-tasks, referred to as Design Change Packages (DCP), are listed below the main project title. Generally a project will require more than one DCP because multiple activities are required to complete a major project, each requiring significant changes to facility operations. The spreadsheet now has the resource information categorized in a configuration suitable for optimization. Note that Table 8 only indicates the first page of the projects identified for optimization. Appendix E includes the entire table of projects, DCPs, labor estimates, and cost estimates.

4.4 Mathematical Optimization

To determine the optimum allocation of resources to projects, one must find the combination of projects that yield the maximum contribution to the facility strategic direction, subject to budgetary and labor constraints. This effort can be accomplished with a binary integer programming model with the objective being to maximize the relative benefits of the projects. Because there is no return-on-investment calculation possible, the benefit of each project is assessed by its total priority score in the ratings spreadsheet (Table 6). In the integer programming approach for resource allocation, the following definitions will apply:

$X_i = 1$ if project i is selected and 0 if project i is not selected

$P_i =$ Weight or priority of project i from ratings spreadsheet

C_i = Cost of project i

B = Total budget available for funding projects

R_{ij} = Resource required from each labor category j for each project i

TR_j = Total resource available for each labor category j

The integer programming objective function is therefore:

$$\text{Maximize } Z = P_1X_1 + P_2X_2 + \dots P_nX_n$$

The integer programming constraints are:

$$X_1C_{1i} + X_2C_{2i} + \dots X_nC_{ni} \leq B_i \text{ for each type of cost } i$$

$$X_1R_{1j} + X_2R_{2j} + \dots X_nR_{nj} \leq TR_j \text{ for each labor category } j$$

To perform the optimization, the optimization program in EXCEL is used.

The process function is referred to as Solver. Table 9 is developed by taking Table 8 and adding in the various columns and rows necessary for setting up the equations noted above and is therefore a spreadsheet setup for a linear programming solution to the problem.

The data in the spreadsheet is organized so that the objective function and constraint equations are clear. The top four rows of the spreadsheet, titled "Parameter Field for Calculational Purposes," indicate summary information for each decision variable. These rows are placed at the top of the spreadsheet so that the decision variables can be viewed along with the highest priority projects. In addition, having the decision variables at the top of the spreadsheet allows for the addition of new projects, both within the body and at the end of the spreadsheet, without having to

Table 9: Project Priority Spreadsheet to Include Configuration for Optimization (partial table)

	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Project Title to include Design Change Packages for each Project	EC Priority	Enable	Priority Factor	Design & Procure Cost (\$k)	Procure Capital (\$k)	Procure Operat (\$k)	Install Cost (\$k)	Total Cost (\$k)	Design Hours	Procure Hours	Fac. Eng Hours	ESH Hours	Shimil Hours	Electrician Hours	Fitter Hours
2	Parameter field for calculational purposes															
3	Total Required to Perform Work				2610	24864	2707	3652	33833	37659	2634	5442	2026	9896	13482	21161
4	Total Consumed As Selected		0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	Total Available to do Work per Four Months				398.00	1000	5000	570	6968	4800	2000	600	160	2080	3120	4680
6	Labor Rates (\$/hr.)									60	55	72	60	54	57	58
7																
8	TA-55 Compressors															
9	#9603031 (DCP 95-0-27)TA-55 Compressors R&A	1.000	0	0.000	7.1	0	700	42	749	100	20	40	4	0	240	480
10	TA-55 Replace Fire Protection Main															
11	#9603031 (DCP 95-0-27)TA-55 Compressors R&A	1.000	0	0.000	7.1	0	700	42	749	100	20	40	4	0	240	480
12	Replace Nitric Acid Supply Line															
13	#9710025 (97-005)Repl & Repair Nitric Supply Line R&A	0.901	0	0.000	7.1	700	0	5	712	100	20	40	4	0	0	80
14	#9711039 (97-015)Change Nitric Acid Supply Valve R&A	0.901	0	0.000	1.1	0	50	3	54	0	20	20	4	0	0	40
15	Acid Recycle Additional Tanks															
16	#9609036(95-0-12)NPDES Recycle	0.901	0	0.000	93.3	100	0	10	203	1500	60	40	4	80	16	80
17	#9407034 (DCP 95-002)Evaporator Removal R&A	0.901	0	0.000	0.0	0	0	16	16	0	0	20	4	160	40	80
18	ARIES															
19	#9601012B1 (96-026B1) ARIES Move	0.795	0	0.000	2.4	0	0	21	23	40	0	20	4	80	120	160
20	#9601012E1 (96-026E1)ARIES Move	0.795	0	0.000	2.4	0	0	22	24	40		20	4	80	120	180
21	#9601012F (DCP 96-026F) ARIES Move Raman	0.795	0	0.000	2.4	0	0	10	13	40	0	20	4	60	60	60
22	#9601012F1 (96-026F) ARIES Move	0.795	0	0.000	2.4	0	0	48	51	40	0	20	4	120	240	480

See Appendix F, "Project Priority Spreadsheet to Include Configuration for Optimization."

reinitialize the decision equations. The use of the information in these rows will now be discussed.

4.4.1 Defining the Objective Function

The objective of this problem is to maximize the total sum of the priority weights, based on the selection of the various projects. Recall that the priority weights were arrived at in the prioritization step and are listed in Table 9 under the column titled "EC Priority." This is column "D" in the spreadsheet. These values represent the coefficients in the maximization equation. The variables in the maximization equation are represented by the column entitled "Enable." The values in each cell in this column are constrained to be either 0 or 1 by the following spreadsheet equations. (Note: For reference purposes, this column is column "E" in the spreadsheet.)

$$\$E\$8:\$E\$317 \leq 1$$

$$\$E\$8:\$E\$317 = \text{Integer}$$

$$\$E\$8:\$E\$317 \geq 0$$

These three equations indicate that cells E8 through E317 must assume integer values no greater than 1 and no less than 0. Thus, these constraints ensure that cells E8 through E317 will operate as binary variables. The objective function of the model is implemented in cell F4 as:

Formula for cell F4: =SUMPRODUCT(D8:D317,E8:E317)

Cell F4 is referred to as the “Target Cell” in the Solver routine and the command for the target cell is to “Maximize.”

4.4.2 Defining the Constraints

The box at the top of the spreadsheet, entitled “Parameter Field for Calculation Purposes,” holds all of the constraint information together with additional information of interest to managers in evaluating the results of the optimization. The first row of the field, “Total Required to Perform Work,” is the sum total of the data in that column and indicates the total amount of that resource necessary if all projects were to be successfully completed within the allotted time. It is simply an indicator to management of the magnitude of need for all projects. Row two in the field, “Total Consumed as Selected,” represents the amount of resource used in the optimal solution. Row three in the field, “Total Available to do Work per Four Months,” represents the constraints for each resource. For example, under “Fitter Hours,” the row three value is 4680. This means that there are only 4680 hours per month of fitter time available to devote to the various projects. Note that the row one value under “Fitter Hours” is 21161, indicating that in order to do all of the projects within the month, 21161 hours of fitter time would be required. Therefore, the 4680 hours available represents a constraint to the decision on project selection. Row four in the field indicates the applicable labor rates for the various labor categories. These labor

rates are used to calculate the "Design & Procurement Cost" and the "Installation Cost." Having this parameter field at the top of the spreadsheet makes it convenient for quick evaluation and decision making.

Several constraints affect this problem. Two have to do with available dollars and are indicated in columns "H" (Procure Capital) and "I" (Procure Operating).

Procure Capital is defined as a special category of funding restricted for the procurement of large capital equipment, generally in the >\$25,000 range. Procure Operating is defined as a category of funding for use in the procurement of <\$25,000 items. The Operating dollars are also used for general spending including labor, utilities, materials, and supplies, while the Capital dollars are restricted to large item purchases that represent capital improvements to the physical plant. The equations for the two constraints are as follows:

Formula for cell H4, Procure Capital: =SUMPRODUCT(\$E\$8:\$E\$317,H8:H317)

Formula for cell I4, Procure Operating: =SUMPRODUCT(\$E\$8:\$E\$317,I8:I317)

In the formulas for cells H4 and I4, the values in the range E8 through E317 are multiplied by the corresponding values in the range H8 through H317 and I8 through I317, respectively. These individual products are then added together. Therefore, the formula is simply the sum of the products.

The next set of constraints has to do with the labor categories. In Table 9, the various labor categories occupy columns "L" (Design Hours) through "R" (Fitter Hours). In the problem, there is insufficient labor available in all categories as

identified by comparing the “Total Required to Perform Work” row with the “Total Available to do Work per Four Months” row. The equations identified above for cost are duplicated for the various labor categories.

Formula for cell L4, Design Hours: =SUMPRODUCT(\$E\$8:\$E\$317,L8:L317)

Formula for cell M4, Procure Hours: =SUMPRODUCT(\$E\$8:\$E\$317,M8:M317)

Formula for cell N4, Fac. Engr. Hours: =SUMPRODUCT(\$E\$8:\$E\$317,N8:N317)

Formula for cell O4, ESH Hours: =SUMPRODUCT(\$E\$8:\$E\$317,O8:O317)

Formula for cell P4, Shtmtl Hours: =SUMPRODUCT(\$E\$8:\$E\$317,P8:P317)

Formula for cell Q4, Electrician Hours: =SUMPRODUCT(\$E\$8:\$E\$317,Q8:Q317)

Formula for cell R4, Fitter Hours: =SUMPRODUCT(\$E\$8:\$E\$317,R8:R317)

4.4.3 Setting up the Constraints and Solving the Model

To solve the optimization, the target cell, changing cells, and the constraint cells must be identified. As previously mentioned, the Solver add-in routine in the EXCEL program is used to perform the optimization. Therefore, by clicking the Tools/Solver command, the Solver parameters dialog box is shown. The target cell represents the results of the optimization and is located in cell F4. Below the target cell entry is indicated the “Max” button, which indicates the optimization goal. The changing cells represent the decision variables in the model, and are cells E8:E317. Solver will determine the optimal selection of cells during the optimization. Next the constraint cells are defined. The constraint formulas and cells are as follows:

Constraint Formula for Binary Integer:	$SE\$8:SE\$317 \leq 1$
Constraint Formula for Binary Integer:	$SE\$8:SE\$317 = \text{Integer}$
Constraint Formula for Binary Integer:	$SE\$8:SE\$317 \geq 0$
Constraint Formula for Procure Capital:	$SH\$4 \leq SH\5
Constraint Formula for Procure Operating:	$SI\$4 \leq SI\5
Constraint Formula for Design Hours:	$SL\$4 \leq SL\5
Constraint Formula for Procure Hours:	$SM\$4 \leq SM\5
Constraint Formula for Fac. Engr. Hours:	$SN\$4 \leq SN\5
Constraint Formula for ESH Hours:	$SO\$4 \leq SO\5
Constraint Formula for Sheetmetal Hours:	$SP\$4 \leq SP\5
Constraint Formula for Electrician Hours:	$SQ\$4 \leq SQ\5
Constraint Formula for Fitter Hours:	$SR\$4 \leq SR\5

After entering the appropriate parameters, the optimization can be performed by initiating the "Solve" function. The first page of the optimal solution is shown in Table 10, with the entire solution table shown in Appendix G.

4.5 Management Analysis of the Optimization Results

The optimal solution shown in Table 10 indicates the results of project selection once an analysis of the constrained resources are taken into account. Table

10 indicates that, over a 4 month period of time, 56 projects can be accomplished (cell E4). Looking down column E, there are a number of ones and zeros. In each cell where a one is indicated, that project has been selected to be performed. Each cell where a zero is indicated suggests that that project cannot be performed, assuming optimization of the objective function. Row 4 of Table 10 indicates the details of the optimization. The results are read as follows:

Cell F4: This indicates the value of the optimization of "priority factor." This is the target cell for optimization. In the example shown in Table 10, the optimum solution occurs when the sum of priority values totals 30. Any other combination of projects results in a priority factor either being smaller than 30 or in one of the resource constraints exceeding its limit.

Cell G4: This indicates that the total Design & Procurement Cost for doing the 56 projects is \$306K. The maximum allowable would be \$398K (cell G5). The maximum allowable is calculated using the maximum allowable Design and Procurement hours times their respective hourly rates. The fact that the cost of the projects is less than allowable indicates that not all Design and Procurement hours were exhausted in performing the 56 projects. This further indicates that it might be possible to reduce the number of Design and Procurement hours available and to move those resources elsewhere in the resource set in order to achieve a better optimization.

Table 10: Project Priority Spreadsheet Indicating Optimal Solution (partial table)

	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Project Title to include Design Change Packages for each Project	EC Priority	Enable	Priority Factor	Design & Procure Cost (\$k)	Procure Capita (\$k)	Procure Operat (\$k)	Install Cost (\$k)	Total Cost (\$k)	Design Hours	Procure Hours	Fac. Eng Hours	ESH Hours	Shutnd Hours	Electrician Hours	Fitter Hours
2	Parameter field for calculational purposes															
3	Total Required to Perform Work				2610	24864	3707	3611	34791	37659	2634	5442	2026	9896	13242	20681
4	Total Consumed As Selected		56	30	306	1000	2462	351	4388	4781	343	600	147	1060	1686	3270
5	Total Available to do Work per Four Months				398.00	1000	5000	570	6968	4800	2000	600	160	2080	3120	4680
6	Labor Rates (\$/hr.)									60	55	72	60	54	57	58
7																
8	TA-55 Compressors															
9	#9603031 (DCP 95-0-27)TA-55 Compressors R&A	1.000	1	1.000	7.1	0	700	42	749	100	20	40	4	0	240	480
10	TA-55 Replace Fire Protection Main															
11	LN06526(97-014)Repl Fire Protection Main R&A*	1.000	1	1.000	7.1	0	1700	0	1707	100	20	40	4	0	0	0
12	Replace Nitric Acid Supply Line															
13	#9710025 (97-005)Repl & Repair Nitric Supply Line R&A	0.901	0	0.000	7.1	700	0	5	712	100	20	40	4	0	0	80
14	#9711039 (97-015)Change Nitric Acid Supply Valve R&A	0.901	1	0.901	1.1	0	50	3	54	0	20	20	4	0	0	40
15	Acid Recycle Additional Tanks															
16	#9609036(95-0-12)NPDES Recycle	0.901	1	0.901	93.3	100	0	10	203	1500	60	40	4	80	16	80
17	#9407034 (DCP 95-002)Evaporator Removal R&A	0.901	1	0.901	0.0	0	0	16	16	0	0	20	4	160	40	80
18	ARIES															
19	#9601012B1 (96-026B1) ARIES Move	0.795	1	0.795	2.4	0	0	21	23	40	0	20	4	80	120	160
20	#9601012E1 (96-026E1)ARIES Move	0.795	1	0.795	2.4	0	0	22	24	40		20	4	80	120	180
21	#9601012F (DCP 96-026F) ARIES Move Raman	0.795	1	0.795	2.4	0	0	10	13	40	0	20	4	60	60	60
22	#9601012F1 (96-026F1)ARIES Move	0.795	1	0.795	2.4	0	0	48	51	40	0	20	4	120	240	480
23	#9601012G (DCP 96-026G) ARIES	0.795	1	0.795	2.4	0	0	44	51	40	0	20	4	120	240	480

See Appendix G, "Project Priority Spreadsheet Indicating Optimal Solution."

Cell H4: This indicates that the total amount of capital equipment dollars being spent is \$1000K. This is exactly the amount available (cell H5) and therefore the optimization has selected projects that fully consume the capital equipment dollars available. There is, therefore, a binding constraint.

Cell I4: This indicates that the total amount of operating dollars being spent is \$2462K. The amount of available dollars is \$5000K (cell I5), which indicates that the dollars available were not exhausted. If this problem persists in future months of work on the projects, this category of funding is a candidate for reallocation in order to enhance another one of the constrained resource areas.

Cell L4: This indicates the total Design Hours consumed in performing the 56 projects was 4781 compared to the 4800 available. This suggests that the design capacity is properly sized because the hours available are essentially consumed. This is not the limiting resource, though, because there are still 19 hours available for additional design work.

Cell M4: This indicates that only 343 hours of the 2000 available are consumed in completing the 56 projects. This is clearly an area where too much labor is available for the prescribed work, and labor in this area needs to be de-emphasized.

Cell N4: This indicates that the 600 hours available for Facility Engineering to perform work is fully consumed (cell N5). This is an area where additional

resources would allow additional work to be completed. It also suggests that resources in other areas might be better used if additional Facility Engineers were employed. Further, there is an opportunity to reallocate to allow for the addition of Facility Engineers (for instance, at the expense of procurement personnel).

Cell O4: This indicates that 147 ESH hours were used in performing ESH reviews for the identified projects. This is essentially all of the 160 hours available (cell O5) and represents an adequate personnel loading in this area.

Cell P4: This indicates that 1060 hours of available Sheetmetal Worker time is used in completing the projects. This is only about half of the hours available (2080 hours available as indicated in cell P5) and represents a significant amount of excess time available. Management should consider a reallocation of resources and to de-emphasize this resource.

Cell Q4: This indicates that 1686 hours of Electrician time is used in completing the 56 projects. This also represents only about half of the time available (3120 hours available as indicated in cell Q5) and again represents a significant amount of excess time available. Management should consider a reallocation of resources and to de-emphasize this resource.

Cell R4: This indicates that 3270 hours of Fitter time is used in completing the 56 projects. This represents about 70% of the available hours represented in cell R5. Although not as serious an overage as indicated for Electrician and

Sheetmetal workers, management should consider reducing the number of electrician hours available and to perhaps rebalance the distribution of resources to the other resource areas.

With regard to all labor categories, but with special attention to areas involving skilled crafts such as electricians and fitters, often special and expensive training is provided that is unique to the operations. This situation is the case at the plutonium facility. Special training includes working with nuclear materials, plutonium contamination control, criticality safety, industrial safety, and special security features. Because this training is often expensive and challenging to provide, special care needs to be taken when making the decision to emphasize one area of labor at the expense of another. By the time the new employees are fully trained and prepared to contribute to work assignments, the profile of work may have changed. Therefore, management needs to consider if the projection of needs over the 4 month period, indicated in Table 10, is indicative of future forecasts or just an artifact of the current workload.

Also indicated on Table 10 (and Appendix G) are the specific projects to be performed. These are indicated in column E. A quick evaluation indicates that, generally, projects at the top of the priority are selected while projects at the bottom are not selected. This is intuitively consistent. Going down the table, the first two projects are selected and each contribute one priority point to the optimization. The third item (Replace Nitric Acid Supply Line S. Basement PF-4) has two sub-items,

only one of which is selected. Presumably the first sub-item is not selected as a result of reaching a constraint boundary. The fourth item (Acid Recycle Additional Tanks) also has two sub-items, both of which are selected. The fifth item (ARIES) is comprised of 17 sub-items, only 10 of which are selected. Looking further down the table, the selection process continues while the program optimizes the constraint categories. Of special interest is, on projects where sub-items exist, whether there is a precedence relationship between sub-items and whether the sub-items are selected in precedence order. If, for instance, a sub-item is selected that requires another sub-item be performed first, and that first sub-item is not selected, what should management decide. Management must decide to either select both items or to drop both items, because having a second order item selected without also selecting the primary item is not feasible.

A final evaluation must involve considering sponsor specific desires. Remember, one of the challenges is to integrate the needs and wants of a number of sponsors simultaneously. In this case, a sponsor may specifically request a package of work that does not represent one of those selected under optimum resource utilization. In this instance, management must evaluate the importance of that package of work and determine if accepting the inefficiency in resource utilization is acceptable. Selecting a project will displace another, in terms of consuming resources, and therefore, will create inefficiency.

Before making specific decisions, management needs to evaluate the impact that scheduling has on the actual utilization of resources. To this point, the optimization has indicated that the 56 projects are possible, but this result is only achievable if the scheduling of the resources can be made in a noninterference fashion. In view of the number of resources and the number of potential projects, the probability of interference is very likely. Therefore, the results of the optimization step only represent an interim product and further evaluation is necessary before a final decision on project selection can be made. Indeed, further evaluation is essential before a decision is made to move resources from one area to another. Finally, management must evaluate the predecessor/successor relationship of non-selected projects as well as sponsor specific desires.

Chapter 5

PLANNING AND SCHEDULING

5.1 Planning and Scheduling Literature Review

Planning and scheduling aid coordination and communication, provide a basis for control, are often required to satisfy requirements of sponsors, identify the time relationship of project tasks, and as a result, are designed to help avoid problems in project completion. Plans are designed to provide control over future events, and in a sense, represent a simulation of how things are expected to occur in the future. For plans to be effective, they must be quantitative rather than qualitative. Rosenau [44] does a thorough job of defining plans and schedules, the mechanism used to develop these tools, and the purpose behind the tools. The most dramatic development of project management approaches occurred in the mid-1960s and involved the aerospace industry in contracting with the United States government for aircraft manufacturing. Tools were developed and adopted by the Defense Department for use in all major procurements. Computer technology has enhanced the application of these tools, but the basic tools remain intact [45,46,47].

To develop a plan and schedule, each of the projects needs to be viewed as a stand-alone project with specifically defined goals, objectives, and milestones, with tasks leading to the specific milestones. Avots [48] discusses the reasons that project management succeeds and fails and points out that one of the most common reasons

that projects fail is that task definitions are inadequate. He goes on to show how preparing good project plans forces the future project manager to organize task requirements into meaningful elements. Each project requires a specific set of steps to include a schedule. Objectives are defined in terms of performance parameters and scheduling charts. Hansen [49] points out that both the manager and customer must have a clear understanding of the objectives of the project. To properly make tradeoffs, the requirements and project objectives must be considered as possible variables to trade with other program elements. To be properly analyzed as tradeoffs, they must be thoroughly understood. Hansen goes on to develop the reasoning behind having program plans that are well prepared and highly visible. The visibility allows for a regular and thorough review of plans and progress. All participants have the opportunity to see their roles and the roles of others in completing project tasks.

After defining the milestones and determining the necessary delivery dates, the next thing is to lay out the project tasks and milestones on a time chart. This activity is referred to as structuring the project. Betz [50] and Rosenau [44] thoroughly discuss the need to structure the project plan before applying resource estimates, and note the benefits of using tools such as PERT charts, Gantt charts, and functional flow block diagrams. Mulvaney [51], Rosenau [44], and Archibald [52] provide easy-to-use guides for applying structuring techniques such as PERT and CPM. The product of the structuring is a logic network of tasks, often referred to as a PERT chart or a functional flow block diagram. Each step on the diagram must then be

resource loaded to include the needs for each effected labor category and each procurement requirement.

The Gantt chart is a popular technique for displaying the schedule of a project's activities over time. Recent computer-based project planner systems, which include Gantt charts, also allow for the loading of resources and the analysis of resource needs, including the leveling of resources. For this research, the Primavera [53] software system is used to organize and evaluate the scheduling of project tasks. Gantt charts are useful in helping a project manager see when activities begin and end, and help to track the progress of activities to completion. Ragsdale [43] points out that Gantt charts do not directly show the precedence relationship between activities in a project. They must be used with functional flow block diagrams and the knowledge of the project manager in order to properly identify successor/predecessor relationships of tasks. Furthermore, Rosenau [44] points out weaknesses in the use of Gantt charts in that when progress is noted on the chart, it is unclear if the progress represents scope, schedule, or cost progress. He also supports Ragsdale's observation that one activity's dependence on another and the entire project's dependence upon any particular activity is not immediately apparent. Therefore, Gantt charts must be used by the manager in evaluating decisions and the progress of a project and not be relied upon to make the actual decision for the manager. The human interface is essential.

Once the individual project's charts are developed, they are assembled in the overall program chart. Since individual projects use similar resources, conflicts in utilization will occur. Assembling the overall program chart will point out these conflicts and allow the manager to evaluate priorities, optimization results, and timing needs.

5.2 Utilizing Planning and Scheduling to Select Project Sequencing

In developing the execution plan for each project, the manager must ask a number of questions concerning the level of detail, size, and scope of project, and overall time duration. The first major step is to make a detailed list of activities. For each of the projects identified in Table 10, a standard list of major steps can be prepared. The major steps are as follows:

1. Design equipment or other changes involved in the project.
2. Perform facility engineering review in order to determine facility configuration issues.
3. Procure equipment, materials, and supplies, with particular focus on long-lead time procurements that may become critical path items.
4. Perform ESH review and make any corrections necessary to meet facility and industrial safety standards.

5. Install or modify equipment identified in the project plan. This step may involve numerous skills and sub-tasks depending on the scope of the project.

Each project will have unique details within each of these general steps, but essentially every project can identify relationships to each of these steps.

The next step is to develop the network diagram that clearly shows the relationship between tasks. This diagram is commonly referred to as a Functional Flow Block Diagram. Naturally, each project will have unique needs and will result in a slightly different diagram, depending on the relationship of individual steps. Creating a block diagram is performed by the project members to ensure that the logic for completing the project is consistent. Figure 4 is a Functional Flow Block Diagram that shows the standard planning and scheduling steps to be performed for the projects. It shows that Design must be performed before both Engineering Review and Procurement. Procurement can take place simultaneously with the various Engineering and ESH reviews, but must be complete before Installation is performed. Again, this represents a generic flow and each individual project will require development of its own individual diagram.

The individual project diagrams represent the beginning of the development of the Gantt charts. Table 11 demonstrates the development of the Gantt chart for the various projects and includes the identification of each task within each project.

Appendix H includes the Gantt charts for all of the projects selected from the

optimization step, as indicated in Table 9. These Gantt charts are generated using the Primavera Systems Inc. software. Looking at Table 11, the first project shows that the design step for Replacing the Fire Protection Main begins on 19 February and is planned to be complete by 7 March.

Figure 4: Functional Flow Block Diagram Showing Standard Planning and Scheduling Steps for Projects

Once completed, the Engineering Review of the DCP can commence and will be complete by 4 April. Simultaneous with the Engineering Review, Procurement can commence. The ESH review is performed at the end of the Engineering Review and is planned to be complete within one day. Once the ESH review is complete, the actual installation can commence. On the calendar side of the table (right side) are bar charts that indicate start dates, end dates, time durations, and the relationship of each task with the others in the project. Each of the projects indicated in Table 11 and in Appendix H can be evaluated in a similar manner.

Table 11: Gantt Charts for First 4 Month Series of Selected Projects (partial table)

Activity ID	Activity Description	OD	Early Start	Early Finish	Resource	Budgeted quantity	1997	1998
TA-55 Replace Fire Protection Main								
Replace Fire Protection Main								
97014010	Design Fire Protection Main	13	19FEB97	07MAR97	DESIGNE	100.00	▼ Design Fire Protection Main	
97014020	DCP#97-014 Repl Fire Protection Main R&A	20	10MAR97	04APR97	SYS ENG	40.00	▼ DCP#97-014 Repl Fire Protection Main R&A	
97014030	Fire Protection Main Procurement	5	10MAR97	14MAR97	PROCURE	20.00	▼ Fire Protection Main Procurement	
97014040	Fire Protection Main ESH Review	1	07APR97	07APR97	ESH	4.00	▼ Fire Protection Main ESH Review	
97014050	Install Fire Protection Main	120	08APR97	22SEP97		0.00	▼ Install Fire Protection Main	
TA-55 Compressors								
TA-55 Compressors								
95027010	Design TA-55 Compressors	13	19FEB97	07MAR97	DESIGNE	100.00	▼ Design TA-55 Compressors	
95027020	DCP TA-55 Compressor Review & Approval	20	10MAR97	04APR97	SYS ENG	40.00	▼ DCP TA-55 Compressor Review & Approval	
95027030	TA-55 Compressor Procurement	5	10MAR97	14MAR97	PROCURE	20.00	▼ TA-55 Compressor Procurement	
95027040	TA-55 Compressor ESH Review	1	08APR97	08APR97	ESH	4.00	▼ TA-55 Compressor ESH Review	
95027050	Install TA-55 Compressors (WR#9603031)	45	09APR97	10JUN97	ELECT+	720.00	▼ Install TA-55 Compressors (WR#9603031)	
Replace Nitric Acid Supply Line								
Replace & Repair Nitric Supply Line								
97005010	Design Repair & Replace Nitric Supply Line	13	10MAR97	26MAR97	DESIGNE	100.00	▼ Design Repair & Replace Nitric Supply Line	
97005030	DCP#97-005 Repr & Replace Nitric Supply	20	27MAR97	23APR97	SYS ENG	40.00	▼ DCP#97-005 Repr & Replace Nitric Supply L	
97005040	Repr & Replace Nitric Supply Line	5	27MAR97	02APR97	PROCURE	20.00	▼ Repr & Replace Nitric Supply Line Procureme	
97005050	Repr & Replace Nitric Supply Line ESH	1	24APR97	24APR97	ESH	4.00	▼ Repr & Replace Nitric Supply Line ESH Rev	
97005020	Repr & Replace Nitric Supply Line	5	25APR97	01MAY97	FITTER	80.00	▼ Repr & Replace Nitric Supply Line (WR#971	
Project Start 14FEB97 Project Finish 22SEP97 Data Date 14FEB97 Plot Date 12MAR97							Sheet 1 of 13	

See Appendix H, "Gantt Charts for First 4 Month Series of Selected Projects."

The next step in the plan development is to apply the resources to the various activities and to evaluate the individual time durations for each step. Table 9 identifies the necessary resources so the challenge is to understand when the resources are to be needed. Again Table 11 shows this relationship in terms of time durations. As a subset of the duration analysis, the total resource required can be divided by the time in order to develop a labor utilization table. By adding up all of the labor utilization values across all projects, one can develop a total labor utilization profile. By evaluating the labor utilization values, it is easily determined if any specific labor category is over- or under-utilized over each time increment.

Table 12 represents the labor utilization profile for all projects selected and is arrived at by rolling up all labor required across all projects. It also takes into account the time duration requirements indicated in each project. The first column of Table 12 indicates the Resource Category by labor type. The second column indicates the maximum hours available for each labor category on a per day basis. These same numbers can be found in Table 10 row 5 but are indicated there as "Total Available to do Work per Four Months." The body of Table 12 indicates the labor consumed across all projects on a per day basis. For instance, the Designer labor category has only 60 hours per day available for work. The body of the table shows that Designer labor is consumed at approximately 59 hours per day performing projects, very close to the saturation level. A table such as this represents a valuable tool for evaluating the actual utilization profile for labor categories and is used to determine if certain

Table 12: Resource Utilization Profile for All Projects

[illegible]

labor categories are to be supplemented or not.

Once complete, the next step in the plan development is to reallocate resources and/or modify the schedules so as to accommodate the availability of each labor category. By modifying the schedules, one can resolve conflicts with other activities that use the same resources. This reallocation has already been reflected in Table 12.

Another effective approach is to plot histograms for each labor category and look at the utilization profile over time. Figure 5 is a representative histogram for the labor category Fitter and indicates the utilization over the time period of study. It is a standard printout from the Primavera software and provides a variety of information for use by the manager. Across the top of the histogram is a line at the 59 hours per day level. This line indicates the maximum available labor hours. If the histogram exceeds this line, a reallocation of resource is necessary. Also plotted on the chart is a cumulative profile for labor. It is readout along the right ordinate and, in this case, is read as hours times 100. Appendix I contains the histograms for all labor categories used in the set of selected projects.

5.3 Management Issues Involved in Project Planning and Scheduling

At this point in the project, all of the tools have been introduced and discussed. The planning and scheduling step provides the first real opportunity for the manager to make an informed decision as to how to deploy resources in meeting

Figure 5: Histogram Indicating Labor Utilization of Fitters

See Appendix I, "Resource Loading Histograms for Constrained Resources Identified in the First 4 Months of Identified Projects."

sponsor expectations. Leaders for individual projects are easily able to prepare plans with a high expectation for implementation, but without looking at the problem from an overall systems point of view, a project leader would simply be sub-optimizing relative to his/her own project. Systematically evaluating the prioritization, optimization, and planning/ scheduling sequence outlines the limits within which the manager must operate.

The major issue to be addressed at this point in the decision process has to do with evaluating the project-by-project relationships and ensuring that the sponsor expectations can be met. From the senior management level, this means evaluating the precedence relationship at the project level as opposed to within a project. For instance, looking at Table 11, project number 3 (Replace Nitric Acid Supply Line S. Bsmt PF-4), the project design starts on 10 March and the project is due to finish on 1 May. There is an option to bring the project forward in time, thereby saving a few weeks, if required by sponsor needs. This will create a cascade of change across the various labor categories which may require an evaluation to see if sufficient resources are available. Of course, moving the project out in time is always an option if delivering the project is not critical on the noted time frame. Again, resource utilization will be impacted. By having the projects on an electronic Gantt chart, the impacts of change can be readily observed and understood.

One of the most valuable tools, from a senior management standpoint, is the histogram of labor utilization. The Gantt charts provide an opportunity to evaluate

each project while the compilation of labor utilization provides the opportunity to evaluate all labor utilization. An examination of the Designer histogram (see Appendix I), it is clear that this labor category is well utilized over the 4 month period. The utilization indicates that nearly all of the 60 hours per day available are utilized. In fact, the small variance between actual hours and maximum hours is likely an artifact of the compilation in that the designers can simply move from one project into the next without time delay if they so choose. The drop off at the end of 4 months is also a result of the lack of data input. It is important to note that only 4 months of information has been loaded into the planning system. As more projects become selected, it is expected that the utilization bars will continue to hover close to the 60 hours per day maximum level consumed. This outcome for the Designer labor category is not unexpected in that the design step is the initiating step in the planning process. This means that design can begin on all selected projects at once and it is simply the choice of the manager as to which to select first. Assuming that all other labor categories are properly balanced, this category of labor should always be fully utilized. This outcome is also supported by the outcome of the optimization step. Looking back to Table 10, the Designer category shows that, over the 4 months available, 4681 hours are consumed out of a total of 4800 hours that are available. Achieving this degree of labor utilization assumes that the hours can be properly scheduled and their precedence relationship in the process ensures that this is accomplished.

The second histogram in Appendix I demonstrates the utilization for Facility System's Engineering. By first examining Table 10, the results of optimization of the objective function suggest that this Facility System's Engineering is also fully utilized (600 hours consumed out of 600 hours available). Again the histogram supports the fact that scheduling of the Facility Engineering function can achieve this result. There are 8 hours per day available and the histogram indicates that after an initial start-up period, the engineering labor is fully used. The start-up period appears to take approximately 6 weeks, which is both an artifact of the delay introduced in the design step as well as a sequencing of initial projects. Note that in the histogram there a couple of days before the end of March where Facility Engineering time is fully utilized followed by a few days where full utilization is not achieved. If achieving maximum efficiency during start-up is important then a reevaluation of project sequencing may be in order. The down-turn in utilization after May is a result of not having the next 4 months of projects lined up to continue work. It is fully expected that once the next segment of work is selected through the optimization step, the histogram will indicate full utilization.

Procurement Labor is the next category and the next in the decision sequence. The optimization step indicates that Procurement Labor is poorly utilized in that only 323 hours are used out of a total of 2000 hours that are available (see Table 10). The histogram in Appendix I proves this fact. The histogram shows that during the first few weeks of the 4 month period, Procurement Labor is heavily consumed but, after

an initial intense effort, the utilization drops off dramatically. Even at the lower level, the utilization is sporadic. This is a circumstance where employing a full-time procurement function is likely not justified and sharing the function with other users or contracting the function may be a more appropriate use of funding. At a very minimum, the level of support should be reduced. The manager must evaluate the importance and cost benefit of having a captured procurement function.

The next labor category is the ESH Review function. Table 10 indicates that the ESH function is nearly fully utilized because 143 hours out of the 160 available hours are to be consumed during the 4 month period. This suggests that not much management attention is necessary in evaluating the use of this resource. The opposite is discovered when examining the utilization of this resource on the histogram in Appendix I. The first thing noticed is that the use of ESH labor stretches beyond the desired 4 month period. The utilization is relatively flat at 4 hours per day with a maximum available of 5 hours per day. In order to understand the reason behind the stretch-out of the ESH labor utilization, you have to return to the Gantt charts in Appendix H. An evaluation of the charts indicates that there are a number of projects, particularly low on the selection list, that simply cannot get through the Design and Facility Engineering reviews within the 4 month period. This forces much of the ESH review to take place in later months. This is the first indication that the projects identified in the optimization step cannot be successfully completed within the allotted period and is also an indication that, in order to gain an adequate

understanding of the labor needed, more than the first iteration of project optimization must be added to the list. Another observation can be made on the ESH histogram. There are two periods where ESH labor exceeds that available; one in mid-April and one in mid-July. Actually, the period in mid-July occurs over two days where the labor needed is 8 hours per day but the labor available is only 4 hours per day. The mid-April problem indicates that on one day 16 hours are needed. In looking at days adjacent to those identified, there are clearly a number of no-usage periods. This indicates that the manager can make the decision to cover the extra labor by spreading it over an unused period immediately following the heavy need period. This means that the completion of the installation step which follows will likely incur a day-to-day slip for each day delayed in the ESH review. By evaluating the Gantt charts of the effected projects, the impact of those slips can be immediately evaluated. In the event that the project slips cannot be tolerated, the manager has the opportunity to make the decision to temporarily employ contract labor to fill in the shortfall or to apply overtime to the ESH labor. Both of these actions will require financial resource and, as a result, will require a financial analysis. The most important observation in looking at the ESH Labor histogram is the fact that the optimization results are clearly insufficient to adequately make the decision concerning project commitments.

The next histograms involve the utilization of Electricians, Fitters, and Sheetmetal workers. These histograms clearly indicate the affect of the time phasing of activities necessary to perform the entire project, as indicated in Figure 4. Despite

the fact that the results indicated that the projects could be completed within the 4 month time period, the time relationship of tasks precludes achieving that goal. In all three cases, there is a significant start-up period wherein the utilization slowly moves from essentially no utilization up to near full utilization. The near constant slope of the cumulative labor graph indicates that the start-up period is essentially linear to the point of full utilization. It appears that near full utilization can be achieved after overcoming the initial start-up period. This is indicated by the fact that the peak utilization for all three labor categories occurs near the maximum available time.

These observations together indicate that over long periods of time, the utilization of installation labor will likely be near the maximum available. This result is somewhat contrary to observations after the optimization step. After this step, it seems that these labor categories are over-staffed and some economies could be gained by reducing the number of idle time hours being paid out for these employees. Again, without having completed the entire model analysis, this set of conclusions would not have been intuitively obvious.

For the manager who oversees and must integrate projects, the resources loaded schedule is the critical management tool. It represents the mechanism to track progress and identify conflicts in resource utilization. As a result, it also represents the tools for managing change. Change manifests itself in the form of project slippages, overcommitments in resource utilization, and changing requirements from either oversight organizations or sponsors. As demonstrated here, the plan and

schedule cannot be used alone in evaluating the status of the overall suite of projects, but must be used with other tools to make a reasonable and educated judgment of needs. Indeed, the use of the various tools, assembled as a set of supporting elements represents an entire decision support system. The product of each element leads to the next process step and represents a further refinement of information necessary to make a complete decision as to project selection, task alignments, and resource utilization. Each element alone is insufficient in making the judgment, and in fact, will lead to inappropriate decisions. It is the entire information management system which is necessary to provide the satisfactory solution.

Chapter 6

SUMMARY AND FUTURE DIRECTIONS

6.1 Summary of Results

The issues addressed in this research fall into four categories: 1) developing a non-market-driven strategic foundation from which to evaluate organizational performance, 2) developing a basis for allocating critical facility resources where a relevant financial metric does not exist, 3) developing an approach that is sufficiently flexible to accommodate planned activities and stochastic events while simultaneously addressing the facility's strategic interests and the parochial interests of sponsors, and 4) designing an application that is simple, yet effective, in meeting managerial needs so that management is motivated to implement the approach.

With regard to strategic foundation, the approach demonstrated was to use an expert-based system wherein a majority of the stakeholders in the strategic decision are engaged in performing a qualitative analysis. The approach includes using the software-based application of the Analytic Hierarchy Process, *Expert Choice*, to perform pair-wise comparisons of each dimension of the strategic focus and thereby develop the relative importance of each strategic area to the overall strategy for the facility. By using the Analytic Hierarchy Process, a numerical rating is generated which is used later for evaluating the priority of various projects as they contribute to both near term success as well as the long-range goals for the facility. Using this

approach, five distinct strategic business areas were identified with importance weightings ranging from 0.483 to 0.031. This broad range allowed for clear discrimination of the contribution of discrete projects. Overall, the approach for employing the Analytic Hierarchy Process to develop a relative emphasis associated with various strategic foci was very effective.

With regard to developing a logical rationale for allocation of critical facility resources where traditional financial metrics are not available, the approach taken was to configure the problem statement into a form solvable by zero-one integer programming. Key to the problem is the fact that there are a number of constrained labor resources and there is a limited amount of funding, evolving from two sources: capital equipment budget and operating budget. Optimizing resource utilization within constrained resource availability is a problem ideally suited to programming. The challenge being faced in this problem is that there is no clear basis from which to optimize. Most problems discussed in the literature involve maximizing financial factors such as profits or return-on-investment, but in this problem the organization is a non-profit, government-supported national laboratory where profits are not relevant as a performance measure. Indeed, the most important factor valued by the government sponsor is the intangible measure of service and contribution to mission. This fact required that a measure of merit be developed wherein projects could be compared, and subsequently ranked. The approach taken was to use the analytic results of the strategic analysis to rank each project's contribution to the strategic

mission. The Ratings module, embedded within the Analytic Hierarchy Process, provided an excellent vehicle to perform this ranking. The results demonstrated that a large number of projects can be quickly prioritized against the strategic mission by using a set of intensity factors. The prioritized list is easily modified and added to without disrupting the prior work. This feature provides ease of implementation. In addition to providing a prioritized list, the approach generates a relative value of merit for each project in regard to its contribution to the strategic mission of the organization.

It is this relative value of merit that provides the opportunity to perform the linear optimization. Specifically, binary integer optimization is utilized through maximizing the sum of the relative values of merit for each project. Resource requirements are compiled for each project and then evaluated against each other in an effort to arrive at a consistent set of projects that support the strategic emphasis, meets sponsor expectations, and uses facility resources in a cost-effective manner. The product was a down-selected list of projects that most fully meets the overall goals while remaining within the resource constraints of the facility. Indeed, the list represents a modification of the prioritized list, indicating the importance of moving beyond a mere prioritization for project selection. The approach provides the opportunity to initially evaluate staffing levels and question if certain categories are either over- or under-staffed. It was demonstrated that making this evaluation at this

point in time is premature and could lead to reducing a critical resource necessary for project completion.

In order to fully evaluate the overall scope of all projects (particularly the scope of resource requirements), the temporal dimension must be evaluated. This was demonstrated by using a commercially available project planner, Primavera. The down-selected list of projects was resource loaded, and time durations for individual steps were developed. These were then placed into a Gantt chart format, and resource leveling along the time dimension was performed. The approach provides the opportunity to communicate the quantity of work that can be performed in a fixed amount of time, as well as provide an ability to evaluate the loading of constrained labor resources. Therefore, using the dimensionless priority value as a basis for overall resource selection is successful.

With regard to developing an approach which is flexible to change each of the tools used easily accommodates additions, deletions, and other modifications. Although not demonstrated in this project, the strategic emphasis step can be easily modified by adding areas of strategic emphasis, performing pair-wise comparisons, and recompiling the results. New areas of emphasis can be added and deleted through the use of the Analytic Hierarchy Process. Two issues exist in assessing the flexibility of the ratings approach for project prioritization. The first issue has to do with applying a modified strategic emphasis. If an analysis results in adding to or subtracting from the strategic emphasis, then the ratings scores will need to be re-

evaluated for all projects. This introduces a somewhat time consuming step, but one which is rather straight forward. The other issue has to do with adding or subtracting projects from the ratings list. When subtracting items, there is no change to the overall structure, and therefore, no additional manager involvement is necessary. When adding items, the manager must simply apply the ratings intensity scores to the new items. The items then can be immediately inserted into the appropriate level within the priority list. Again, this step is rather straight forward. Applying the optimization constraints simply requires that any new project be evaluated for labor and cost requirements. Since this step is required under any management mode, this action does not introduce any additional complexity to the application of the decision model. Finally, transitioning from the optimization to the planning and scheduling step is straight forward, once the time durations for each step have been determined. By using a computer based tool, such as Primavera, the compilation of resources can be performed directly, and the final analysis of resource utilization can be performed. Based on the fact that the individual tool easily accommodates change and the fact that the movement of information between tasks is easily accomplished, it appears that the approach provides flexibility to accommodate change and modification. Only under one circumstance does reworking of previous evaluations become necessary: when the initial strategic emphasis dramatically changes.

The question of ease of application cannot be directly addressed here. At the plutonium facility, the approach is being tested, in a demonstration mode, with

success. The speed and flexibility of desktop computing systems has introduced significant analytical power to the decision process. This outcome was forecast by a number of the reference authors who stated that the lack of adequate computer-based tools represented a roadblock to decision making. The next necessary step is to integrate systems in a fashion that allows for the electronic transfer of databases between applications. The problem of transferability is manifested in this project, but one that is clearly poised to change. Therefore, "ease of application" can be assessed as being positive, with the change vector being pointed in a positive direction.

6.2 Future Directions of Study

With regard to future directions for research in this area, a number of key initiatives are appropriate. First, the most time-consuming step in the model involves gathering resource estimates for work. This information is required prior to performing the optimization step. Improved methods of forecasting are needed, particularly when each package of work is different than past packages. But, the individual tasks within a package of work are often common to a number of other projects. This fact suggests that the use of neural networks and fuzzy logic could be employed to improve resource forecasting, dependent on the quality of existing data. Tsoukalas and Uhrig [54] discuss the application of neural approaches in engineering. The application of neural networks in forecasting will require that a significant database be developed which reflects fundamental learning elements for a project. This

means that individual tasks, such as assembling a pipe gang, will need to be analyzed and catalogued in terms of an assembly pattern. When the network recalls the pattern, it can then apply the appropriate forecasting information. Other aspects of artificial intelligence can be similarly applied as the model increases in sophistication.

A second area of future work involves the incorporation of risk assessments into the selection process. Assessment of risks associated with individual projects and activities performed at the plutonium facility is an important aspect of selecting projects. The objective function in optimization does not take into account the change in risk associated with both the project and the act of implementing the project. Key to deciding to move ahead with a project is the fact that the risks can be properly assessed and, as required, managed and that the approved licensing basis for the facility is not violated. Sage [55] defines risk in an engineering environment and discusses the application of risk approaches to engineering systems. The American Institute of Chemical Engineers [56] has published guidelines for hazard evaluation with specific applications to engineering environments. Finally, Hench [57] discusses the application of risk in terms of evaluating accident scenarios in a chemical operation. These references suggest that risk can be managed via the establishment of probability functions. These can then be used as a factor in the decision process in terms of either a constraint to implementation or a factor in the scoring steps. Incorporation of risk evaluation in the selection process will become an important element in the future.

Finally, an important improvement to implementation of the model will be the combining of the individual analysis tools into an integrated decision support system. This combining should facilitate the evaluation of sensitivity of each decision to the decision variables. Today, the results of the project rankings have to be manually transferred from one database to another prior to optimization. The results of optimization must be manually transferred to the planning and scheduling system. Both of these transfers introduce the opportunity for errors. Human reliability statistics suggest that, even under tightly supervised environments, human errors introduced during repetitive actions fall within the percentage range. It is therefore highly probable that decisions will be made using inaccurate information. It is these uncertainties that lead management to abandon a structured approach to decision making and to continue to use intuition and simple heuristics for its decision basis. New software systems are emerging which recognize the problems and are beginning to address them. For instance, Ascent Logic Corporation is now producing a software package, entitled RDD-100 [58], which represents a requirements-driven project planning and management system. The system begins to demonstrate how strategic mission requirements are translated into tactical activities in the decision process. RDD-100 introduces the concept of critical issues in the same way that critical path approaches were introduced in PERT analysis. Elements in the decision process can be added and subtracted and the critical-issue links are maintained. It can be seen that concepts such as risk issues and ESH issues can be introduced and managed

throughout the decision process without having to provide the continuous quality checks required in transitioning between software packages. The rapidly changing state of computer technology will likely create an entirely new suite of decision-support tools which will result in making the current tools obsolete.

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Appendix A

EIGEN VECTOR CALCULATION FOR THE STRATEGIC EMPHASIS MATRIX

Table 3 is repeated as Table A.1 below.

Table A.1: Comparison of the Relative Importance of Business Areas, Including Reciprocal Relationships.

	Stk Mngt	Mat Liab	Opertnl	NonProl	Energy
Stk Mngt	1.0	2.0	5.0	7.0	9.0
Mat Liab	0.5	1.0	2.0	5.0	7.0
Opertnl	0.2	0.5	1.0	3.0	6.0
NonProl	0.14	0.2	0.33	1.0	5.0
Energy	0.11	0.14	0.17	0.2	1.0

Step 1: Sum the values in each column of the pair-wise comparison matrix:

	Stk Mngt	Mat Liab	Opertnl	NonProl	Energy
Stk Mngt	1.0	2.0	5.0	7.0	9.0
Mat Liab	0.5	1.0	2.0	5.0	7.0
Opertnl	0.2	0.5	1.0	3.0	6.0
NonProl	0.14	0.2	0.33	1.0	5.0
Energy	0.11	0.14	0.17	0.2	1.0
	1.95	3.84	8.50	16.20	28.00

Step 2: Divide each element in the pair-wise comparison matrix by its column total; the resulting matrix is referred to as the normalized pair-wise comparison matrix.

	Stk Mngt	Mat Liab	Opertnl	NonProl	Energy
Stk Mngt	0.512	0.520	0.588	0.432	0.321
Mat Liab	0.256	0.260	0.235	0.309	0.250
Opertnl	0.102	0.130	0.118	0.185	0.214
NonProl	0.073	0.052	0.039	0.062	0.179
Energy	0.057	0.037	0.020	0.012	0.036

Step 3: Compute the average of the elements in each row of the normalized matrix; these averages provide an estimate of the relative priorities of the elements being compared.

	Stk Mngt	Mat Liab	Opertnl	NonProl	Energy	Σ of the Row	Average
Stk Mngt	0.512	0.520	0.588	0.432	0.321	2.374	0.483
Mat Liab	0.256	0.260	0.235	0.309	0.250	1.310	0.263
Opertnl	0.102	0.130	0.118	0.185	0.214	0.750	0.149
NonProl	0.073	0.052	0.039	0.062	0.179	0.405	0.075
Energy	0.057	0.037	0.020	0.012	0.036	0.162	0.031

Appendix B

CALCULATION FOR CONSISTENCY RATIO FOR STRATEGIC EMPHASIS MATRIX¹

¹ Reference for this Appendix is Thomas A. Saaty, *The Analytic Hierarchy Process*, New York: McGraw-Hill, 1980.

Step 1: Multiply each value of the first column of the pair-wise comparison matrix by the first term of the Eigen Vector; multiply each value in the second column of the matrix by the second term of the Eigen Vector; multiply each value in the third column of the matrix by the third term of the Eigen Vector; multiply each value in the fourth column of the matrix by the fourth term of the Eigen Vector; multiply each value in the fifth column of the matrix by the fifth term of the Eigen Vector. Sum the values across the rows to obtain a vector of values labeled the "weighted sum."

$$\begin{aligned}
 &0.483 \begin{bmatrix} 1.00 \\ 0.50 \\ 0.20 \\ 0.14 \\ 0.11 \end{bmatrix} + 0.263 \begin{bmatrix} 2.00 \\ 1.00 \\ 0.50 \\ 0.20 \\ 0.14 \end{bmatrix} + 0.149 \begin{bmatrix} 5.00 \\ 2.00 \\ 1.00 \\ 0.33 \\ 0.17 \end{bmatrix} + 0.075 \begin{bmatrix} 7.00 \\ 5.00 \\ 3.00 \\ 1.00 \\ 0.20 \end{bmatrix} + 0.031 \begin{bmatrix} 9.00 \\ 7.00 \\ 6.00 \\ 5.00 \\ 1.00 \end{bmatrix} = \\
 &\begin{bmatrix} 0.483 \\ 0.242 \\ 0.097 \\ 0.067 \\ 0.053 \end{bmatrix} + \begin{bmatrix} 0.526 \\ 0.263 \\ 0.132 \\ 0.053 \\ 0.037 \end{bmatrix} + \begin{bmatrix} 0.745 \\ 0.298 \\ 0.149 \\ 0.049 \\ 0.025 \end{bmatrix} + \begin{bmatrix} 0.525 \\ 0.375 \\ 0.225 \\ 0.075 \\ 0.015 \end{bmatrix} + \begin{bmatrix} 0.279 \\ 0.217 \\ 0.186 \\ 0.155 \\ 0.031 \end{bmatrix} = \begin{bmatrix} 2.558 \\ 1.395 \\ 0.789 \\ 0.399 \\ 0.161 \end{bmatrix}
 \end{aligned}$$

Step 2: Divide the elements of the vector of weighted sums obtained in Step 1 by the corresponding priority value.

$$\begin{aligned}
 2.558/0.483 &= 5.296 \\
 1.395/0.263 &= 5.304 \\
 0.789/0.149 &= 5.295 \\
 0.399/0.075 &= 5.320 \\
 0.161/0.031 &= 5.194
 \end{aligned}$$

Step 3: Compute the average of the values computed in Step 2; this average is denoted by $\lambda_{\max}$. Substituting our real numbers from Step 2, we have

$$\lambda_{\max} = \frac{5.296 + 5.304 + 5.295 + 5.320 + 5.194}{5} = 5.282.$$

Step 4: Compute the Consistency Index (CI), which is defined as:

$$CI = \frac{\lambda_{\max} - n}{n - 1}$$

where n = the number of items being compared. With numbers substituted, this yields:

$$CI = \frac{5.282 - 5}{5 - 1} = 0.071.$$

Step 5: Compute the Inconsistency Ratio (CR), which is defined as:

$$CR = \frac{CI}{RI}$$

where RI, the Random Index, is the Consistency Index of a randomly generated pairwise comparison matrix. It can be shown that RI depends on the number of elements being compared and takes on the following values:

<u>n</u>	<u>RI</u>
3	0.58
4	0.90
5	1.12
6	1.24
7	1.32
8	1.41

Thus, for our case with $n = 5$ and $RI = 1.12$ we obtain the following inconsistency ratio:

$$CR = \frac{0.071}{1.12} = \sim 0.07.$$

As mentioned above, an inconsistency ratio of 0.10 or less is considered acceptable. An inconsistency ratio of 0.07 is therefore very acceptable as being within consistency constraints and, therefore, a reevaluation of the pair-wise comparison matrix is not necessary.

Appendix C

CALCULATION OF INTENSITY VALUES
FOR APPLICATION TO THE RATINGS-BASED
ASSESSMENT OF PROJECTS

Step 1

	High	Medium High	Medium Medium	Medium Low	Low
High	1.0000	3.0000	5.0000	7.0000	9.0000
Medium High	0.3333	1.0000	3.0000	5.0000	7.0000
Medium	0.2000	0.3333	1.0000	3.0000	5.0000
Medium Low	0.1429	0.2000	0.3333	1.0000	3.0000
Low	0.1111	0.1429	0.2000	0.3333	1.0000
Sum of Column	1.7873	4.6762	9.5333	16.3333	25.0000

Step 2

	High	Medium High	Medium Medium	Medium Low	Low	Σ Row	Normalized* Σ Row
High	0.5595	0.6416	0.5245	0.4286	0.36	2.5141	1.0000
Medium High	0.1865	0.2138	0.3147	0.3061	0.28	1.3012	0.5175
Medium	0.1119	0.0713	0.1049	0.1837	0.20	0.6718	0.2672
Medium Low	0.0799	0.0428	0.0350	0.0612	0.12	0.3388	0.1348
Low	0.0622	0.0306	0.0210	0.0204	0.04	0.1741	0.0693
Sum of Column						5.00	

* The SumRow column is normalized to make the "High" value equal to 1.0000.

Appendix D

PROJECT ALTERNATIVES SHOWING

RANK SCORING RESULTS

Table D.1: Project Alternatives Showing Rank Scoring Results

	Alternatives	TOTAL	Sik Mngt	Energy	Mat Liab	Non Prol	Oprtnl
			4825	0310	2627	0749	1489
1	Replace Air Compressor	1.000	High	High	High	High	High
2	Replace TA-55 Fire Protection	1.000	High	High	High	High	High
3	Install Nitric Acid Tanks NMT-2	0.901	High	Low	High	Low	High
4	Replace Nitric Acid Supply Line	0.901	High	Low	High	Low	High
5	Install ARIES System, NMT-6	0.795	High	Low	High	Med-High	Low
6	Wet and Dry Vacuum Pumps	0.639	Med-High	Med-High	High	Med-High	Med-High
7	Upgrade ROBOCAL Phase I	0.612	Med-High	Medium	Med-High	High	High
8	In-line U Analyzer SRL, NMT-6	0.607	High	Low	Medium	Medium	Medium
9	Replace GB	0.586	Med-High	Low	High	Med-High	Medium
10	Server for Maintenance Management	0.583	Med-High	Med-High	Med-High	Med-High	High
11	Fire Alarm Control Panel Upgrade	0.583	Med-High	Med-High	Med-High	Med-High	High
12	Pit Surveillance Leak Detector	0.565	High	Low	Medium	Low	Low
13	Pit Rebuild Leak Detector	0.565	High	Low	Medium	Low	Low
14	Process Control System Upgrade	0.565	High	Medium	Low	Low	Low
15	Declass. Furnace for SRL	0.565	High	Medium	Low	Low	Low
16	Install Continuous Air Monitors	0.560	Medium	Medium	High	Medium	High
17	Install CLEAR GB line, NMT-2	0.553	Med-High	Low	High	Low	Medium
18	Procure GC Mass Spec., NMT-6	0.540	Medium	Low	High	Low	High
19	Install HCI Delivery Piping	0.534	Med-High	Low	High	Low	Med-Low
20	Mod HVAC	0.532	High	Low	Med-Low	Low	Low
21	Relocate Foundry GB	0.516	High	Low	Low	Low	Low
22	Install Services to 40mm, NMT-9	0.516	High	Low	Low	Low	Low
23	Inspection Area Trunk Line	0.516	High	Low	Low	Low	Low
24	NMT-5 Sheffield Rot. Cont. Gage	0.516	High	Low	Low	Low	Low
25	NMT-5 Ring-Rotocon GB	0.516	High	Low	Low	Low	Low
26	Install PIGMA welder, NMT-5	0.516	High	Low	Low	Low	Low
27	Install New Moore T-Base Lathe	0.516	High	Low	Low	Low	Low
28	Procure Micro Fiche of Doc. C	0.510	Med-High	Med-High	Med-High	Med-High	Med-High
29	Install Automated Gamma Counter	0.496	Med-High	Low	Med-High	Med-High	Med-High
30	Procure SUN Sparc Server	0.481	Med-High	Med-High	Med-High	Med-Low	Med-High
31	Procure UPS for Network	0.481	Med-High	Med-High	Med-High	Med-Low	Med-High
32	Procure Material Handler	0.477	Med-High	Med-High	Med-High	Low	Med-High

	Alternatives	TOTAL	Stk Mngt 4825	Energy 0310	Mat Liab 2627	Non Prol 0749	Oprtnl 1489
33	Yard Scale, NMT-7	0.477	Med-High	Med-High	Med-High	Low	Med-High
34	Upgrade Rm X, CST-15	0.435	Med-High	Medium	Med-High	Med-Low	Medium
35	Replace Wet Vac Pump & Catch	0.424	Med-High	Low	Med-High	Low	Medium
36	Relocate GB Penetra. for Wet Vac	0.411	Med-High	Medium	Med-High	Low	Med-Low
37	Install Packaging Line GB	0.410	Low	Low	High	Med-High	Med-High
38	Install X-Ray Diffractometer in	0.410	Low	Low	High	Med-High	Med-High
39	Procure Calorimeter, NMT-6	0.381	Low	Low	High	High	Low
40	Replace Boiler, NMT-9	0.363	Medium	Medium	Medium	Medium	High
41	Upgrade Potable Water System	0.363	Medium	Medium	Medium	Medium	High
42	Procure CCD Detector	0.343	Medium	Low	Medium	Low	High
43	Procure Metallograph w/Digital	0.330	Med-high	Med-Low	Medium	Low	Low
44	Upgrade Metal Prep room	0.295	Med-High	Low	Med-Low	Low	Low
45	Install Restraining Clips on UPS	0.290	Medium	Medium	Medium	Medium	Med-High
46	Mod Intake Valves	0.290	Medium	Medium	Medium	Medium	Med-High
47	Connect 3" Vac Header	0.284	Medium	Low	Medium	Medium	Med-High
48	Procure Laser Optics System	0.280	Med-High	Low	Low	Low	Low
49	Install Kolsky Bar	0.280	Med-High	Low	Low	Low	Low
50	Install Pit Boost Box, NMT-5	0.280	Med-High	Low	Low	Low	Low
51	Install Back Machining Lathe	0.280	Med-High	Low	Low	Low	Low
52	Install Inspection Room	0.280	Med-high	Low	Low	Low	Low
53	Install Pit Burst System	0.280	Med-high	Low	Low	Low	Low
54	Install Slant Bed Lathe, NMT-5	0.280	Med-High	Low	Low	Low	Low
55	Replace Motor Gen w/Solid State	0.280	Med-High	Low	Low	Low	Low
56	Install Elec. Feedthroughs in GB	0.280	Med-High	Low	Low	Low	Low
57	Arc Melter, Rolling Hill & Lathe	0.280	Med-High	Low	Low	Low	Low
58	Radioactive Liquid Waste line	0.278	Medium	Medium	Med-High	Low	Low
59	Install N2 & Ar Flowmeter	0.272	Medium	Low	Med-High	Low	Low
60	Connect House Vac	0.272	Medium	Low	Med-high	Low	Low
61	Install Bubbler Bypass	0.272	Medium	Low	Med-High	Low	Low
62	Connect House Vac & N2	0.676	Medium	Low	Med-High	Low	Low
63	NMT-4 TV Security System	0.267	Low	Low	Medium	Medium	High
64	Install Sanitary Waste Detectors	0.254	Med-Low	Med-Low	Med-Low	Med-Low	High
65	Upgrade Station Y, NMT-8	0.252	Medium	Medium	Medium	Medium	Medium
66	Install PRD Bypass System	0.252	Medium	Medium	Medium	Medium	Medium

	Alternatives	TOTAL	Stk Mngt	Energy	Mat Liab	Non Prol	Oprtnl
			4825	0310	2627	0749	1489
67	Install Butterfly Valves	0.252	Medium	Medium	Medium	Medium	Medium
68	Remove Autoclose Shuffie Valve	0.252	Medium	Medium	Medium	Medium	Medium
69	Install Vac "Scroll Pump"	0.252	Medium	Medium	Medium	Medium	Medium
70	Procure Digital Still Camera	0.252	Medium	Medium	Medium	Medium	Medium
71	Install Seismic Monitor	0.252	Medium	Medium	Medium	Medium	Medium
72	Mod All CAM Alarm Outputs	0.252	Medium	Medium	Medium	Medium	Medium
73	Chlorine Detection System	0.232	Medium	Low	Medium	Low	Medium
74	Install Check Valve	0.232	Medium	Low	Medium	Low	Medium
75	Install Hydrothermal Reactor	0.232	Medium	Low	Medium	Low	Medium
76	Install Mass Spec Attachment	0.218	Medium	Low	Medium	Medium	Low
77	Procure Scanning Augur, NMT-5	0.206	Medium	Med-Low	Medium	Low	Low
78	Procure Secondary-Ion Mass	0.206	Medium	Med-Low	Medium	Low	Low
79	Replace Emergency Eyewash	0.204	Low	Low	Low	Low	High
80	Install PCM-2 Monitors, ESH-1	0.204	Low	Low	Low	Low	High
81	Modify GB	0.204	Medium	Low	Medium	Low	Low
82	Install On/Off Switch Rod	0.204	Medium	Low	Medium	Low	Low
83	Replace Optical Well	0.204	Medium	Low	Medium	Low	Low
84	Upgrade TNC	0.204	Medium	Low	Medium	Low	Low
85	Install 208V 39 Amp Receptacle	0.204	Medium	Low	Medium	Low	Low
86	Install Services for De-duster	0.182	Low	Low	Med-High	Low	Low
87	Install New Speakers	0.181	Med-Low	Med-Low	Med-Low	Med-Low	Med-High
88	Install Water Sensors Near	0.161	Medium	Medium	Low	Low	Low
89	Replace DB	0.155	Medium	Low	Low	Low	Low
90	Replace Service Panel on	0.155	Medium	Low	Low	Low	Low
91	Install 110V Flex Runs	0.147	Med-Low	Low	Medium	Med-Low	Low
92	Install Emergency Shower	0.147	Low	Low	Med-Low	Low	Med-High
93	Relocate Radiograph	0.144	Med-Low	Med-Low	Medium	Low	Low
94	Upgrade Services	0.142	Med-Low	Low	Medium	Low	Low
95	Review and Repair Inert Gas	0.124	Med-Low	Med-Low	Med-Low	Med-Low	Med-Low
96	Procure Solid State NMR	0.114	Low	Low	Medium	Low	Low
97	Install HFM-8 Monitors	0.114	Low	Low	Medium	Low	Low
98	Install BISCO Shielding Gamma	0.113	Med-Low	Low	Med-Low	Med-Low	Low
99	Modify GB (EED)	0.109	Med-Low	Low	Med-Low	Low	Low
100	Replace GBs	0.094	Low	High	Low	Low	Low

	Alternatives	TOTAL	Stk Mngt	Energy	Mat Liab	Non Prol	Oprtnl
			.4825	.0310	.2627	.0749	.1489
101	Seismic Mods to GBs	0.094	Low	High	Low	Low	Low
102	Replace GBs	0.094	Low	High	Low	Low	Low
103	Replace GBs	0.094	Low	High	Low	Low	Low
104	Procure Fuel Processing Furnace	0.094	Low	High	Low	Low	Low
105	Install GB	0.094	Low	High	Low	Low	Low
106	Replace GBs	0.094	Low	High	Low	Low	Low
107	Procure Atmosphere Control	0.094	Low	High	Low	Low	Low
108	Remove Breathing Air Station	0.093	Low	Low	Low	Low	Medium
109	Remove Thermodetectors	0.093	Low	Low	Low	Low	Medium
110	Remove UPS Powerstripe	0.093	Low	Low	Low	Low	Medium
111	Remove GB	0.079	Low	Med-High	Low	Low	Low
112	Remove GB	0.079	Low	Med-High	Low	Low	Low
113	Install 4" Floor Penetration	0.079	Low	Med-High	Low	Low	Low
114	Cap Floor Drains	0.079	Low	Med-High	Low	Low	Low
115	Modify GB	0.079	Low	Med-High	Low	Low	Low
116	Install Solenoid in GB	0.079	Low	Med-High	Low	Low	Low
117	Weld Mounting Plate to Floor	0.079	Low	Med-High	Low	Low	Low
118	Modify CAM Alarm System	0.079	Low	Med-High	Low	Low	Low
119	Install Services to GB	0.079	Low	Med-High	Low	Low	Low
120	Relocate CAM Alarm	0.079	Low	Med-High	Low	Low	Low
121	Install 2 9mm Camera Systems	0.079	Low	Med-High	Low	Low	Low
122	Install Pressure Regulator	0.079	Low	Med-High	Low	Low	Low
123	Install In-line Metal Filters to Furnace	0.079	Low	Med-High	Low	Low	Low
124	Replace Ion Gauge Assembly	0.079	Low	Med-High	Low	Low	Low
125	Remove Traps, etc.	0.071	Low	Medium	Low	Low	Low
126	Install Vac Vent	0.071	Low	Medium	Low	Low	Low
127	Modify Piping Fans	0.071	Low	Medium	Low	Low	Low

Appendix E

RESOURCE ESTIMATES NECESSARY TO
COMPLETE INDIVIDUAL PROJECTS

Table E.1: Resource Estimates Necessary to Complete Individual Projects

1	Project Title to include Design Change Packages for each	Design & Cost	Procure Capital (\$k)	Procure Operat (\$k)	Install Cost (\$k)	Total Cost (\$k)	Design Hours	Procure Hours	Pac Eng Hours	BSH Hours	Shmld Hours	Electrician Hours	Filter Hours	M
2	TA-55 Compressors													
3	#9603031 DCP 95-0-27TA-55 Compressors R&A	7.1	0	700	42	749	100	20	40	4	0	240	480	
4	TA-55 Replace Fire Protection Main													
5	#9603031 DCP 95-0-27TA-55 Compressors R&A	7.1	0	700	42	749	100	20	40	4	0	240	480	
6	Replace Nitric Acid Supply Line													
7	#9710025 (97-005)Repl & Repair Nitric Supply Line R&A	7.1	700	0	5	712	100	20	40	4	0	0	80	
8	#9711039 (97-015)Change Nitric Acid Supply Valve R&A	1.1	0	50	3	54	0	20	20	4	0	0	40	
9	Acid Recycle Additional Tanks													
10	#9609036(95-0-12)NPDES Recycle	93.3	100	0	10	203	1500	60	40	4	80	16	80	
11	#9407034 DCP 95-002)Evaporator Removal R&A	0.0	0	0	16	16	0	0	20	4	160	40	80	
12	ARIES													
13	#9601012B1 (96-026B1) ARIES Move	2.4	0	0	21	23	40	0	20	4	80	120	160	
14	#9601012E1 (96-026E1)ARIES Move	2.4	0	0	22	24	40	0	20	4	80	120	180	
15	#9601012F (DCP 96-026F) ARIES Move Raman	2.4	0	0	10	13	40	0	20	4	60	60	60	
16	#9601012F1 (96-026F1)ARIES Move	2.4	0	0	48	51	40	0	20	4	120	240	480	
17	#9601012G (DCP 96-026G) ARIES Move	2.4	0	0	48	51	40	0	20	4	120	240	480	
18	#9601012G1 (96-026G1)ARIES Move	2.4	0	0	32	35	40	0	20	4	80	160	320	
19	#9601012H (96-026H) ARIES Inst Conveyor	49.1	150	0	75	274	800	20	30	4	700	320	320	
20	#9601012I (96-026I) ARIES Relocate	24.0	0	0	21	45	400	0	40	4	80	120	160	
21	#9601012J (96-026J) ARIES D&D	24.0	0	0	32	56	400	0	40	4	80	160	320	
22	#9601012K (96-026K) ARIES Trolley Supp Frame	37.1	150	0	9	196	600	20	30	4	160	0	0	
23	#9601012L (96-026L) ARIES Inst TNC	25.1	150	0	32	207	400	20	40	4	80	160	320	
24	#9601012M (96-026M) ARIES Inst NDA	50.8	300	0	32	383	800	50	30	4	80	160	320	
25	#9601012N (96-026N) ARIES Inst Elec/Dec	49.1	150	0	48	247	800	20	40	4	120	240	480	
26	#9601012O (96-026O) ARIES Inst H/D	49.1	150	0	48	247	800	20	40	4	120	240	480	
27	#9601012P (96-026P) ARIES Inst Pit Bis	49.1	150	0	48	247	800	20	40	4	120	240	480	
28	#9601012Q (96-026Q) ARIES Inst Cannig	49.1	150	0	48	247	800	20	40	4	120	240	480	
29	#9601012R (96-026R) ARIES Inst L1NL	49.1	150	0	48	247	800	20	40	4	120	240	480	
30	Wet and Dry Vacuum Pumps													
31	Procure Replacement Pumps	2.3	150	0	25	177	20	20	20	4	150	40	240	
32	Upgrade ROBOCAL Phase I													
33	DCPs for Robocal	3.5	250	0	6	259	40	20	20	4	0	100	0	
34	In-line U Analyzer for Spec. Recov. Line													
35	Procure Uranium Analyzer	13.1	1000	0	3	1016	200	20	20	4	0	40	0	
36	Replace GB													
37	#9509006 (95-0-33) Repl GB	2.4	0	0	37	39	40	0	20	4	120	40	480	

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Project Title to include Design Change Packages for each Project	Design & Procure Cost (\$k)	Procure Capital (\$k)	Procure Operat. (\$k)	Install Cost (\$k)	Total Cost (\$k)	Design Hours	Procure Hours	Fac. Eng Hours	ESH Hours	Shimul Hours	Electrician Hours	Fitter Hours
38	Fire Alarm Control Panel Upgrade												
39	#9508065 (DCP 95-16) Replace Smoke Detectors RFC	3.5	200		3	206	40	20	30	4	0	40	0
40	#9508076 (DCP 95-26D) Add Fire Relay Mods R&A	3.5	0	20	3	26	40	20	30	4	0	40	0
41	#9605023 (DCP 96-072) Rewire Frangible Links R&A	0.6	0	0	5	5	10	0	10	0	0	80	0
42	Server for Maintenance Mgt. System												
43	Procure Servers	1.1	30	0	0	31	0	20	0	0	0	0	0
44	Declass. furnace for SRL												
45	DCPs for Furnaces	5.2	400	0	33	438	80	8	40	8	0	80	480
46	Pit Surveillance Leak Detector												
47	Procure Leak Detector	1.1	30	0	0	31	0	20	0	0	0	0	0
48	Pit Rebuild Leak Detector												
49	Procure Leak Detector	1.1	35	0	0	36	0	20	0	0	0	0	0
50	Process Control System Upgrade SRL												
51	DCPs for Process Control System	24.4	50	0	5	79	400	8	16	8	0	80	0
52	Continuous Air Monitor Replacements												
53	Procure CAMs	7.1	9000	0	0	9007	100	20	20	4	0	0	0
54	Install CLEAR Glovebox Line												
55	#9503099 (95-0-20) CLEAR GB	1.1	300	0	104	405	0	20	80	20	300	500	1000
56	GC Mass Spectrometer												
57	Procure GC Mass Spectrometer	0.2	70	0	0	70	0	4	4	4	0	0	0
58	Install Piping System for HCL Delivery												
59	#9604011 (96-057A) HCl Piping Syst	4.6	0	50	5	59	40	40	20	4	0	0	80
60	Mod SRL												
61	#9412072 (DCP 95-006) Mod R&A	3.5	0	50	4	58	40	20	20	0	80	0	0
62	Inspection Area Trunkline & Trolley System												
63	97-013 Install Inspection Glove-boxes	81.9	75	0	16	173	1200	180	40	4	300	0	0
64	Sheffield rotary Contour Gauge												
65	DCPs for Gauge	3.5	135	0	7	145	40	20	40	4	120	0	0
66	Ring Rotary Contour Gauge												
67	DCPs for Ring Rotocon	3.5	0	0	7	10	40	20	40	4	120	0	0
68	PIGMA Welder												
69	#9602003(95-0-15A) PIGMA Proc Control	252.4	203	0	238	694	4060	160	640	640	636	1222	1655
70	#9611007 (DCP 95-15C) C/M Design Development	0.0			1	1					0	20	0
71	#9611007 (DCP 95-15C) Mod Door Entry	0.0			0	0							
72	#9611007 (DCP 95-15C) Release for Construction	0.0			0	0							
73	#9611007 (DCP 95-15C) Compile/Review As-builts	0.0			0	0							
74	#9611007 (DCP 95-15C) CM DCP Closeout	0.0			0	0							
75	#9710046(95-015D) Dem/Rem svcs for PIGMA R&A	0.0			0	0							
76	Complete Phase II Field Change Requests	0.0			0	0							

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Project Title to include Design Change Packages for each Project	Design & Procure Cost (\$k)	Procure Capital (\$k)	Procure Operat. (\$k)	Install Cost (\$k)	Total Cost (\$k)	Design Hours	Procure Hours	Fac. Eng. Hours	ESH Hours	Shtmtl Hours	Electrician Hours	Fitter Hours
77	#9710044(95-0-15E)Const Rm&Svcs for PIGMA R&A	0.0			0	0							
78	Relocate Moore "T" Base Lathe												
79	#9606029 (96-083)Rel T-Base Lathe	2.4	0	0	13	15	40	0	80	4	80	100	40
80	Rel. & Inst NW End Foundry Upgd												
81	#9605017 (96-073) Rem Arc Melter Svcs R&A	154.4	125	0	40	320	2500	80	160	400	0	40	240
82	Install Services to 40MM												
83	#9611050 (DCP 96-014) 40MM Design R & A	0.0			27	27	0	0	0	0	120	180	180
84	Micro Fiche Equip. for Document Control												
85	Procure Micro Fiche Equipment	1.1	200	0	0	201	0	20	0	0	0	0	0
86	Gamma Counter, Automated												
87	Procure Automated Gamma Counter	0.2	80		0	80	0	4	0	0	0	0	0
88	Uninterruptable Power Supply for Network												
89	Procure UPS system	1.1	28		0	29	0	20	0	0	0	0	0
90	Sun SPARC Server												
91	Procure Sun SPARC Server	1.1	28		0	29	0	20	0	0	0	0	0
92	Yard Scale												
93	Procure Yard Scale	1.1	20		0	21	0	20	0	0	0	0	0
94	Material Handler												
95	Procure Material Handler	1.1	75		0	76	0	20	0	0	0	0	0
96	Room X Upgrade												
97	#9602054C (DCP 95-008C) Release for Construction	0.6	0	0	27	28	10	0	10	4	240	120	120
98	#9602054D-1 (DCP 95-008D-1) Install GB	0.6	0	0	18	19	10	0	40	4	80	80	160
99	#9602054E (95-008E) Install New GB	49.1	150	0	58	257	800	20	40	4	120	264	630
100	#9602054F (DCP 95-008F) Remove GB	0.6	0	0	27	28	10	0	10	4	240	120	120
101	#9602054F-1 (95-008F-1) Install GB	49.1	0	0	48	97	800	20	40	4	120	240	480
102	#9602054G (DCP 95-008G) Remove GB	0.6	0	0	27	28	10	0	10	4	240	120	120
103	#9602054G-1 (95-008G-1) Install GB	49.1	0	0	48	97	800	20	40	4	120	240	480
104	#9602054H (DCP 95-008H) Rem Trans. GB	0.6	0	0	14	14	10	0	10	4	120	60	60
105	#9602054H-1 (95-008H-1) Inst GB	49.1	150	0	48	247	800	20	40	4	120	240	480
106	#9602054I (DCP 95-008I) Rel Trans.GB	0.6	0	0	14	14	10	0	10	4	120	60	60
107	#9602054I-1 (95-008I-1) Inst GB	49.1	150	0	48	247	800	20	40	4	120	240	480
108	#9602054J (95-008J) Inst GB	49.1	150	0	55	254	800	20	40	4	120	240	600
109	#9602054K (95-008K) Inst GB	49.1	150	0	55	254	800	20	40	4	120	240	600
110	#9602054L (95-008L) Inst GB	49.1	150	0	55	254	800	20	40	4	120	240	600
111	Replace Wet Vacuum Pump & Install Catch Pan												
112	#9609012 (96-115)Rem/Repl Wet Vac Pump R&A	2.3	50	0	9	61	20	20	20	4	50	20	80
113	Relocate GB Penetrations for Wet Vac & RTD for Hydrothermal Proc.												
114	#9611048 (DCP 96-012B)Reloc GB Pen/Wet Vac R&A	0.0			2	2	0	0	0	0	16	0	24

1	A	Project Title to include Design Change Packages for each	Design & Cost (\$K)	Procure Capital (\$K)	Procure Operat. (\$K)	Install Cost (\$K)	Total Cost (\$K)	Design Hours	Procure Hours	Fac. Eng. Hours	ESH Hours	Shmnl Hours	Electrician Hours	Filter Hours
115		Packaging Line Glove-boxes	0.6	0	0	3	4	10	0	0	4	16	16	16
116		#9607039(96-094)Rem & Disc GB	0.6	0	0	3	4	10	0	0	4	16	16	16
117		WR# TBID (DCP#TBID) Inst. Packaging Line	10.1	300	0	91	401	150	20	40	4	120	500	960
118		X-Ray Diffractometer												
119		Procure Diffractometer	1.1	230	0	0	231	0	20	0	0	0	0	0
120		Potable Water System Upgrade												
121		Procure Potable Water system	26.2	1000	0	0	1026	400	40	80	4	0	0	0
122		CCD Detector												
123		CCD Detector	0.0	30	0	0	30	0	0	0	0	0	0	0
124		CST-15 Metallograph with Digital Camera												
125		CST-15 Metallograph with Digital Camera	1.1	170		0	171	0	20	0	4	0	0	0
126		NMT-6 Calorimeter												
127		Procure Calorimeter	2.6	90	0	0	93	40	4	4	4	0	0	0
128		Room V Upgrades												
129		#9605042A (DCP 96-076A)Rem GB	0.6	0	0	9	10	10	0	10	4	80	40	40
130		#9605042B (DCP 96-076B)Rem GB	0.6	0	0	9	10	10	0	10	4	80	40	40
131		#9605042C (DCP 96-076C)Rem GB	0.6	0	0	9	10	10	0	10	4	80	40	40
132		#9605042D (96-076D)Rem GB	0.6	0	0	10	11	10	0	10	4	80	40	60
133		#9605042E (96-076E)Rem Metal Prep Line	0.6	0	0	2	2	10	0	10	4	0	0	24
134		#9605042F (96-076F)Decom Cyl GBs	0.6	0	0	3	3	10	0	0	4	0	0	40
135		#9605042G (96-076G)Decom/Disc GBs	0.6	0	0	11	12	10	0	10	4	80	80	40
136		#9605042H (96-076H) Rem Causitic Syst	0.6	0	0	2	3	10	0	20	4	40	0	0
137		#9605042I (96076I)Rem Laser System	0.6	0	0	8	9	10	0	0	4	0	140	0
138		Install " Restraining Chips" on UPS Static Switch												
139		#9603035 (DCP 96-044)Inst UPS Static Swatch R&A	0.6	0	0	2	2	10	0	10	4	0	24	0
140		Modify Intake Valves												
141		#9608034 (96-105)Mod Valves	2.3	0	0	1	3	20	20	40	4	16	0	0
142		Connect 3" Wet Vacuum Header												
143		#9601066 (DCP 96-029) 3" Wetvac	0.0	0	0	4	4	0	0	10	4	0	0	60
144		Install Pit Boost Box												
145		#9404062(DCP 95-003) Boost Box R&A	49.1	150	0	48	247	800	20	40	4	120	240	480
146		Installation of Inspection Room												
147		#9711001 (97-013) Install Inspect.	53.5	450	0	145	648	800	100	120	10	360	720	1440
148		Install Elec Feedthrough in GB												
149		#9607010 (96-085) Inst Elec Feed to GB	0.1	0	0	2	2	0	2	4	0	0	30	0
150		Slant Bed Lath												
151		#9602016(DCP 95-019B2)Rem Arc Welder	0.6	0	0	18	19	10	0	10	4	80	160	80
152		Back-Machining Lath												
153		#9711037 (97-016) Back-Mach Lath Exh Tie-in R&A	32.2	25	20	12	89	500	40	240	160	0	0	40

1	A Project Title to include Design Change Packages for each Project	B Design & Procure Cost (\$k)	C Procure Capital (\$k)	D Procure Operat. (\$k)	E Install Cost (\$k)	F Total Cost (\$k)	G Design Hours	H Procure Hours	I Fac. Eng Hours	J ESH Hours	K Shtmtl Hours	L Electrician Hours	M Fitter Hours
154	Replace Motor Generators w/ "Pillar Solid State Converters"												
155	#9608018 (96-101) Revised Foundry Upgrade R&A	4.6	50	0	17	72	40	40	120	20	40	240	0
156	Install & Implement Pit Burst Equipment & Process												
157	#9605036 (96-075) Pit Burst Inst GB	49.1	150	0	48	247	800	20	40	4	120	240	480
158	NMT-5 Laser Optics												
159	NMT-5 Laser Optics	2.6	30	10	0	43	40	4	10	10	0	0	0
160	Install Kolsky Bar												
161	#9605068 (96-078) Kolsky Bar	14.8	250	0	37	302	240	8	60	10	0	240	400
162	Arc Melter Rolling Mill & Lathe												
163	#9601033 (96-018) Arc Melter Mod GB	49.1	0	0	48	97	800	20	40	4	120	240	480
164	Radioactive Liquid Waste Line Tie-in												
165	#9710033 (97-011)Rad Waste Line Tie-in	2.6	0	10	2	14	40	4	40	4	0	0	24
166	Connect Hose Vacuum & Nitrogen												
167	#9603067 (DCP 96-049)Con Vac/N	2.6	0	10	2	15	40	4	40	4	0	0	30
168	Install Bubler Bypass on GB												
169	#9603068 (DCP 96-050)Inst Bubbler	0.2	0	5	0	6	0	4	4	4	0	0	10
170	Connect House Vacuum to GBs												
171	#9603069 (DCP 96-051)Conn Vac	0.2	0	5	10	15	0	4	4	4	0	0	160
172	Install Nitrogen Argon Flowmeter												
173	#9608083 (96-117)Inst Nit/Arg Flowmeter	0.5	0	2	3	5	4	4	4	4	0	0	40
174	Install Vault TV Monitoring System												
175	NMT-4 TV Security System (JO 693813) (95DO)	3.5	50	10	7	70	40	20	20	4	40	80	0
176	WR# (DCP 96-021)Inst Vault TV Monitor R&A	2.3	5	5	4	16	20	20	10	4	20	40	0
177	Install Sanitary Waste Detectors												
178	#9610015 (DCP 96-007)Inst Sanit Waste Detec R&A	3.0	25	0	4	32	40	10	40	4	20	24	20
179	Install New Butterfly Valves Bleedoffs												
180	#9607031 (96-093)Inst Butterfly Valves	1.2	0	5	2	9	10	10	40	4	40	0	0
181	Remove Autoclose Shuffle Valves												
182	#9607040 (96-095)Rem Intake Shuffle Valves R&A	0.3	0	0	3	3	5	0	10	4	0	0	40
183	Install "Scroll Pump" Vacuum Pump												
184	#9607060 (96-098)Inst Scroll Vacuum Pump R&A	1.8	0	10	7	19	20	10	40	4	0	40	80
185	Install Seismic Monitor												
186	#9608042 (96-107)Inst Seismic Monitor	3.0	25	0	4	32	40	10	40	4	20	24	20
187	Station XYZ Upgrade												
188	#9604063(95-0-21) XYZ Upgrade R&A	65.5	0	0	0	66	1000	100	40	4	0	0	0
189	#9609004 (96-114)Rem/Repl StatXYZ Vault	6.0	500		8	514	100	0	0	4	100	40	0
190	#9609046 (97-004)Inst Conduit Stat. XYZ	1.8	0	25	5	32	20	10	20	4	0	80	0

1	A Project	B Design & Procure Cost (\$k)	C Procure Capital Cost (\$k)	D Procure Operat. Cost (\$k)	E Install Cost (\$k)	F Total Cost (\$k)	G Design Hours	H Procure Hours	I Fac Eng Hours	J ESH Hours	K Shuttl Hours	L Electrician Hours	M Filter Hours
191	CST-15 Digital Still Camera												
192	CST-15 Digital Still Camera	0.0	0	5	0	5	0	0	0	0	0	0	0
193	Install PRD Bypass System												
194	#9604030 (DCP 96-061)C/M Dsgn Review & Approval	0.6	0	0	14	15	0	10	40	4	0	0	240
195	Modify All CAM Alarm Outputs												
196	#9603045 (DCP 96-047) CAM's Mod DCP R & A	13.1	0	25	5	43	200	20	80	4	80	0	0
197	Chlorine Detection System												
198	#9603008(DCP 96-023)Chlor Det Sy R	13.1	100	20	37	170	200	20	40	8	0	320	320
199	Install Check Valve in Process Line												
200	#9608015 (96-100)Inst Check Valve	3.5	0	50	3	56	40	20	40	4	0	40	0
201	Hydrothermal Reactor Unit Glovebox												
202	Hydrothermal Reactor Unit Glovebox	7.0	600	0	12	619	80	40	80	40	0	40	120
203	Mass Spectrometer Attachment to TGA/DSC												
204	Mass Spectrometer Attachment to TGA/DSC	0.2	250	0	3	253	0	4	4	4	0	40	0
205	Upgrade TNC GB												
206	#9711029 (97-017)Upgr TNC GB	3.0	0	25	0	28	40	10	10	4	0	0	0
207	Replace Optical Well in GB												
208	#9607026 (96-081)Repl Optic Well in GB	1.8	0	40	1	43	20	10	10	4	16	0	0
209	Inst On/Off Safety Switch ROD Mill GB												
210	#9609018 (96-121)Inst Safety Swth GB	1.2	0	20	5	26	10	10	0	4	0	80	0
211	Modify GB												
212	#9603005(DCP 96-022)Mod GB	3.0	0	20	9	32	40	10	10	4	160	0	0
213	NMT-5 Secondary-Ion Mass Spec												
214	NMT-5 Secondary-Ion Mass Spec	1.1	250	0	9	260	0	20	0	4	80	80	0
215	NMT-5 Scanning Auger												
216	NMT-5 Scanning Auger	1.1	250	0	9	260	0	20	0	4	80	80	0
217	Install 208V 30 Amp Outlet												
218	#9605024 (96-103)Inst 208V Outlet	1.2	0	1	3	5	20	0	10	4	0	20	20
219	ESH-1 PCM-2 Monitors												
220	ESH-1 PCM-2 Monitors	7.0	600	20	9	636	80	40	40	4	0	80	80
221	Replace Emergency Eyewash w/ New Sprayer												
222	#9507024 (DCP 95-0-29)Repl Emerg Eye-wash R&A	0.3	0	2	1	4	0	5	0	4	0	0	20
223	Install Services for "De-duster"												
224	#9710001(97-008)Inst Svc	1.5	0	20	2	24	20	5	20	4	16	0	24
225	Install New Speakers												
226	#9612003 (DCP 96-015) Release for Construction	3.5	0	20	5	28	40	20	40	4	0	80	0
227	#9711042 (97-018)Upgr Emerg Paging System	3.5	0	50	6	59	40	20	40	4	0	100	0
228	Install Water Sensors Near W. Wall												
229	#9603015 (DCP 96-040)Inst Water Sensor	1.8	0	20	14	36	20	10	20	4	0	80	160

	A	B	C	D	E	F	G	H	I	J	K	L	M
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230	Replace Service Panel												
231	#9609051 (97-002)Repl Svc Panel	1.8	0	20	2	23	20	10	20	4	24	0	0
232	Replace DB												
233	#9607050 (96-096)Repl DB window	0.0	0	5	0	6	0	0	0	2	8	0	0
234	Boiler Replacement												
235	#9602042 (DCP 96-035)Boiler Replacement R&A	4.6	250	0	30	284	40	40	80	10	240	40	240
236	Install 110 Volt Flex Runs												
237	#9604068 (DCP 96-067)Inst 110V Flexruns	3.0	0	20	3	25	40	10	40	4	0	40	0
238	Install Emergency Shower												
239	#9608072 (96-113)Inst Emerg Shower	0.9	0	5	5	11	10	5	40	4	0	0	80
240	Relocate Radiographic Syst												
241	#9607004 (96-084)Rel Rad Syst	3.0	0	20	8	31	40	10	40	4	0	0	140
242	Upgrade Services												
243	#9605035 (DCP 96-074)Upgrade Serv	3.0	0	50	34	87	40	10	40	4	200	200	200
244	Review & Repair Inert Gas Photohelics												
245	#9604032 (DCP 96-062)Repair GAs Photohelics R&A	0.6	0	10	3	13	0	10	0	4	0	0	40
246	NMT-6 Solid State NMR Instrument												
247	NMT-6 Solid State NMR Instrument	0.4	500	0	8	509	0	8	8	8	0	140	0
248	ESH-1 HFM-8 Monitors												
249	ESH-1 HFM-8 Monitors	3.5	250	20	0	274	40	20	10	4	0	0	0
250	Inst Bisco Shielding Behind Gamma Detector												
251	#9608061 (96-112)Inst Bisco Shield	3.0	0	100	11	114	40	10	40	4	200	0	0
252	EED Modify GB												
253	#9404051 (DCP 96-059) GBs (EDD) R&A	3.0	0	50	7	60	40	10	40	4	40	40	40
254	Replace GBs												
255	Replace GBs	48.6	450	100	140	738	800	10	40	20	480	960	1000
256	Replacement GBs												
257	Replacement GBs	48.6	300	75	97	521	800	10	40	20	240	480	960
258	Replacement GB's												
259	Replacement GB's	48.6	300	75	97	521	800	10	40	20	240	480	960
260	Replace GBs												
261	Replace GBs	48.6	300	75	97	521	800	10	40	20	240	480	960
262	Fuel Processing Furnaces												
263	Fuel Processing Furnaces	3.0	300	20	18	341	40	10	20	4	0	320	0
264	GB's Atmosphere Controllers (Dritrains)												
265	GB's Atmosphere Controllers (Dritrains)	1.2	300	20	48	370	10	10	10	4	40	320	480
266	Replacement GB's												
267	Replacement GB's	48.6	300	75	97	521	800	10	40	20	240	480	960

	A	B	C	D	E	F	G	H	I	J	K	L	M
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268	Install DB Replacements												
269	Install DB Replacements	48.6	300	75	97	521	800	10	40	20	240	480	960
270	Modify/Upgrade GB & XB For Earthquakes												
271	#9607019 (96-088)Mod 4GB/TB for Earthquake R&A	24.6	0	200	117	342	400	10	80	12	2160		
272	Remove UPS Powerstrip												
273	#9604018 (DCP 96-058)Rem UPS Powerstrip	0.6	0	0	3	4	10	0	10	4	40	10	0
274	Remove All Thermometers & Associated Wiring												
275	#9604043 (DCP 96-065)Rem Thermo/Wiring R&A	0.6	0	0	5	6	10	0	10	12	0	80	0
276	Remove Breathing Air Station from UPS												
277	#9605015 (DCP 96-070)Rem UPS Breathing Air R&A	0.6	0	0	3	3	10	0	10	4	0	40	0
278	CAM Alarm System Mods												
279	#9511004 (DCP 95-007) Release for Construction	1.2	0	0	3	4	20	0	20	4	0	40	0
280	4" Diameter Floor Penetration												
281	#9401125 (DCP 96-016)4" flr Penetration	1.8	0	5	1	8	20	10	40	4	0	20	0
282	Cap Floor Drains												
283	#9601038 (DCP 96-020) C/M Dsgn Review & Approval	0.0	0	2	5	7	0	0	20	4	0	0	80
284	Install Solenoid												
285	#9603012 (DCP 96-039)Inst Solenoid	1.8	0	5	3	9	20	10	40	4	0	40	0
286	Remove for Discard GBs												
287	#9605061 (96-077)Rem GBs	1.2	0	20	39	60	10	10	20	4	120	160	400
288	Remove Gbs to Other Areas												
289	#9607016 (96-086)Rem GBs	1.2	0	40	16	57	10	10	20	4	120	80	80
290	Install Services to GB												
291	#9607018 (96-087)Inst Svcs to GB	3.5	0	40	14	57	40	20	40	4	80	80	80
292	Modify GB												
293	#9607020 (96-089)Mod GB/Loadg Chute	1.8	0	20	5	26	20	10	40	4	80	0	0
294	Relocate CAM Alarm												
295	#9609008 (96-118)Rel CAM Alarm	1.8	0	10	0	12	20	10	20	4	0	0	8
296	Install 2 9MM Camera System												
297	#9609009 (96-119)Inst 9mm Camera	3.0	0	40	1	44	40	10	40	4	0	16	0
298	Install Pressure Regulator												
299	#9609026 (97-003)Inst Regulator	0.9	0	5	2	8	10	5	20	4	0	0	30
300	Install Inline Metal Filters to Furnace Syst.												
301	#9710002 (97-006)Inst Metal Filters	0.6	0	20	2	23	0	10	20	4	40	0	0
302	Replace Ion Gauge Assembly												
303	#9710021 (97-007)Repl Vac Gauge R&A	0.3	0	20	7	27	0	5	0	4	0	80	40
304	Weld Mounting Plate to Floor												
305	#9710043 (97-009)Weld Plate to floor	0.9	0	20	0	22	10	5	20	4	8	0	0

I	A													M
	Project Title (to include Design Change Packages for each Project)	B	C	D	E	F	G	H	I	J	K	L		
		Design & Procure Cost (\$k)	Procure Capital (\$k)	Procure Operat (\$k)	Install Cost (\$k)	Total Cost (\$k)	Design Hours	Procure Hours	Fac. Eng Hours	ESH Hours	Shmtl Hours	Electrician Hours	Filter Hours	
306	Modify Piping Fans													
307	#9608021 (96-102)Mod Piping Fans R&A	8.2	0	100	40	148	100	40	40	4	200	500	0	
308	Install Vacuum Vent													
309	#9608058 (96-109)Inst Vacuum Vent	1.8	0	20	5	26	20	10	40	4	40	0	40	
310	Remove Traps, etc. on the Floor													
311	#9710047 (97-012)Rem Traps GB	0.0	0	0	2	2					40	0	0	

Appendix F

PROJECT PRIORITY SPREADSHEET TO
INCLUDE CONFIGURATION
FOR OPTIMIZATION

Table F.1: Project Priority Spreadsheet to Include Configuration for Optimization

	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Project Title to include Design Change Packages for each Project	EC Priority	Enable	Priority Factor	Design & Procure Cost (\$k)	Procure Capital (\$k)	Procure Operat (\$k)	Install Cost (\$k)	Total Cost (\$k)	Design Hours	Procure Hours	Fac. Eng Hours	ESH Hours	Shtmtl Hours	Electrician Hours	Fitter Hours
2	Parameter field for calculational purposes															
3	Total Required to Perform Work				2610	24864	2707	3652	33833	37659	2634	5442	2026	9896	13482	21161
4	Total Consumed As Selected		0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	Total Available to do Work per Four Months				398.00	1000	5000	570	6968	4800	2000	600	160	2080	3120	4680
6	Labor Rates (\$/hr.)									60	55	72	60	54	57	58
7																
8	TA-55 Compressors															
9	#9603031 (DCP 95-0-27)TA-55 Compressors R&A	1.000	0	0.000	7.1	0	700	42	749	100	20	40	4	0	240	480
10	TA-55 Replace Fire Protection Main															
11	#9603031 (DCP 95-0-27)TA-55 Compressors R&A	1.000	0	0.000	7.1	0	700	42	749	100	20	40	4	0	240	480
12	Replace Nitric Acid Supply Line															
13	#9710025 (97-005)Repl & Repair Nitric Supply Line R&A	0.901	0	0.000	7.1	700	0	5	712	100	20	40	4	0	0	80
14	#9711039 (97-015)Change Nitric Acid Supply Valve R&A	0.901	0	0.000	1.1	0	50	3	54	0	20	20	4	0	0	40
15	Acid Recycle Additional Tanks															
16	#9609036(95-0-12)NPDES Recycle	0.901	0	0.000	93.3	100	0	10	203	1500	60	40	4	80	16	80
17	#9407034 (DCP 95-002)Evaporator Removal R&A	0.901	0	0.000	0.0	0	0	16	16	0	0	20	4	160	40	80
18	ARIES															
19	#9601012B1 (96-026B1) ARIES Move	0.795	0	0.000	2.4	0	0	21	23	40	0	20	4	80	120	160
20	#9601012E1 (96-026E1)ARIES Move	0.795	0	0.000	2.4	0	0	22	24	40	0	20	4	80	120	180
21	#9601012F (DCP 96-026F) ARIES Move Raman	0.795	0	0.000	2.4	0	0	10	13	40	0	20	4	60	60	60
22	#9601012F1 (96-026F1)ARIES Move	0.795	0	0.000	2.4	0	0	48	51	40	0	20	4	120	240	480
23	#9601012G (DCP 96-026G) ARIES Move	0.795	0	0.000	2.4	0	0	48	51	40	0	20	4	120	240	480
24	#9601012G1 (96-026G1)ARIES Move	0.795	0	0.000	2.4	0	0	32	35	40	0	20	4	80	160	320
25	#9601012H (96-026H) ARIES Inst Conveyor	0.795	0	0.000	49.1	150	0	75	274	800	20	30	4	700	320	320
26	#9601012I (96-026I) ARIES Relocate	0.795	0	0.000	24.0	0	0	21	45	400	0	40	4	80	120	160
27	#9601012J (96-026J) ARIES D&D	0.795	0	0.000	24.0	0	0	32	56	400	0	40	4	80	160	320
28	#9601012K (96-026K) ARIES Trolley Supp Frame	0.795	0	0.000	37.1	150	0	9	196	600	20	30	4	160	0	0
29	#9601012L (96-026L) ARIES Inst TNC	0.795	0	0.000	25.1	150	0	32	207	400	20	40	4	80	160	320

1	C	Project Title to include Design Change	EC	Priority	Factor	Design & Procure Cost (\$K)	Procure Capital (\$K)	Procure Operat (\$K)	Install Cost (\$K)	Total Cost (\$K)	Design Hours	Procure Hours	Fac Eng Hours	ESH Hours	Skilled Hours	Electrician Hours	Filter Hours
30		#9601012M (96-026M) ARIES Inst NDA	0.795	0	0.000	50.8	300	0	32	383	800	50	30	4	80	160	320
31		#9601012N (96-026N) ARIES Inst Elec/Dec	0.795	0	0.000	49.1	150	0	48	247	800	20	40	4	120	240	480
32		#9601012O (96-026O) ARIES Inst H/D	0.795	0	0.000	49.1	150	0	48	247	800	20	40	4	120	240	480
33		#9601012P (96-026P) ARIES Inst Pit Bis	0.795	0	0.000	49.1	150	0	48	247	800	20	40	4	120	240	480
34		#9601012Q (96-026Q) ARIES Inst Cann'g	0.795	0	0.000	49.1	150	0	48	247	800	20	40	4	120	240	480
35		#9601012R (96-026R) ARIES Inst LTNL	0.795	0	0.000	49.1	150	0	48	247	800	20	40	4	120	240	480
36		Wet and Dry Vacuum Pumps															
37		Procure Replacement Pumps	0.639	0	0.000	2.3	150	0	25	177	20	20	20	4	150	40	240
38		Upgrade ROBOCAL Phase I															
39		DCPs for Robocal	0.612	0	0.000	3.5	250	0	6	259	40	20	20	4	0	100	0
40		In-line U Analyzer for Spec. Recov. Line															
41		Procure Uranium Analyzer	0.607	0	0.000	13.1	1000	0	3	1016	200	20	20	4	0	40	0
42		Replace GB															
43		#9509006 (95-0-33) Repl GB	0.586	0	0.000	2.4	0	0	37	39	40	0	20	4	120	40	480
44		Fire Alarm Control Panel Upgrade															
45		#9508065 (DCP 95-16) Replace Smoke Detectors RFC	0.583	0	0.000	3.5	200		3	206	40	20	30	4	0	40	0
46		#9508076 (DCP 95-26D)Add Fire Relay	0.583	0	0.000	3.5	0	20	3	26	40	20	30	4	0	40	0
47		#9605023 (DCP 96-072)Rewire Frangible Links R&A	0.583	0	0.000	0.6	0	0	5	5	10	0	10	0	0	80	0
48		Server for Maintenance Mgt. System															
49		Procure Servers	0.583	0	0.000	1.1	30	0	0	31	0	20	0	0	0	0	0
50		Declass. furnace for SRL															
51		DCPs for Furnaces	0.565	0	0.000	5.2	400	0	33	438	80	8	40	8	0	80	480
52		Pit Surveillance Leak Detector															
53		Procure Leak Detector	0.565	0	0.000	1.1	30	0	0	31	0	20	0	0	0	0	0
54		Pit Rebuild Leak Detector															
55		Procure Leak Detector	0.565	0	0.000	1.1	35	0	0	36	0	20	0	0	0	0	0
56		Process Control System Upgrade SRL															
57		DCPs for Process Control System	0.565	0	0.000	24.4	50	0	5	79	400	8	16	8	0	80	0
58		Continuous Air Monitor Replacements															
59		Procure CAMs	0.560	0	0.000	7.1	9000	0	0	9007	100	20	20	4	0	0	0
60		Install CLEAR Glovebox Line															
61		#9503099 (95-0-20) CLEAR GB	0.553	0	0.000	1.1	300	0	104	405	0	20	80	20	300	500	1000
62		GC Mass Spectrometer															
63		Procure GC Mass Spectrometer	0.540	0	0.000	0.2	70	0	0	70	0	4	4	4	0	0	0
64		Install Piping System for HCL Delivery															
65		#9604011 (96-057A) HCl Piping Syst	0.534	0	0.000	4.6	0	50	5	59	40	40	20	4	0	0	80

	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Project Title to include Design Change Packages for each Project	EC Priority	Enable	Priority Factor	Design & Procure Cost (\$k)	Procure Capital (\$k)	Procure Operat (\$k)	Install Cost (\$k)	Total Cost (\$k)	Design Hours	Procure Hours	Fac Eng Hours	ESH Hours	Shuttl Hours	Electrician Hours	Fitter Hours
66	Mod SRL															
67	#9412072 (DCP 95-006)Mod R&A	0.532	0	0.000	3.5	0	50	4	58	40	20	20	0	80	0	0
68	Inspection Area Trunkline & Trolley System															
69	97-013 Install Inspection Room Glove-boxes	0.516	0	0.000	81.9	75	0	16	173	1200	180	40	4	300	0	0
70	Sheffield rotary Contour Gauge															
71	DCPs for Gauge	0.516	0	0.000	3.5	135	0	7	145	40	20	40	4	120	0	0
72	Ring Rotary Contour Gauge															
73	DCPs for Ring Rotocon	0.516	0	0.000	3.5	0	0	7	10	40	20	40	4	120	0	0
74	PIGMA Welder															
75	#9602003(95-0-15A)PIGMA Proc Control	0.516	0	0.000	252.4	203	0	238	693	4060	160	640	640	636	1222	1655
76	#9611007 (DCP 95-15C) C/M Design Development	0.516	0	0.000	0.0			1	1					0	20	0
77	#9611007(DCP 95-15C)Mod Door Entry	0.516	0	0.000	0.0			0	0							
78	#9611007 (DCP 95-15C) Release for Construction	0.516	0	0.000	0.0			0	0							
79	#9611007 (DCP 95-15C) Compile/Review As-builts	0.516	0	0.000	0.0			0	0							
80	#9611007 (DCP 95-15C) CM DCP Closeout	0.516	0	0.000	0.0			0	0							
81	#9710046(95-015D)Dem/Rem svcs for PIGMA R&A	0.516	0	0.000	0.0			0	0							
82	Complete Phase II Field Change Requests	0.516	0	0.000	0.0			0	0							
83	#9710044(95-0-15E)Const Rm&Svcs for PIGMA R&A	0.516	0	0.000	0.0			0	0							
84	Relocate Moore "T" Base Lathe															
85	#9606029 (96-083)Rel T-Base Lathe	0.516	0	0.000	2.4	0	0	13	15	40	0	80	4	80	100	40
86	Rel. & Inst NE End Foundry Upgd															
87	#9605017 (96-073) Rem Arc Melter Svcs	0.516	0	0.000	154.4	125	0	40	320	2500	80	160	400	0	40	240
88	Install Services to 40MM															
89	#9611050 (DCP 96-014) 40MM Design	0.516	0	0.000	0.0			27	27	0	0	0	0	120	180	180
90	Micro Fiche Equip. for Document Control															
91	Procure Micro Fiche Equipment	0.510	0	0.000	1.1	200	0	0	201	0	20	0	0	0	0	0
92	Gamma Counter, Automated															
93	Procure Automated Gamma Counter	0.496	0	0.000	0.2	80		0	80	0	4	0	0	0	0	0
94	Uninterruptable Power Supply for Network															
95	Procure UPS system	0.481	0	0.000	1.1	28		0	29	0	20	0	0	0	0	0
96	Sun SPARC Server															
97	Procure Sun SPARC Server	0.481	0	0.000	1.1	28		0	29	0	20	0	0	0	0	0

1	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
	Project Title to include Design Change Packages for each Project	EC Priority	Enable	Priority Factor	Design & Procure Cost (\$K)	Procure Capital (\$K)	Procure Operat (\$K)	Instal Cost (\$K)	Total Cost (\$K)	Design Hours	Procure Hours	Fac Eng Hours	ESH Hours	Shunt Hours	Electrician Hours	Filter Hours
98	Yard Scale															
99	Procure Yard Scale			0.477	0	0.000	1.1	20	0	0	20	0	0	0	0	0
100	Material Handler															
101	Procure Material Handler			0.477	0	0.000	1.1	75	0	76	0	0	0	0	0	0
102	Room X Upgrade															
103	#9602054C (DCP 95-008C) Release for Construction			0.435	0	0.000	0.6	0	27	10	0	10	4	240	120	
104	#9602054D-1 (DCP 95-008D-1) Instal GB			0.435	0	0.000	0.6	0	18	10	0	40	4	80	80	160
105	#9602054E (95-008E) Instal New GB			0.435	0	0.000	49.1	150	58	800	20	40	4	120	264	630
106	#9602054F (DCP 95-008F) Remove GB			0.435	0	0.000	0.6	0	27	10	0	10	4	240	120	120
107	#9602054F-1 (95-008F-1) Instal GB			0.435	0	0.000	49.1	0	48	800	20	40	4	120	240	480
108	#9602054G (DCP 95-008G) Remove GB			0.435	0	0.000	0.6	0	27	10	0	10	4	240	120	120
109	#9602054G-1 (95-008G-1) Instal GB			0.435	0	0.000	49.1	0	48	800	20	40	4	120	240	480
110	#9602054H (DCP 95-008H) Rem Trans GB			0.435	0	0.000	0.6	0	14	10	0	10	4	120	60	60
111	#9602054H-1 (95-008H-1) Instal GB			0.435	0	0.000	49.1	150	48	800	20	40	4	120	240	480
112	#9602054I (DCP 95-008I) Rel Trans GB			0.435	0	0.000	0.6	0	14	10	0	10	4	120	60	60
113	#9602054I-1 (95-008I-1) Instal GB			0.435	0	0.000	49.1	150	48	800	20	40	4	120	240	480
114	#9602054J (95-008J) Instal GB			0.435	0	0.000	49.1	150	55	800	20	40	4	120	240	600
115	#9602054K (95-008K) Instal GB			0.435	0	0.000	49.1	150	55	800	20	40	4	120	240	600
116	#9602054L (95-008L) Instal GB			0.435	0	0.000	49.1	150	55	800	20	40	4	120	240	600
117	Replace Wet Vacuum Pump & Install Catch Pan															
118	#9609012 (96-115)Rem/Repl Wet Vac Pump R&A			0.424	0	0.000	2.3	50	9	61	20	20	4	50	20	80
119	Relocate GB Penetrations for Wet Vac & RTD for Hydrothermal Proc.															
120	#9611048 (DCP 96-012B)Reloc GB Pen/Wet Vac R&A			0.411	0	0.000	0.0		2	2	0	0	0	16	0	24
121	Packaging Line Glove-boxes															
122	#9607039(96-094)Rem & Disc GB			0.410	0	0.000	0.6	0	3	4	10	10	4	16	16	
123	WR# TBD (DCP#TBD) Inst. Packaging Line			0.410	0	0.000	10.1	300	91	401	150	20	40	4	120	960
124	X-Ray Diffractometer															
125	Procure Diffractometer			0.401	0	0.000	1.1	230	0	231	0	20	0	0	0	0
126	Potable Water System Upgrade															
127	Procure Potable Water system			0.363	0	0.000	26.2	1000	0	1026	400	40	80	4	0	0
128	CCD Detector															
129	CCD Detector			0.343	0	0.000	0.0	30	0	30	0	0	0	0	0	0
130	CST-15 Metallograph with Digital Camera															
131	CST-15 Metallograph with Digital Camera			0.330	0	0.000	1.1	170	0	171	0	20	0	4	0	0

	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Project Title to include Design Change Packages for each Project	EC Priority	Enable	Priority Factor	Design & Procure Cost (\$k)	Procure Capital (\$k)	Procure Operat (\$k)	Install Cost (\$k)	Total Cost (\$k)	Design Hours	Procure Hours	Fac Eng Hours	ESH Hours	Shmtl Hours	Electrician Hours	Fitter Hours
132	NMT-6 Calorimeter															
133	Procure Calorimeter	0.381	0	0.000	2.6	90	0	0	93	40	4	4	4	0	0	0
134	Room Y Upgrades															
135	#9605042A (DCP 96-076A)Rem GB	0.295	0	0.000	0.6	0	0	9	10	10	0	10	4	80	40	40
136	#9605042B (DCP 96-076B)Rem GB	0.295	0	0.000	0.6	0	0	9	10	10	0	10	4	80	40	40
137	#9605042C (DCP 96-076C)Rem GB	0.295	0	0.000	0.6	0	0	9	10	10	0	10	4	80	40	40
138	#9605042D (96-076D)Rem GB	0.295	0	0.000	0.6	0	0	10	11	10	0	10	4	80	40	60
139	#9605042E (96-076E)Rem Metal Prep Line	0.295	0	0.000	0.6	0	0	2	2	10	0	10	4	0	0	24
140	#9605042F (96-076F)Decom Cyl GBs	0.295	0	0.000	0.6	0	0	3	3	10	0	0	4	0	0	40
141	#9605042G (96-076G)Decom/Disc GBs	0.295	0	0.000	0.6	0	0	11	12	10	0	10	4	80	80	40
142	#9605042H (96-076H) Rem Caustic Syst	0.295	0	0.000	0.6	0	0	2	3	10	0	20	4	40	0	0
143	#9605042I (96076I)Rem Laser System	0.295	0	0.000	0.6	0	0	8	9	10	0	0	4	0	140	0
144	Install " Restraining Clips" on UPS Static Switch															
145	#9603035 (DCP 96-044)Inst UPS Static Swtch R&A	0.290	0	0.000	0.6	0	0	2	2	10	0	10	4	0	24	0
146	Modify Intake Valves															
147	#9608034 (96-105)Mod Valves	0.290	0	0.000	2.3	0	0	1	3	20	20	40	4	16	0	0
148	Connect 3" Wet Vacuum Header															
149	#9601066 (DCP 96-029) 3" Wetvac	0.284	0	0.000	0.0	0	0	4	4	0	0	10	4	0	0	60
150	Install Pit Boost Box															
151	#9404062(DCP 95-003) Boost Box R&A	0.280	0	0.000	49.1	150	0	48	247	800	20	40	4	120	240	480
152	Installation of Inspection Room															
153	#9711001 (97-013) Install Inspec..	0.280	0	0.000		450	0	144	594	800	100	120	10	360	720	1440
154	Install Elec Feedthrough in GB															
155	#9607010 (96-085) Inst Elec Feed to GB	0.280	0	0.000	0.1	0	0	2	2	0	2	4	0	0	30	0
156	Slant Bed Lathe															
157	#9602016(DCP 95-019B2)Rem Arc Welder	0.280	0	0.000	0.6	0	0	18	19	10	0	10	4	80	160	80
158	Back-Machining Lathe															
159	#9711037 (97-016) Back-Mach Lathe Exh Tie-in R&A	0.280	0	0.000	32.2	25	20	12	89	500	40	240	160	0	0	40
160	Replace Motor Generators w/ "Pillar Solid State Converters"															
161	#9608018 (96-101) Revised Foundry Upgrade R&A	0.280	0	0.000	4.6	50	0	17	72	40	40	120	20	40	240	0
162	Install & Implement Pit Burst Equipment & Process															
163	#9605036 (96-075) Pit Burst Inst GB	0.280	0	0.000	49.1	150	0	48	247	800	20	40	4	120	240	480
164	NMT-5 Laser Optics															
165	NMT-5 Laser Optics	0.280	0	0.000	2.6	30	10	1	43	40	4	10	10	0	0	0

I	Project Title to include Design Change Packages for each Project	EC	Enable	Priority	Design & Procure Cost (\$k)	Procure Capital (\$k)	Procure Operat (\$k)	Install Cost (\$k)	Total Cost (\$k)	L	Procure Hours	Fac Eng Hours	RSH Hours	ShmH Hours	P	Electrician Hours	R	Filter Hours
166	Install Kolsky Bar																	
167	#9605068 (96-078) Kolsky Bar	0.280	0	0.000	14.8	250	0	37	302	240	8	60	10	0	240	400		
168	Arc Melter Rolling Mill & Lathe	0.280	0	0.000	49.1	0	0	48	97	800	20	40	4	120	240	480		
169	#9601033 (96-018) Arc Melter Mod GB	0.280	0	0.000	49.1	0	0	48	97	800	20	40	4	120	240	480		
170	Radioactive Liquid Waste Line Tie-in	0.278	0	0.000	2.6	0	0	2	14	40	4	40	4	0	0	24		
171	#9710033 (97-011)Rad Waste Line Tie-in	0.278	0	0.000	2.6	0	0	2	14	40	4	40	4	0	0	24		
172	Connect Hose Vacuum & Nitrogen	0.272	0	0.000	2.6	0	0	10	2	14	40	4	40	4	0	0		
173	#9603067 (DCP 96-049)Con Vac/N	0.272	0	0.000	2.6	0	0	10	2	15	40	4	40	4	0	0	30	
174	Install Bubbler Bypass on GB	0.272	0	0.000	0.2	0	5	1	6	0	4	4	4	0	0	10		
175	#9603068 (DCP 96-050)Inst Bubbler	0.272	0	0.000	0.2	0	5	1	6	0	4	4	4	0	0	10		
176	Connect House Vacuum to GBs	0.272	0	0.000	0.2	0	5	1	6	0	4	4	4	0	0	10		
177	#9603069 (DCP 96-051)Conn Vac	0.272	0	0.000	0.2	0	5	10	15	0	4	4	4	0	0	160		
178	Install Nitrogen Argon Flowmeter	0.272	0	0.000	0.5	0	5	3	5	4	4	4	4	0	0	40		
179	#9608083 (96-117)Inst Nit/Arg Flowmeter	0.272	0	0.000	0.5	0	5	3	5	4	4	4	4	0	0	40		
180	Install Vault TV Monitoring System	0.267	0	0.000	3.5	50	10	7	70	40	20	20	4	40	80	0		
181	NMT-4 TV Security System (JO 693813) (95DO)	0.267	0	0.000	3.5	50	10	7	70	40	20	20	4	40	80	0		
182	WR# (DCP 96-021)Inst Vault TV Monitor R&A	0.267	0	0.000	2.3	5	5	4	16	20	20	10	4	20	40	0		
183	Install Sanitary Waste Detectors	0.254	0	0.000	3.0	25	0	4	32	40	10	40	4	20	24	20		
184	#9610015 (DCP 96-007)Inst Sanit Waste Detec R&A	0.254	0	0.000	3.0	25	0	4	32	40	10	40	4	20	24	20		
185	Install New Butterfly Valves Bleedoffs	0.252	0	0.000	1.2	0	5	2	9	10	10	40	4	40	0	0		
186	#9607031 (96-093)Inst Butterfly Valves	0.252	0	0.000	1.2	0	5	2	9	10	10	40	4	40	0	0		
187	Remove Autoclase Shutoff Valves	0.252	0	0.000	0.3	0	0	3	3	5	0	10	4	0	0	40		
188	#9607040 (96-095)Rem Intake Shutoff Valves R&A	0.252	0	0.000	0.3	0	0	3	3	5	0	10	4	0	0	40		
189	Install "Scroll Pump" Vacuum Pump	0.252	0	0.000	1.8	0	0	7	19	20	10	40	4	0	40	80		
190	#9607060 (96-098)Inst Scroll Vacuum Pump R&A	0.252	0	0.000	1.8	0	0	7	19	20	10	40	4	0	40	80		
191	Install Seismic Monitor	0.252	0	0.000	3.0	25	0	4	32	40	10	40	4	20	24	20		
192	#9608042 (96-107)Inst Seismic Monitor	0.252	0	0.000	3.0	25	0	4	32	40	10	40	4	20	24	20		
193	Station XYZ Upgrade	0.252	0	0.000	65.5	0	0	66	1000	100	40	40	4	0	0	0		
194	#9604063(95-0-21) XYZ Upgrade R&A	0.252	0	0.000	65.5	0	0	66	1000	100	40	40	4	0	0	0		
195	#9609004 (96-114)Rem/Repl StaXYZ Vault	0.252	0	0.000	6.0	500	8	514	100	0	0	4	4	100	40	0		
196	#9609046 (97-004)Inst Conduit Stat. XYZ	0.252	0	0.000	1.8	0	25	5	32	20	10	20	4	0	80	0		
197	CST-15 Digital Still Camera																	
198	CST-15 Digital Still Camera	0.252	0	0.000	0.0	0	5	0	0	0	0	0	0	0	0	0		

	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Project Title to include Design Change Packages for each Project	EC Priority	Enable	Priority Factor	Design & Procure Cost (\$k)	Procure Capital (\$k)	Procure Operat (\$k)	Install Cost (\$k)	Total Cost (\$k)	Design Hours	Procure Hours	Fac. Eng Hours	ESH Hours	Shuntl Hours	Electrician Hours	Fitter Hours
199	Install PRD Bypass System															
200	#9604030 (DCP 96-061)C/M Dsgn Review & Approval	0.252	0	0.000	0.6	0	0	14	15	0	10	40	4	0	0	240
201	Modify All CAM Alarm Outputs															
202	#9603045 (DCP 96-047) CAM's Mod DCP R & A	0.242	0	0.000	13.1	0	25	5	43	200	20	80	4	80	0	0
203	Chlorine Detection System															
204	#9603008(DCP 96-023)Chlor Det Sys	0.232	0	0.000	13.1	100	20	37	170	200	20	40	8	0	320	320
205	Install Check Valve in Process Line															
206	#9608015 (96-100)Inst Check Valve	0.232	0	0.000	3.5	0	50	3	56	40	20	40	4	0	40	0
207	Hydrothermal Reactor Unit Glovebox															
208	Hydrothermal Reactor Unit Glovebox	0.232	0	0.000	7.0	600	0	12	619	80	40	80	40	0	40	120
209	Mass Spectrometer Attachment to TGA/DSC															
210	Mass Spectrometer Attachment to TGA/DSC	0.218	0	0.000	0.2	250	0	3	253	0	4	4	4	0	40	0
211	Upgrade TNC GB															
212	#9711029 (97-017)Upgr TNC GB	0.204	0	0.000	3.0	0	25	0	28	40	10	10	4	0	0	0
213	Replace Optical Well in GB															
214	#9607026 (96-081)Repl Optic Well in GB	0.204	0	0.000	1.8	0	40	1	43	20	10	10	4	16	0	0
215	Inst On/Off Safety Switch ROD Mill GB															
216	#9609018 (96-121)Inst Safety Swth GB	0.204	0	0.000	1.2	0	20	5	26	10	10	0	4	0	80	0
217	Modify GB															
218	#9603005(DCP 96-022)Mod GB	0.204	0	0.000	3.0	0	20	9	32	40	10	10	4	160	0	0
219	NMT-5 Secondary-Ion Mass Spec															
220	NMT-5 Secondary-Ion Mass Spec	0.206	0	0.000	1.1	250	0	9	260	0	20	0	4	80	80	0
221	NMT-5 Scanning Auger															
222	NMT-5 Scanning Auger	0.206	0	0.000	1.1	250	0	9	260	0	20	0	4	80	80	0
223	Install 208V 30 Amp Outlet															
224	#9605024 (96-103)Inst 208V Outlet	0.204	0	0.000	1.2	0	1	3	5	20	0	10	4	0	20	20
225	ESH-1 PCM-2 Monitors															
226	ESH-1 PCM-2 Monitors	0.204	0	0.000	7.0	600	20	9	636	80	40	40	4	0	80	80
227	Replace Emergency Eyewash w/ New Sprayer															
228	#9507024 (DCP 95-0-29)Repl Emerg Eyewash R&A	0.204	0	0.000	0.3	0	2	1	4	0	5	0	4	0	0	20
229	Install Services for "De-duster"															
230	#9710001(97-008)Inst Svc	0.182	0	0.000	1.5	0	20	2	24	20	5	20	4	16	0	24
231	Install New Speakers															
232	#9612003 (DCP 96-015) Release for Construction	0.181	0	0.000	3.5	0	20	5	28	40	20	40	4	0	80	0

	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Project Title to include Design Change Packages for each Project	EC Priority	Enable	Priority Factor	Design & Procure Cost (\$k)	Procure Capital (\$k)	Procure Operat (\$k)	Install Cost (\$k)	Total Cost (\$k)	Design Hours	Procure Hours	Fac. Eng Hours	ESH Hours	Shmtl Hours	Electrician Hours	Fitter Hours
233	#9711042 (97-018)Upgr Emerg Paging System	0.181	0	0.000	6.0	0	50	6	62	40	20	40	4	0	100	0
234	Install Water Sensors Near W. Wall															
235	#9603015 (DCP 96-040)Inst Water Sensor	0.161	0	0.000	3.0	0	20	14	37	20	10	20	4	0	80	160
236	Replace Service Panel															
237	#9609051 (97-002)Repl Svc Panel	0.155	0	0.000	3.0	0	20	2	25	20	10	20	4	24	0	0
238	Replace DB															
239	#9607050 (96-096)Repl DB window	0.155	0	0.000	0.0	0	5	1	6	0	0	0	2	8	0	0
240	Boiler Replacement															
241	#9602042 (DCP 96-035)Boiler Replacement	0.147	0	0.000	8.0	250	0	30	288	40	40	80	10	240	40	240
242	Install 110 Volt Flex Runs															
243	#9604068 (DCP 96-067)Inst 110V Flexruns	0.147	0	0.000	5.0	0	20	3	28	40	10	40	4	0	40	0
244	Install Emergency Shower															
245	#9608072 (96-113)Inst Emerg Shower	0.147	0	0.000	1.5	0	5	5	11	10	5	40	4	0	0	80
246	Relocate Radiographic Syst															
247	#9607004 (96-084)Rel Rad Syst	0.144	0	0.000	5.0	0	20	8	33	40	10	40	4	0	0	140
248	Upgrade Services															
249	#9605035 (DCP 96-074)Upgrd Serv	0.142	0	0.000	5.0	0	50	34	89	40	10	40	4	200	200	200
250	Review & Repair Inert Gas Photohelics															
251	#9604032 (DCP 96-062)Repair GAS Photohelics R&A	0.124	0	0.000	1.0	0	10	3	14	0	10	0	4	0	0	40
252	NMT-6 Solid State NMR Instrument															
253	NMT-6 Solid State NMR Instrument	0.114	0	0.000	0.8	500	0	8	509	0	8	8	8	0	140	0
254	ESH-1 HFM-8 Monitors															
255	ESH-1 HFM-8 Monitors	0.114	0	0.000	6.0	250	20	0	276	40	20	10	4	0	0	0
256	Inst Bisco Shielding Behind Gamma Detector															
257	#9608061 (96-112)Inst Bisco Shield	0.113	0	0.000	5.0	0	100	11	116	40	10	40	4	200	0	0
258	EED Modify GBs															
259	#9404051 (DCP 96-059) Gbs (EDD) R&A	0.109	0	0.000	5.0	0	50	7	62	40	10	40	4	40	40	40
260	Replace GBs															
261	Replace GBs	0.094	0	0.000	81.0	450	100	139	770	800	10	40	20	480	960	1000
262	Replacement GBs															
263	Replacement GBs	0.094	0	0.000	81.0	300	75	97	553	800	10	40	20	240	480	960
264	Replacement GB's															
265	Replacement GB's	0.094	0	0.000	81.0	300	75	97	553	800	10	40	20	240	480	960
266	Replace GBs															
267	Replace GBs	0.094	0	0.000	81.0	300	75	97	553	800	10	40	20	240	480	960

	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
I	Project Title to include Design Change Packages for each Project	EC Priority	Enable	Priority Factor	Design & Procure Cost (\$k)	Procure Capital (\$k)	Procure Operat (\$k)	Install Cost (\$k)	Total Cost (\$k)	Design Hours	Procure Hours	Fac. Eng Hours	ESH Hours	Shtmtl Hours	Electrician Hours	Filter Hours
268	Fuel Processing Furnaces															
269	Fuel Processing Furnaces	0.094	0	0.000	5.0	300	20	18	343	40	10	20	4	0	320	0
270	GB's Atmosphere Controllers (Dritrains)															
271	GB's Atmosphere Controllers (Dritrains)	0.094	0	0.000	2.0	300	20	48	370	10	10	10	4	40	320	480
272	Replacement GB's															
273	Replacement GB's	0.094	0	0.000	81.0	300	75	97	553	800	10	40	20	240	480	960
274	Install GB Replacements															
275	Install GB Replacements	0.094	0	0.000	81.0	300	75	97	553	800	10	40	20	240	480	960
276	Modify/Upgrade GB & XB For Earthquakes															
277	#9607019 (96-088)Mod 4GB/TB for Earthquake R&A	0.094	0	0.000	41.0	0	200	117	358	400	10	80	12	2160		
278	Remove UPS Powerstrip															
279	#9604018 (DCP 96-058)Rem UPS Powerstrip	0.093	0	0.000	1.0	0	0	3	4	10	0	10	4	40	10	0
280	Remove All Thermodetectors & Associated Wiring															
281	#9604043 (DCP 96-065)Rem Thermo/Wiring R&A	0.093	0	0.000	1.0	0	0	5	6	10	0	10	12	0	80	0
282	Remove Breathing Air Station from UPS															
283	#9605015 (DCP 96-070)Rem UPS Breathing Air R&A	0.093	0	0.000	1.0	0	0	3	4	10	0	10	4	0	40	0
284	CAM Alarm System Mods															
285	#9511004 (DCP 95-007) Release for Construction	0.079	0	0.000	2.0	0	0	3	5	20	0	20	4	0	40	0
286	4" Diameter Floor Penetration															
287	#9401125 (DCP 96-016)4"Flr penetration	0.079	0	0.000	3.0	0	5	1	9	20	10	40	4	0	20	0
288	Cap Floor Drains															
289	#9601038 (DCP 96-020) C/M Dsgn Review & Approval	0.079	0	0.000	0.0	0	2	5	7	0	0	20	4	0	0	80
290	Install Solenoid															
291	#9603012 (DCP 96-039)Inst Solenoid	0.079	0	0.000	3.0	0	5	3	11	20	10	40	4	0	40	0
292	Remove for Discard GBs															
293	#9605061 (96-077)Remove GBs	0.079	0	0.000	2.0	0	20	39	61	10	10	20	4	120	160	400
294	Remove GB's to Other Areas															
295	#9607016 (96-086)Rem GB's	0.079	0	0.000	2.0	0	40	16	58	10	10	20	4	120	80	80
296	Install Services to GBs															
297	#9607018 (96-087)Inst Svcs to GBs	0.079	0	0.000	6.0	0	40	14	60	40	20	40	4	80	80	80
298	Modify GB															
299	#9607020 (96-089)Mod GB/Loadg Chute	0.079	0	0.000	3.0	0	20	5	28	20	10	40	4	80	0	0

	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Project Title to Include Design Change Packages for each Project	EC Priority	Enable	Priority Factor	Design & Procure Cost (\$k)	Procure Capital (\$k)	Procure Operat (\$k)	Install Cost (\$k)	Total Cost (\$k)	Design Hours	Procure Hours	Fac. Eng Hours	ESH Hours	Shtmil Hours	Electrician Hours	Fitter Hours
300	Relocate CAM Alarm															
301	#9609008 (96-118)Rel CAM Alarm	0.079	0	0.000	3.0	0	10	1	14	20	10	20	4	0	0	8
302	Install 2 9MM Camera System															
303	#9609009 (96-119)Inst 9mm Camera	0.079	0	0.000	5.0	0	40	1	46	40	10	40	4	0	16	0
304	Install Pressure Regulator															
305	#9609026 (97-003)Inst Regulator	0.079	0	0.000	1.5	0	5	2	8	10	5	20	4	0	0	30
306	Install Inline Metal Filters to Furnace Syst.															
307	#9710002 (97-006)Inst Metal Filters	0.079	0	0.000	1.0	0	20	2	23	0	10	20	4	40	0	0
308	Replace Ion Gauge Assembly															
309	#9710021 (97-007)Repl Vac Gauge	0.079	0	0.000	0.5	0	20	7	28	0	5	0	4	0	80	40
310	Weld Mounting Plate to Floor															
311	#9710043 (97-009)Weld Plate to Floor	0.079	0	0.000	1.5	0	20	1	22	10	5	20	4	8	0	0
312	Modify Piping Fans															
313	#9608021 (96-102)Mod Piping Fans R&A	0.071	0	0.000	14.0	0	100	39	153	100	40	40	4	200	500	0
314	Install Vacuum Vent															
315	#9608058 (96-109)Inst Vacuum Vent	0.071	0	0.000	3.0	0	20	5	28	20	10	40	4	40	0	40
316	Remove Traps, etc. on the Floor															
317	#9710047 (97-012)Rem Traps GB	0.071	0	0.000	0.0	0	0	2	2					40	0	0

Appendix G

PROJECT PRIORITY SPREADSHEET

INDICATING OPTIMAL SOLUTION

Table G.1: Project Priority Spreadsheet Indicating Optimal Solution

1	Project Title to include Design Change Packages for each Project	EC	Enable	Priority	Design & Procure Cost (\$k)	Capital Procure Cost (\$k)	Operat Procure Cost (\$k)	Install Cost (\$k)	Total Cost (\$k)	Design Hours	Procure Hours	Fac. Eng Hours	ESH Hours	Shmtl Hours	Electrician Hours	Fitter Hours
2	Parameter field for calculational purposes															
3	Total Required to Perform Work				2610	24864	3707	3611	34791	37659	2634	5442	2026	9896	13242	20681
4	Total Consumed As Selected			56	306	1000	2462	351	4388	4781	343	600	147	1060	1686	3270
5	Total Available to do Work per Four Months				398.00	1000	5000	570	6968	4800	2000	600	160	2080	3120	4680
6	Labor Rates (\$/hr.)									60	55	72	60	54	57	58
7																
8	TA-55 Compressors															
9	#9603031 (DCP 95-0-27)TA-55 Compressors R&A	1.000	1	1.000	7.1	0	700	42	749	100	20	40	4	0	240	480
10	TA-55 Replace Fire Protection Main															
11	LN06526(97-014)Repl Fire Protection Main R&A*	1.000	1	1.000	7.1	0	1700	0	1707	100	20	40	4	0	0	0
12	Replace Nitric Acid Supply Line															
13	#9710025 (97-005)Repl & Repair Nitric Supply Line R&A	0.901	0	0.000	7.1	700	0	5	712	100	20	40	4	0	0	80
14	Supply Valve R&A															
15	Supply Valve R&A	0.901	1	0.901	1.1	0	50	3	54	0	20	20	4	0	0	40
16	Acid Recycle Additional Tanks															
17	#9609036(95-0-12)NPDES Recycle Removal R&A	0.901	1	0.901	93.3	100	0	10	203	1500	60	40	4	80	16	80
18	ARIES															
19	#9601012B1 (96-026B1) ARIES Move	0.795	1	0.795	2.4	0	0	21	23	40	0	20	80	120	160	
20	#9601012B1 (96-026B1)ARIES Move	0.795	1	0.795	2.4	0	0	22	24	40	0	20	80	120	180	
21	#9601012F (DCP 96-026F) ARIES Move Raman	0.795	1	0.795	2.4	0	0	10	13	40	0	20	4	60	60	
22	#9601012F1 (96-026F1)ARIES Move	0.795	1	0.795	2.4	0	0	48	51	40	0	20	4	120	240	480
23	#9601012G (DCP 96-026G) ARIES Move	0.795	1	0.795	2.4	0	0	48	51	40	0	20	4	120	240	480
24	#9601012H (96-026H) ARIES Inst	0.795	1	0.795	2.4	0	0	32	35	40	0	20	4	80	160	320
25	Conveyor															
26	#9601012I (96-026I) ARIES Relocate	0.795	1	0.795	24.0	0	0	21	45	400	0	40	4	80	120	160
27	#9601012J (96-026J) ARIES D&D	0.795	0	0.405	24.0	0	0	32	56	400	0	40	4	80	160	320
28	Supp Frame															
	#9601012K (96-026K) ARIES Trolley	0.795	1	0.795	37.1	150	0	9	196	600	20	30	4	160	0	0

I	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
	Project Title to include Design Change Packages for each Project	EC Priority	Enable	Priority Factor	Design & Procure Cost (\$k)	Procure Capital (\$k)	Procure Operat (\$k)	Install Cost (\$k)	Total Cost (\$k)	Design Hours	Procure Hours	Fac. Eng. Hours	BSH Hours	Shtmtl Hours	Electrician Hours	Fitter Hours
29	#9601012L (96-026L) ARIES Inst TNC	0.795	0	0.000	25.1	150	0	32	207	400	20	40	4	80	160	320
30	#9601012M (96-026M) ARIES Inst NDA	0.795	0	0.000	50.8	300	0	32	383	800	50	30	4	80	160	320
31	#9601012N (96-026N) ARIES Inst Elec/Dec	0.795	0	0.000	49.1	150	0	48	247	800	20	40	4	120	240	480
32	#9601012O (96-026O) ARIES Inst H/D	0.795	0	0.000	49.1	150	0	48	247	800	20	40	4	120	240	480
33	#9601012P (96-026P) ARIES Inst Pit Bis	0.795	0	0.000	49.1	150	0	48	247	800	20	40	4	120	240	480
34	#9601012Q (96-026Q) ARIES Inst Cann'g	0.795	0	0.000	49.1	150	0	48	247	800	20	40	4	120	240	480
35	#9601012R (96-026R) ARIES Inst LLNL	0.795	0	0.169	49.1	150	0	48	247	800	20	40	4	120	240	480
36	Wet and Dry Vacuum Pumps															
37	Procure Replacement Pumps	0.639	0	0.000	2.3	150	0	25	177	20	20	20	4	150	40	240
38	Upgrade ROBOCAL Phase I															
39	DCPs for Robocal	0.612	0	0.000	3.5	250	0	6	259	40	20	20	4	0	100	0
40	In-line U Analyzer for Spec. Recov. Line															
41	Procure Uranium Analyzer	0.607	0	0.000	13.1	1000	0	3	1016	200	20	20	4	0	40	0
42	Replace GB															
43	#9509006 (95-0-33) Repl GB	0.586	1	0.586	2.4	0	0	37	39	40	0	20	4	120	40	480
44	Fire Alarm Control Panel Upgrade															
45	#9508065 (DCP 95-16) Replace Smoke Detectors RFC	0.583	0	0.000	3.5	200		3	206	40	20	30	4	0	40	0
46	#9508076 (DCP 95-26D)Add Fire Relay Mods R&A	0.583	0	0.000	3.5	0	20	3	26	40	20	30	4	0	40	0
47	#9605023 (DCP 96-072)Rewire Frangible Links R&A	0.583	1	0.583	0.6	0	0	5	5	10	0	10	0	0	80	0
48	Server for Maintenance Mgt. System															
49	Procure Servers	0.583	1	0.583	1.1	30	0	0	31	0	20	0	0	0	0	0
50	Declass. furnace for SRL															
51	DCPs for Furnaces	0.565	0	0.000	5.2	400	0	33	438	80	8	40	8	0	80	480
52	Pit Surveillance Leak Detector															
53	Procure Leak Detector	0.565	1	0.565	1.1	30	0	0	31	0	20	0	0	0	0	0
54	Pit Rebuild Leak Detector															
55	Procure Leak Detector	0.565	1	0.565	1.1	35	0	0	36	0	20	0	0	0	0	0
56	Process Control System Upgrade SRL															
57	DCPs for Process Control System	0.565	1	0.565	24.4	50	0	5	79	400	8	16	8	0	80	0
58	Continuous Air Monitor Replacements															
59	Procure CAMs	0.560	0	0.000	7.1	9000	0	0	9007	100	20	20	4	0	0	0
60	Install CLEAR Glovebox Line															
61	#9503099 (95-0-20) CLEAR GB	0.553	0	0.000	1.1	300	0	104	405	0	20	80	20	300	500	1000

	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Project Title to include Design Change Packages for each Project	EC Priority	Enable	Priority Factor	Design & Procure Cost (\$k)	Procure Capita (\$k)	Procure Operat (\$k)	Install Cost (\$k)	Total Cost (\$k)	Design Hours	Procure Hours	Fac. Eng Hours	ESH Hours	Shimul Hours	Electrician Hours	Fitter Hours
62	GC Mass Spectrometer															
63	Procure GC Mass Spectrometer	0.540	1	0.540	0.2	70	0	0	70	0	4	4	4	0	0	0
64	Install Piping System for HCL Delivery															
65	#9604011 (96-057A) HCl Piping Syst	0.534	0	0.000	4.6	0	50	5	59	40	40	20	4	0	0	80
66	Mod SRL															
67	#9412072 (DCP 95-006)Mod R&A	0.532	0	0.000	3.5	0	50	4	58	40	20	20	0	80	0	0
68	Inspection Area Trunkline & Trolley System															
69	97-013 Install Inspection Room GB's	0.516	0	0.014	81.9	75	0	16	173	1200	180	40	4	300	0	0
70	Sheffield rotary Contour Gauge															
71	DCPs for Gauge	0.516	0	0.000	3.5	135	0	7	145	40	20	40	4	120	0	0
72	Ring Rotary Contour Gauge															
73	DCPs for Ring Rotocon	0.516	0	0.000	3.5	0	0	7	10	40	20	40	4	120	0	0
74	PIGMA Welder															
75	#9602003(95-0-15A)PIGMA Proc Control	0.516	0	0.000	252.4	203	0	238	693	4060	160	640	640	636	1222	1655
76	#9611007 (DCP 95-15C) C/M Design Development	0.516	0	0.000	0.0			1	1					0	20	0
77	#9611007(DCP 95-15C)Mod Door Entry	0.516	0	0.516	0.0			0	0							
78	#9611007 (DCP 95-15C) Release for Construction	0.516	0	0.516	0.0			0	0							
79	#9611007 (DCP 95-15C) Compile/Review As-builts	0.516	0	0.516	0.0			0	0							
80	#9611007 (DCP 95-15C) CM DCP Closeout	0.516	0	0.516	0.0			0	0							
81	#9710046(95-015D)Dem/Rem svcs for PIGMA R&A	0.516	0	0.516	0.0			0	0							
82	Complete Phase II Field Change Requests	0.516	1	0.516	0.0			0	0							
83	#9710044(95-0-15E)Const Rm&Svcs for PIGMA R&A	0.516	0	0.516	0.0			0	0							
84	Relocate Moore T Base Lathe															
85	#9606029 (96-083)Rel T-Base Lathe	0.516	0	0.000	2.4	0	0	13	15	40	0	80	4	80	100	40
86	Rel. & Inst GB to Foundry Upgd															
87	#9605017 (96-073) Rem Arc Melter Svcs	0.516	0	0.000	154.4	125	0	40	320	2500	80	160	400	0	40	240
88	Install Services to 40MM															
89	#9611050 (DCP 96-014) 40MM Design	0.516	1	0.516	0.0			27	27	0	0	0	0	120	180	180
90	Micro Fiche Equip. for Document Control															
91	Procure Micro Fiche Equipment	0.510	0	0.000	1.1	200	0	0	201	0	20	0	0	0	0	0

	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Project Title to include Design Change Packages for each Project	EC Priority	Enable	Priority Factor	Design & Procure Cost (\$k)	Procure Capita (\$k)	Procure Operat (\$k)	Install Cost (\$k)	Total Cost (\$k)	Design Hours	Procure Hours	Fac. Eng Hours	ESH Hours	Shmtl Hours	Electrician Hours	Filter Hours
92	Gamma Counter, Automated															
93	Procure Automated Gamma Counter	0.496	1	0.496	0.2	80		0	80	0	4	0	0	0	0	0
94	Uninterruptable Power Supply for Network															
95	Procure UPS system	0.481	1	0.481	1.1	28		0	29	0	20	0	0	0	0	0
96	Sun SPARC Server															
97	Procure Sun SPARC Server	0.481	1	0.481	1.1	28		0	29	0	20	0	0	0	0	0
98	Yard Scale															
99	Procure Yard Scale	0.477	1	0.477	1.1	20		0	21	0	20	0	0	0	0	0
100	Material Handler															
101	Procure Material Handler	0.477	1	0.477	1.1	75		0	76	0	20	0	0	0	0	0
102	Room X Upgrade															
103	#9602054C (DCP 95-008C) Release for Construction	0.435	0	0.000	0.6	0	0	27	27	10	0	10	4	240	120	120
104	#9602054D-1 (DCP 95-008D-1) Install GB	0.435	0	0.000	0.6	0	0	18	19	10	0	40	4	80	80	160
105	#9602054E (95-008E) Install New GB	0.435	0	0.000	49.1	150	0	58	257	800	20	40	4	120	264	630
106	#9602054F (DCP 95-008F) Remove GB	0.435	0	0.435	0.6	0	0	27	27	10	0	10	4	240	120	120
107	#9602054F-1 (95-008F-1) Install GB	0.435	0	0.000	49.1	0	0	48	97	800	20	40	4	120	240	480
108	#9602054G (DCP 95-008G) Remove GB	0.435	0	0.435	0.6	0	0	27	27	10	0	10	4	240	120	120
109	#9602054G-1 (95-008G-1) Install GB	0.435	0	0.000	49.1	0	0	48	97	800	20	40	4	120	240	480
110	#9602054H (DCP 95-008H) Rem Trans. GB	0.435	1	0.435	0.6	0	0	14	14	10	0	10	4	120	60	60
111	#9602054H-1 (95-008H-1) Inst GB	0.435	0	0.000	49.1	150	0	48	247	800	20	40	4	120	240	480
112	#9602054I (DCP 95-008I) Rel Trans.GB	0.435	0	0.435	0.6	0	0	14	14	10	0	10	4	120	60	60
113	#9602054I-1 (95-008I-1) Inst GB	0.435	0	0.000	49.1	150	0	48	247	800	20	40	4	120	240	480
114	#9602054J (95-008J) Inst GB	0.435	0	0.000	49.1	150	0	55	254	800	20	40	4	120	240	600
115	#9602054K (95-008K) Inst GB	0.435	0	0.000	49.1	150	0	55	254	800	20	40	4	120	240	600
116	#9602054L (95-008L) Inst GB	0.435	0	0.000	49.1	150	0	55	254	800	20	40	4	120	240	600
117	Replace Wet Vacuum Pump & Install Catch Pan															
118	#9609012 (96-115)Rem/Repl Wet Vac Pump R&A	0.424	0	0.000	2.3	50	0	9	61	20	20	20	4	50	20	80
119	Relocate GB Penetrations for Wet Vac & RTD for Hydrothermal Proc.															
120	#9611048 (DCP 96-012B)Reloc GB Pen/Wet Vac R&A	0.411	1	0.411	0.0			2	2	0	0	0	0	16	0	24
121	Packaging Line Glove-boxes															
122	#9607039(96-094)Rem & Disc GB	0.410	1	0.410	0.6	0	0	3	4	10	0	10	4	16	16	16

I	C Project Title to include Design Change Packages for each Project	D EC Priority	E Enable	F Priority Factor	G Design & Procure Cost (\$k)	H Procure Capital (\$k)	I Procure Operat (\$k)	J Install Cost (\$k)	K Total Cost (\$k)	L Design Hours	M Procure Hours	N Fac. Eng Hours	O ESH Hours	P Shmtl Hours	Q Electrician Hours	R Filter Hours
123	WR# TBD (DCP#TBD) Inst. Packaging Line	0.410	0	0.000	10.1	300	0	91	401	150	20	40	4	120	500	960
124	X-Ray Diffractometer															
125	Procure Diffractometer	0.401	0	0.000	1.1	230	0	0	231	0	20	0	0	0	0	0
126	Potable Water System Upgrade															
127	Procure Potable Water system	0.363	0	0.000	26.2	1000	0	0	1026	400	40	80	4	0	0	0
128	CCD Detector															
129	CCD Detector	0.343	1	0.343	0.0	30	0	0	30	0	0	0	0	0	0	0
130	CST-15 Metallograph with Digital Camera															
131	CST-15 Metallograph with Digital Camera	0.330	0	0.000	1.1	170		0	171	0	20	0	4	0	0	0
132	NMT-6 Calorimeter															
133	Procure Calorimeter	0.381	1	0.381	2.6	90	0	0	93	40	4	4	4	0	0	0
134	Room Y Upgrades															
135	#9605042A (DCP 96-076A)Rem GB	0.295	1	0.295	0.6	0	0	9	10	10	0	10	4	80	40	40
136	#9605042B (DCP 96-076B)Rem GB	0.295	1	0.295	0.6	0	0	9	10	10	0	10	4	80	40	40
137	#9605042C (DCP 96-076C)Rem GB	0.295	1	0.295	0.6	0	0	9	10	10	0	10	4	80	40	40
138	#9605042D (96-076D)Rem GB	0.295	1	0.295	0.6	0	0	10	11	10	0	10	4	80	40	60
139	#9605042E (96-076E)Rem Metal Prep Line	0.295	1	0.295	0.6	0	0	2	2	10	0	10	4	0	0	24
140	#9605042F (96-076F)Decom Cyl GBs	0.295	0	0.295	0.6	0	0	3	3	10	0	0	4	0	0	40
141	#9605042G (96-076G)Decom/Disc GBs	0.295	1	0.295	0.6	0	0	11	12	10	0	10	4	80	80	40
142	#9605042H (96-076H) Rem Caustic Syst	0.295	0	0.000	0.6	0	0	2	3	10	0	20	4	40	0	0
143	#9605042I (96076I)Rem Laser System	0.295	1	0.295	0.6	0	0	8	9	10	0	0	4	0	140	0
144	Install Restraining Clips on UPS Static Switch															
145	#9603035 (DCP 96-044)Inst UPS Static Switch R&A	0.290	1	0.290	0.6	0	0	2	2	10	0	10	4	0	24	0
146	Modify Intake Valves															
147	#9608034 (96-105)Mod Valves	0.290	0	0.000	2.3	0	0	1	3	20	20	40	4	16	0	0
148	Connect 3 Wet Vacuum Header															
149	#9601066 (DCP 96-029) 3 Wetvac	0.284	0	0.000	0.0	0	0	4	4	0	0	10	4	0	0	60
150	Install Pit Boost Box															
151	#9404062(DCP 95-003) Boost Box R&A	0.280	0	0.000	49.1	150	0	48	247	800	20	40	4	120	240	480
152	Installation of Inspection Room															
153	#9711001 (97-013) Install Inspec.	0.280	0	0.000		450	0	144	594	800	100	120	10	360	720	1440
154	Install Elec Feedthrough in GB															
155	#9607010 (96-085) Inst Elec Feed to GB	0.280	1	0.280	0.1	0	0	2	2	0	2	4	0	0	30	0

1	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
Project Title to include Design Change Packages for each Project	BC	Priority	Enable	Factor	Design & Procure Cost (\$k)	Capita Procure (\$k)	Operat (\$k)	Install (\$k)	Total Cost (\$k)	Design Hours	Procure Hours	Fac. Eng Hours	ESH Hours	Shmll Hours	Electrician Hours	Filter Hours
156																
157		0.280	0	0.000	0.6	0	0	18	19	10	0	10	4	80	160	80
158																
159		0.280	0	0.000	32.2	25	20	12	89	500	40	240	160	0	0	40
160																
161		0.280	0	0.000	4.6	50	0	17	72	40	40	120	20	40	240	0
162																
163		0.280	0	0.000	49.1	150	0	48	247	800	20	40	4	120	240	480
164																
165		0.280	0	0.000	2.6	30	10	0	43	40	4	10	10	0	0	0
166																
167		0.280	0	0.000	14.8	250	0	37	302	240	8	60	10	0	240	400
168																
169		0.280	0	0.000	49.1	0	0	48	97	800	20	40	4	120	240	480
170																
171		0.278	0	0.000	2.6	0	10	2	14	40	4	40	4	0	0	24
172																
173		0.272	0	0.000	2.6	0	10	2	15	40	4	40	4	0	0	30
174																
175		0.272	0	0.272	0.2	0	5	0	6	0	4	4	4	0	0	10
176																
177		0.272	1	0.272	0.2	0	5	10	15	0	4	4	4	0	0	160
178																
179		0.272	1	0.272	0.5	0	2	3	5	4	4	4	4	0	0	40
180																
181		0.267	0	0.000	3.5	50	10	7	70	40	20	20	4	40	80	0
182		0.267	0	0.000	2.3	5	5	4	16	20	20	10	4	20	40	0
183																
184		0.254	0	0.000	3.0	25	0	4	32	40	10	40	4	20	24	20
185																
186		0.252	0	0.000	1.2	0	5	2	9	10	10	40	4	40	0	0

	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Project Title to include Design Change Packages for each Project	EC Priority	Enable	Priority Factor	Design & Procure Cost (\$k)	Procure Capital (\$k)	Procure Operat (\$k)	Install Cost (\$k)	Total Cost (\$k)	Design Hours	Procure Hours	Fac. Eng Hours	ESH Hours	Shmtl Hours	Electrician Hours	Filter Hours
187	Remove Autoclose Shuffle Valves															
188	#9607040 (96-095)Rem Intake Shuffle Valves R&A	0.252	0	0.000	0.3	0	0	3	3	5	0	10	4	0	0	40
189	Install "Scroll Pump" Vacuum Pump															
190	#9607060 (96-098)Inst Scroll Vacuum Pump R&A	0.252	0	0.000	1.8	0	10	7	19	20	10	40	4	0	40	80
191	Install Seismic Monitor															
192	#9608042 (96-107)Inst Seismic Monitor	0.252	0	0.000	3.0	25	0	4	32	40	10	40	4	20	24	20
193	Station XYZ Upgrade															
194	#9604063(95-0-21) XYZ Upgrade R&A	0.252	0	0.000	65.5	0	0	0	66	1000	100	40	4	0	0	0
195	#9609004 (96-114)Rem/Repl StatXYZ Vault Dr	0.252	0	0.000	6.0	500		8	514	100	0	0	4	100	40	0
196	#9609046 (97-004)Inst Conduit StatXYZ	0.252	0	0.000	1.8	0	25	5	32	20	10	20	4	0	80	0
197	CST-15 Digital Still Camera															
198	CST-15 Digital Still Camera	0.252	0	0.000	0.0	0	5	0	5	0	0	0	0	0	0	0
199	Install PRD Bypass System															
200	#9604030 (DCP 96-061)C/M Dsgn Review & Approval	0.252	0	0.000	0.6	0	0	14	15	0	10	40	4	0	0	240
201	Modify All CAM Alarm Outputs															
202	#9603045 (DCP 96-047) CAM's Mod DCP R & A	0.242	0	0.000	13.1	0	25	5	43	200	20	80	4	80	0	0
203	Chlorine Detection System															
204	#9603008(DCP 96-023)Chlor Det Sys	0.232	0	0.000	13.1	100	20	37	170	200	20	40	8	0	320	320
205	Install Check Valve in Process Line															
206	#9608015 (96-100)Inst Check Valve	0.232	0	0.000	3.5	0	50	3	56	40	20	40	4	0	40	0
207	Hydrothermal Reactor Unit Glovebox															
208	Hydrothermal Reactor Unit Glovebox	0.232	0	0.000	7.0	600	0	12	619	80	40	80	40	0	40	120
209	Mass Spectrometer Attachment to TGA/DSC															
210	Mass Spectrometer Attachment to TGA/DSC	0.218	0	0.000	0.2	250	0	3	253	0	4	4	4	0	40	0
211	Upgrade TNC GB															
212	#9711029 (97-017)Upgr TNC GB	0.204	0	0.000	3.0	0	25	0	28	40	10	10	4	0	0	0
213	Replace Optical Well in GB															
214	#9607026 (96-081)Repl Optic Well in GB	0.204	0	0.000	1.8	0	40	1	43	20	10	10	4	16	0	0
215	Inst On/Off Safety Switch ROD Mill GB															
216	#9609018 (96-121)Inst Safety Swth GB	0.204	0	0.000	1.2	0	20	5	26	10	10	0	4	0	80	0

	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Project Title to include Design Change Packages for each Project	EC Priority	Enable	Priority Factor	Design & Procure Cost (\$k)	Procure Capita (\$k)	Procure Operat (\$k)	Install Cost (\$k)	Total Cost (\$k)	Design Hours	Procure Hours	Fac. Eng Hours	ESH Hours	Shtmtl Hours	Electrician Hours	Filter Hours
217	Modify GB															
218	#9603005(DCP 96-022)Mod GB	0.204	0	0.000	3.0	0	20	9	32	40	10	10	4	160	0	0
219	NMT-5 Secondary-Ion Mass Spec															
220	NMT-5 Secondary-Ion Mass Spec	0.206	0	0.000	1.1	250	0	9	260	0	20	0	4	80	80	0
221	NMT-5 Scanning Auger															
222	NMT-5 Scanning Auger	0.206	0	0.000	1.1	250	0	9	260	0	20	0	4	80	80	0
223	Install 208V 30 Amp Outlet															
224	#9605024 (96-103)Inst 208V Outlet	0.204	0	0.000	1.2	0	1	3	5	20	0	10	4	0	20	20
225	ESH-1 PCM-2 Monitors															
226	ESH-1 PCM-2 Monitors	0.204	0	0.000	7.0	600	20	9	636	80	40	40	4	0	80	80
227	Replace Emergency Eyewash w/ New Sprayer															
228	#9507024 (DCP 95-0-29)Repl Emerg Eye-wash R&A	0.204	0	0.000	0.3	0	2	1	4	0	5	0	4	0	0	20
229	Install Services for "De-duster"															
230	#9710001(97-008)Inst Svc	0.182	0	0.000	1.5	0	20	2	24	20	5	20	4	16	0	24
231	Install New Speakers															
232	#9612003 (DCP 96-015) Release for Construction	0.181	0	0.000	3.5	0	20	5	28	40	20	40	4	0	80	0
233	#9711042 (97-018)Upgr Emerg Paging System	0.181	0	0.000	6.0	0	50	6	62	40	20	40	4	0	100	0
234	Install Water Sensors Near W. Wall															
235	#9603015 (DCP 96-040)Inst Water Sensor	0.161	0	0.000	3.0	0	20	14	37	20	10	20	4	0	80	160
236	Replace Service Panel															
237	#9609051 (97-002)Repl Svc Panel	0.155	0	0.000	3.0	0	20	2	25	20	10	20	4	24	0	0
238	Replace DB															
239	#9607050 (96-096)Repl DB window	0.155	0	0.000	0.0	0	5	0	6	0	0	0	2	8	0	0
240	Boiler Replacement															
241	#9602042 (DCP 96-035)Boiler Replacement R&A	0.147	0	0.000	8.0	250	0	30	288	40	40	80	10	240	40	240
242	Install 110 Volt Flex Runs															
243	#9604068 (DCP 96-067)Inst 110V Flexruns	0.147	0	0.000	5.0	0	20	3	28	40	10	40	4	0	40	0
244	Install Emergency Shower															
245	#9608072 (96-113)Inst Emerg Shower	0.147	0	0.000	1.5	0	5	5	11	10	5	40	4	0	0	80
246	Relocate Radiographic Syst															
247	#9607004 (96-084)Rel Rad Syst	0.144	0	0.000	5.0	0	20	8	33	40	10	40	4	0	0	140
248	Upgrade Services															
249	#9605035 (DCP 96-074)Upgrd Serv	0.142	0	0.000	5.0	0	50	34	89	40	10	40	4	200	200	200

1	C Project Title to include Design Change Packages for each Project	D EC Priority	E Enable	F Priority Factor	G Design & Procure Cost (\$k)	H Procure Capita (\$k)	I Procure Operat (\$k)	J Install Cost (\$k)	K Total Cost (\$k)	L Design Hours	M Procure Hours	N Fac. Eng Hours	O ESH Hours	P Shtmtl Hours	Q Electrician Hours	R Filter Hours
250	Review & Repair Inert Gas Photohelics															
251	#9604032 (DCP 96-062)Repair GAS Photohelics R&A	0.124	0	0.000	1.0	0	10	3	14	0	10	0	4	0	0	40
252	NMT-6 Solid State NMR Instrument															
253	NMT-6 Solid State NMR Instrument	0.114	0	0.000	0.8	500	0	8	509	0	8	8	8	0	140	0
254	ESH-1 HFM-8 Monitors															
255	ESH-1 HFM-8 Monitors	0.114	0	0.000	6.0	250	20	0	276	40	20	10	4	0	0	0
256	Inst Bisco Shielding Behind Gamma Detector															
257	#9608061 (96-112)Inst Bisco Shield	0.113	0	0.000	5.0	0	100	11	116	40	10	40	4	200	0	0
258	EED Modify GBs															
259	#9404051 (DCP 96-059) GB (EDD)	0.109	0	0.000	5.0	0	50	7	62	40	10	40	4	40	40	40
260	Replace GBs															
261	Replace GBs	0.094	0	0.000	81.0	450	100	139	770	800	10	40	20	480	960	1000
262	Replacement GBs															
263	Replacement GBs	0.094	0	0.000	81.0	300	75	97	553	800	10	40	20	240	480	960
264	Replacement GB's															
265	Replacement GB's	0.094	0	0.000	81.0	300	75	97	553	800	10	40	20	240	480	960
266	Replace GBs															
267	Replace GBs	0.094	0	0.000	81.0	300	75	97	553	800	10	40	20	240	480	960
268	Fuel Processing Furnaces															
269	Fuel Processing Furnaces	0.094	0	0.000	5.0	300	20	18	343	40	10	20	4	0	320	0
270	GB's Atmosphere Controllers (Dritrains)															
271	GB's Atmosphere Controllers (Dritrains)	0.094	0	0.000	2.0	300	20	48	370	10	10	10	4	40	320	480
272	Replacement GB's															
273	Replacement GB's	0.094	0	0.000	81.0	300	75	97	553	800	10	40	20	240	480	960
274	Install GB replacements															
275	Install GB replacements	0.094	0	0.000	81.0	300	75	97	553	800	10	40	20	240	480	960
276	Modify/Upgrade GB & XB For Earthquakes															
277	#9607019 (96-088)Mod 4GB/TB for Earthquake R&A	0.094	0	0.000	41.0	0	200	117	358	400	10	80	12	2160		
278	Remove UPS Powerstrip															
279	#9604018 (DCP 96-058)Rem UPS Powerstrip	0.093	0	0.000	1.0	0	0	3	4	10	0	10	4	40	10	0
280	Remove All Thermodetectors & Associated Wiring															
281	#9604043 (DCP 96-065)Rem Thermo/Wiring R&A	0.093	0	0.000	1.0	0	0	5	6	10	0	10	12	0	80	0

I	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
	Project Title to include Design Change Packages for each Project	EC Priority	Enable	Priority Factor	Design & Procure Cost (\$k)	Procure Capita (\$k)	Procure Operat (\$k)	Install Cost (\$k)	Total Cost (\$k)	Design Hours	Procure Hours	Fac. Eng Hours	ESH Hours	Stimul Hours	Electrician Hours	Filter Hours
282	Remove Breathing Air Station from UPS															
283	#9605015 (DCP 96-070)Rem UPS Breathing Air R&A	0.093	0	0.000	1.0	0	0	3	4	10	0	10	4	0	40	0
284	CAM Alarm System Mods															
285	#9511004 (DCP 95-007) Release for Construction	0.079	0	0.000	2.0	0	0	3	5	20	0	20	4	0	40	0
286	4 Diameter Floor Penetration															
287	#9401125 (DCP 96-016)4 Flr Penetration	0.079	0	0.000	3.0	0	5	1	9	20	10	40	4	0	20	0
288	Cap Floor Drains															
289	#9601038 (DCP 96-020) C/M Dsgn Review & Approval	0.079	0	0.000	0.0	0	2	5	7	0	0	20	4	0	0	80
290	Install Solenoid															
291	#9603012 (DCP 96-039)Inst Solenoid	0.079	0	0.000	3.0	0	5	3	11	20	10	40	4	0	40	0
292	Remove for Discard Gls															
293	#9605061 (96-077)Remove GBs	0.079	0	0.000	2.0	0	20	39	61	10	10	20	4	120	160	400
294	Remove GB's to Other Areas															
295	#9607016 (96-086)Rem GB's	0.079	0	0.000	2.0	0	40	16	58	10	10	20	4	120	80	80
296	Install Services to GB															
297	#9607018 (96-087)Inst Svcs to GB	0.079	0	0.000	6.0	0	40	14	60	40	20	40	4	80	80	80
298	Modify GB															
299	#9607020 (96-089)Mod GB/Loading chute	0.079	0	0.000	3.0	0	20	5	28	20	10	40	4	80	0	0
300	Relocate CAM Alarm															
301	#9609008 (96-118)Rel CAM alarm	0.079	0	0.000	3.0	0	10	0	14	20	10	20	4	0	0	8
302	Install 2 9MM Camera System															
303	#9609009 (96-119)Inst 9mm Camera	0.079	0	0.000	5.0	0	40	1	46	40	10	40	4	0	16	0
304	Install Pressure Regulator															
305	#9609026 (97-003)Inst Regulator	0.079	0	0.000	1.5	0	5	2	8	10	5	20	4	0	0	30
306	Install Inline Metal Filters to Furnace Syst.															
307	#9710002 (97-006)Inst Metal Filters	0.079	0	0.000	1.0	0	20	2	23	0	10	20	4	40	0	0
308	Replace Ion Gauge Assembly															
309	#9710021 (97-007)Repl Vac Gauge	0.079	0	0.000	0.5	0	20	7	28	0	5	0	4	0	80	40
310	Weld Mounting Plate to Floor															
311	#9710043 (97-009)Weld Plate to floor	0.079	0	0.000	1.5	0	20	0	22	10	5	20	4	8	0	0
312	Modify Piping Fans															
313	#9608021 (96-102)Mod Piping Fans R&A	0.071	0	0.000	14.0	0	100	39	153	100	40	40	4	200	500	0

	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Project Title to include Design Change Packages for each Project	EC Priority	Enable	Priority Factor	Design & Procure Cost (\$k)	Procure Capita (\$k)	Procure Operat (\$k)	Install Cost (\$k)	Total Cost (\$k)	Design Hours	Procure Hours	Fac. Eng Hours	ESH Hours	Shimll Hours	Electrician Hours	Fitter Hours
314	Install Vacuum Vent															
315	#9608058 (96-109)Inst Vacuum Vent	0.071	0	0.000	3.0	0	20	5	28	20	10	40	4	40	0	40
316	Remove Traps, etc. on the Floor															
317	#9710047 (97-012)Rem Traps GB	0.071	0	0.000	0.0	0	0	2	2					40	0	0

Appendix H

GANTT CHARTS FOR FIRST 4 MONTH

SERIES OF SELECTED PROJECTS

Table H.1: Gantt Charts for First 4 Month Series of Selected Projects

Activity ID	Activity Description	OD	Early Start	Early Finish	Resource	Budgeted quantity	1997	1998
ARIES Install Glovebox								
96026E101	Design Install Glovebox	5	14APR97	18APR97	DESIGNE	40.00	Δ	Design Install Glovebox
96026E103	DCP#96-026E1 Install Glovebox R&A	10	21APR97	02MAY97	SYS ENG	20.00	Δ	DCP#96-026E1 Install Glovebox R&A
96026E104	Install Glovebox ESH Review	1	06MAY97	06MAY97	ESH	4.00	Δ	Install Glovebox ESH Review
96026E100	ARIES Install Glovebox (WR9601012E1)	24	07MAY97	09JUN97	SHTMTL+	380.00	Δ	ARIES Install Glovebox (WR9601012E1)
ARIES Move Raman & Glovebox								
96026F010	Design Move Raman & Glovebox	5	21APR97	25APR97	DESIGNE	40.00	Δ	Design Move Raman & Glovebox
96026F030	DCP#96-026F Move Raman & Glovebox R&A	10	05MAY97	16MAY97	SYS ENG	20.00	Δ	DCP#96-026F Move Raman & Glovebox R&A
96026F040	Move Raman & Glovebox ESH Review	1	19MAY97	19MAY97	ESH	4.00	Δ	Move Raman & Glovebox ESH Review
96026F004	ARIES Move Raman & Glovebox	23	20MAY97	19JUN97	SHTMTL+	180.00	Δ	ARIES Move Raman & Glovebox (WR9601012F1)
ARIES Install Glovebox								
96026F101	Design Install Glovebox	5	10MAR97	14MAR97	DESIGNE	40.00	Δ	Design Install Glovebox
96026F103	DCP#96-026F1 Install Glovebox R&A	10	17MAR97	28MAR97	SYS ENG	20.00	Δ	DCP#96-026F1 Install Glovebox R&A
96026F104	Install Glovebox ESH Review	1	31MAR97	31MAR97	ESH	4.00	Δ	Install Glovebox ESH Review
96026F105	Install Glovebox (WR9601012F1)	53	01APR97	12JUN97	SHTMTL+	840.00	Δ	Install Glovebox (WR9601012F1)
AREIS Move Glovebox								
96026G010	Design Install Glovebox	5	17MAR97	21MAR97	DESIGNE	40.00	Δ	Design Install Glovebox
96026G030	DCP#96-026G Install Glovebox R&A	10	31MAR97	11APR97	SYS ENG	20.00	Δ	DCP#96-026G Install Glovebox R&A
96026G040	Install Glovebox ESH Review	1	14APR97	14APR97	ESH	4.00	Δ	Install Glovebox ESH Review
96026G050	Install Glovebox (WR9601012G)	53	15APR97	26JUN97	SHTMTL+	840.00	Δ	Install Glovebox (WR9601012G)
Project Start: 199707, Project Finish: 200004, Data Date: 199707, Plot Date: 199707								
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Activity ID	Activity Description	OD	Early Start	Early Finish	Resource	Budgeted quantity	1997	1998
Rewire Frangible Links								
96072010	Design Rewire of Frangible Links	5	26FEB97	04MAR97	DESIGNER	10.00	Δ	Design Rewire of Frangible Links
96072020	DCP#96-072 Rewire Frangible Links R&A	5	05MAR97	11MAR97	SYS ENG	10.00	Δ	DCP#96-072 Rewire Frangible Links R&A
96072040	Rewire Frangible Links ESH Review	1	13MAR97	13MAR97	ESH	4.00	Δ	Rewire Frangible Links ESH Review
96072050	Rewire Frangible Links (WR#9505023)	10	14MAR97	27MAR97	ELECT	80.00	Δ	Rewire Frangible Links (WR#9505023)
Server for Maintenance Management System								
PROC0020	Procure Server for Maintenance Management	5	19FEB97	25FEB97	PROCURE	20.00	Δ	Procure Server for Maintenance Management Sys
Pit Surveillance Leak Detector								
PROC0030	Procure Leak Detector	5	19FEB97	25FEB97	PROCURE	20.00	Δ	Procure Leak Detector
Pit Rebuild Leak Detector								
PROC0040	Procure Leak Detector	5	19FEB97	25FEB97	PROCURE	20.00	Δ	Procure Leak Detector
Process Control System Upgrade SRL								
97TBD0010	Design Process Control System	50	28APR97	04JUL97	DESIGNER	400.00	Δ	Design Process Control System
97TBD0020	DCP #TBD Process Control System R&A	8	07JUL97	16JUL97	SYS ENG	16.00	Δ	DCP #TBD Process Control System R&A
97TBD0030	Process Control System Procurement	2	07JUL97	08JUL97	PROCURE	8.00	Δ	Process Control System Procurement
97TBD0040	Process Control System ESH Review	1	17JUL97	17JUL97	ESH	8.00	Δ	Process Control System ESH Review
97TBD0050	Install Process Control System (WR#TBD)	10	18JUL97	31JUL97	ELECT	80.00	Δ	Install Process Control System (WR#
Project Start 10FEB97 Project Finish 20SEP98 Data Date 10FEB97 Plot Date 10MAR97								Sheet 6 of 11

Activity ID	Activity Description	OD	Early Start	Early Finish	Resource	Budgeted quantity	1997	1998
Pigma Welder								
Pigma Process Control Room								
95015A010	Design PIGMA Process Control Room	253	28APR97	15APR98	DESIGNE	4,060.00		Design PIGMA Pro
95015A020	DCP#95-0-15A PIGMA Process Control	80	16APR98	05AUG98	SYS ENG	640.00		DCP#95-0-
95015A030	PIGMA Process Control Room Procurement	20	16APR98	13MAY98	PROCURE	160.00		PIGMA Process
95015A040	PIGMA Process Control Room ESH Review	130	07AUG98	04FEB99	ESH	640.00		
95015A050	Install PIGMA Process Control Room	33	05FEB99	23MAR99	SHTMTL+	520.00		
Install Services to 40MM								
Install Services to 40MM								
96014050	Install Services to 40MM (WR#9611050)	30	19FEB97	01APR97	SHTMTL+	480.00		Install Services to 40MM (WR#9611050)
Micro Fiche Equipment								
PROC0050	Procure Micro Fiche Equipment	5	19FEB97	25FEB97	PROCURE	20.00		Procure Micro Fiche Equipment
Automated Gamma Counter								
PROC0060	Procure Automated Gamma Counter	1	21FEB97	21FEB97	PROCURE	4.00		Procure Automated Gamma Counter
UPS System								
PROC0070	Procure UPS System	5	24FEB97	28FEB97	PROCURE	20.00		Procure UPS System
SUN SPARC Server								
PROC0080	Procure SUN SPARC Server	5	26FEB97	04MAR97	PROCURE	20.00		Procure SUN SPARC Server
Yard Scale								
PROC0090	Procure Yard Scale	5	26FEB97	04MAR97	PROCURE	20.00		Procure Yard Scale
Project Start: 19FEB97 Project Finish: 2206F98 Data Date: 19FEB97 Plot Date: 19MAY97							Sheet 5 of 12	

Activity ID	Activity Description	OD	Early Start	Early Finish	Resource	Budgeted quantity	1997	1998
Room Upgrades								
Remove Glovebox								
96076A010	Design Remove Glovebox	5	23APR97	29APR97	DESIGNE	10.00	Δ	Design Remove Glovebox
96076A020	DCP#96-076A Remove Glovebox R&A	5	26MAY97	30MAY97	SYS ENG	10.00	Δ	DCP#96-076A Remove Glovebox R&A
96076A030	Remove Glovebox ESH Review	1	04JUN97	04JUN97	ESH	4.00	Δ	Remove Glovebox ESH Review
96076A040	Remove Glovebox (WR#9605042A)	10	30JUN97	11JUL97	SHTMTL+	160.00	Δ	Remove Glovebox (WR#9605042A)
Remove Glovebox								
96076B010	Design Remove Glovebox	5	30APR97	06MAY97	DESIGNE	10.00	Δ	Design Remove Glovebox
96076B020	DCP#96-076B Remove Glovebox R&A	5	29MAY97	04JUN97	SYS ENG	10.00	Δ	DCP#96-076B Remove Glovebox R&A
96076B030	Remove Glovebox ESH Review	1	05JUN97	05JUN97	ESH	4.00	Δ	Remove Glovebox ESH Review
96076B040	Remove Glovebox (WR#9605042B)	10	30JUN97	11JUL97	SHTMTL+	160.00	Δ	Remove Glovebox (WR#9605042B)
Remove Glovebox								
96076C010	Design Remove Glovebox	5	07MAY97	13MAY97	DESIGNE	10.00	Δ	Design Remove Glovebox
96076C020	DCP#96-076C Remove Glovebox R&A	5	11JUN97	17JUN97	SYS ENG	10.00	Δ	DCP#96-076C Remove Glovebox R&A
96076C030	Remove Glovebox ESH Review	1	18JUN97	18JUN97	ESH	4.00	Δ	Remove Glovebox ESH Review
96076C040	Remove Glovebox (WR#9605042C)	10	01JUL97	14JUL97	SHTMTL+	160.00	Δ	Remove Glovebox (WR#9605042C)
Remove Glovebox								
96076D010	Design Remove Glovebox	5	16APR97	22APR97	DESIGNE	10.00	Δ	Design Remove Glovebox
96076D020	DCP#96-076D Remove Glovebox R&A	5	26MAY97	30MAY97	SYS ENG	10.00	Δ	DCP#96-076D Remove Glovebox R&A
96076D030	Remove Glovebox ESH Review	1	03JUN97	03JUN97	ESH	4.00	Δ	Remove Glovebox ESH Review
96076D040	Remove Glovebox (WR#9605042D)	11	27JUN97	11JUL97	SHTMTL+	180.00	Δ	Remove Glovebox (WR#9605042D)
Project Start 19FEB97 Project Finish 22SEP96 Data Date 19FEB97 Plot Date 12MAY97							© Primavera Systems, Inc. Sheet 11 of 13	

Appendix I

RESOURCE LOADING HISTOGRAMS FOR
CONSTRAINED RESOURCES IDENTIFIED
IN THE FIRST 4 MONTHS OF
IDENTIFIED PROJECTS

Figure I.1: Number of Hours for All Resources

Figure I.2: Number of Hours for Designer

Figure I.3: Number of Hours for System Engineer

Figure I.4: Number of Hours for Procurement

Figure I.5: Number of Hours for Environmental Safety & Health

Figure I.6: Number of Hours for Sheetmetal Workers

Figure I.7: Number of Hours for Fitters

Figure I.8: Number of Hours for Electricians