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A Framework for Evaluation of
Technology Transfer Programs

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EXECUTIVE SUMMARY

The Department of Energy (DOE) and numerous state and private organizations are engaged in research and development projects intended to maximize the economic and environmentally safe producibility of oil and natural gas resources. These efforts include development of new or improved reservoir description techniques, extraction technologies, and environmental technologies. For R&D to achieve its goals, the results and products of research must be communicated or "transferred" to the appropriate end-user audience.

While the ultimate goals of these programs are to sustain or increase oil and gas production, R&D and technology transfer organizations cannot wait until programs have completed their course to determine the effectiveness of the transfer process or the products being transferred. Evaluation is an essential management tool and is a critical element of any program. A systematic program of evaluation is required to measure technology transfer effectiveness against specific standards of performance and to allow for corrective actions to be taken before the technology transfer program continues. In recognition of these concerns, the Department of Energy's efforts to restructure its oil and natural gas research programs, and proposed new cooperative R&D and technology transfer efforts, DOE provided the Interstate Oil and Gas Compact Commission (the Compact) a grant to develop the framework for a technology transfer evaluation methodology.

The Compact has developed a framework for the evaluation of a Technology Transfer Program that will enable managers to monitor the technology transfer program's progress and assure its essential contributions to the Department of Energy's Fossil Energy Research Program. Using a "systems" approach to

evaluation, this framework establishes a paradigm that will contribute to regular assessment and improvement of the technology transfer program that is consistent with the requirements of DOE Orders 5700.6C ("Quality Assurance") and 1332.1A ("Uniform Reporting System"). This systems approach may be applied to any systematic technology transfer program, federal or otherwise, to provide an effective evaluation approach.

The systems approach to planning and evaluation follows six steps:

- Goals, constraints, and system boundaries are set by careful consideration of the environment.
- The broad goals and objectives are analyzed into more concrete objectives, subobjectives, and eventually, meaningful work packages, which are formalized into the Work Breakdown Structure (WBS).
- The processes necessary for the accomplishment of the objectives are laid out as a series of precedence-related tasks.
- The inputs necessary for the conduct of the established processes are determined.
- Statements of inputs, processes, and objectives are combined into an integrated schedule, showing the activities of each individual activity as well as the program as a whole.
- Evaluation and monitoring activities are added into the plan.

The first five steps establish a program design which becomes the standard for comparison during evaluation. Evaluation is defined as the comparison of what *is* (a performance) against an expectation of what *should be* (a standard -- the program design). Differences between performance and the standard are known as discrepancies. Discrepancies may be positive (performance exceeds standard) or negative (performance fails to meet standard). Negative discrepancies are the most common target of management control and may be resolved in two ways:

- An unrealistic standard may be reformulated or redesigned by management; or
- Management may exert controls to improve performance.

The paradigm postulates five stages of evaluation which allow management ample opportunity to institute controls to resolve negative discrepancies:

- *Design Evaluation* -- assessment of the consistency of the design with

established theory, the likelihood of achieving the desired impacts, the internal consistency of the program, and the compatibility of the program with the world outside;

- *Input Evaluation* -- determination of whether the program has been installed as planned (i.e., preconditions met, resources in place, and processes set in motion);
- *Process Evaluation* -- monitoring of the sequential accomplishment of sub-objectives leading to achievement of program goals;
- *Output Evaluation* -- determination of whether the specific products or services of the program have been delivered; and
- *Impact Evaluation* -- assessment of the extent to which the desired impacts of the program in the external world have been obtained.

Traditionally, evaluations have taken the form of Output Evaluation, but, taken alone, this

Figure ES-1. Program and Evaluation Design Within the Paradigm

offers little information about the effectiveness of the program. In the case of the technology transfer program, which seeks to produce changes in the world outside, verification that a service has been provided does not confirm that the program goals have been accomplished. Impact Evaluation provides this essential information. Output and Impact Evaluation alone are not enough, however, because, if the inputs and processes are inadequate, it is unlikely that the desired outputs and impacts can be achieved by the program. Input and Process Evaluation provide the opportunity to assess the adequacy of the inputs and processes. The information provided by these four stages of evaluation will not be valid if the program design is inherently flawed, necessitating Design Evaluation. Thus, five stages of evaluation are necessary to allow management to exercise its control function in any program. Figure ES-1 illustrates the function of evaluation as management control on the program.

In this framework, the program plan and work breakdown structure become the standard

of performance, and the goals and mission of the program become the standards for evaluating the program's impacts. The six-step process of program development and assessment covered by the evaluation paradigm is cyclical in nature. All information generated from the program is used in program redesign. Inputs, processes, and outputs are regularly monitored, and impacts are frequently assessed. Evaluations conducted in this manner become valuable instruments for the managers of any program.

The report of this work describes the Oil R&D Program and a hypothetical technology transfer subprogram in the context of the larger environment in which the federal program exists. It explains the need for the evaluation methodology, describes the principles of evaluation, reviews the fundamentals and approach to designing a program with an integrated evaluation function, and provides a framework for planning the evaluation activity. A worked example of an evaluation program design for one technology transfer activity is provided as an appendix.

Chapter 1

INTRODUCTION

In 1988, the Department of Energy (DOE) provided the Interstate Oil and Gas Compact Commission (the Compact), then the Interstate Oil Compact Commission, with a grant to examine the structure of technology transfer within the oil and gas producing industry and identify the various mechanisms used to transfer technology from R&D organizations to major and independent producers. The analysis sought the means for enlarging and accelerating technology transfer to producers and stimulating technology deployment in lower-48 oil reservoirs.

In its 1990 report of this work, the Compact identified current channels of technology transfer to oil and gas operators from public and private research programs and suggested enhancements for DOE's own technology transfer efforts, recognizing the DOE's intention to change the focus and mission of its Oil R&D Program. Whereas the focus of the R&D program *had* been toward long-term, high-risk scientific research that was limited to proof-of-concept, the refocused program would also stress (1) near-term technology transfer to retain economic access to reservoirs and sustain production; (2) applied field research and demonstration projects for emerging technologies; and (3) supporting research activities to develop new technologies and advancements in geosciences.

It became clear that while previous federal technology transfer functions had been successful in communicating the results of its scientific research to its appropriate target audience -- primarily university and industry researchers and applied technology developers -- the same approaches and mechanisms would not be fully effective in transferring current and emerging technology solutions from the new mission-oriented, problem-focused program directly to

the producing community, especially the less technologically inclined independent producers. the Compact concluded that the most promising approaches to enhance technology transfer efforts would be: (1) the development of state-federal-industry cooperative technology outreach projects in producing states; (2) expansion of the role of industry associations; and (3) greater coordination between industry associations, professional societies, university R&D programs, state agencies, and the Federal Oil R&D Program.

Having already defined technology transfer and "feedback" channels used by various sectors of the U.S. oil and gas R&D and exploration and production (E&P) communities, and suggested improvements in these channels, the Compact sought to identify the specific organizations that could participate in enhancing these technology transfer channels in major producing states. The Compact also recognized a need to be able to test the effectiveness of these technology transfer approaches short of waiting to see if domestic oil production increased.

In early 1991, DOE provided the Compact with a new grant to extend its analyses of technology transfer approaches to assist oil and gas producers and contribute to improved oil and gas production through the performance of two specific tasks:

- Task 1. Technology Transfer Profiles of Eight Major Producing States; and
- Task 2. Framework for a Technology Transfer Evaluation Methodology.

Task 1 involved profiling the state agencies, research universities, and industry organizations in the eight lower-48 states with the largest

known remaining oil-in-place. The purpose of this task was to identify current and potential organizations that could participate effectively in expanded public and private technology transfer activities. The results of this research is provided in detailed state profiles which are provided in a separate report.

Task 2 sought to develop a framework for establishing an evaluation methodology to determine the effectiveness of technology transfer mechanisms in delivering technology to the producing community, changing attitudes towards technology, and encouraging deployment of technology in improved recovery projects. For assistance in performing this work, the Compact contracted with ICF Resources, Incorporated and its subcontractor, Frank Morra and Associates, Incorporated. This volume presents the framework for the evaluation methodology.

BACKGROUND

The mature U.S. lower-48 state oil resource base increasingly requires the application of state-of-the-art technologies to discover and develop new reservoirs and maximize efficient production of known oil resources. More than 340 billion barrels of oil will remain in known reservoirs after conventional production and proved reserves are depleted. This resource is being abandoned at an accelerating rate as technical challenges, operating costs, and risks of potential future environmental liabilities push continued operation beyond economic limits.

At the same time, R&D focused on producing this resource, which has traditionally been performed by major integrated companies and service companies, is being scaled back dramatically due to economic decline, low prices, and the maturity of the resource itself. Independents do not typically perform research or have the facilities to do so. Yet, independent producers are increasingly responsible for the production of oil resources beyond the economic limits of primary recovery processes. Much current technology already exists that can be

economically applied to increase production from reservoirs after primary recovery has reached its economic limit.

Planned and ongoing research sponsored or performed by the federal government, state agencies, universities, or integrated producers and service companies also has significant potential to enable producers to extend the economic limits of reservoirs and increase ultimate maximum efficient recovery. For this R&D to have its effect on production, however, the products of research must be effectively transferred to the producing community.

Technology transfer is the process by which the information, product, and technology results of research are presented to and accepted by the market for deployment in the reservoir. For the results of current and future research, development, and demonstration projects to be fully effective, all producers must be aware of the existence of technology solutions and strategies, understand their potential in the reservoir, and be willing and able to invest in deploying the technology. While market penetration of new approaches and technology eventually occurs naturally through articles, publications, and personnel movements from major producer and service company R&D labs to exploration and production sectors, abandonment rates and economic uncertainties require that rates of market penetration be accelerated quickly through more aggressive technology transfer approaches.

In the near term, effective technology transfer can result in the deployment of existing technologies to extend the life of a reservoir until emerging technologies can be developed, transferred, and economically deployed in the mid-term. Near-term and mid-term technology transfer functions can preserve access to the reservoirs long enough for new technologies resulting from fundamental improvements in the understanding of reservoir geosciences to be brought to the market. Without effective technology transfer, R&D results and technology breakthroughs are meaningless.

OBJECTIVES AND BENEFITS OF THIS WORK

The objective of this volume is to describe a framework with which DOE can develop a program-specific methodology to evaluate its technology transfer efforts. This approach could also be applied to an integrated private sector technology transfer organization. Several benefits will be realized from the application of this work. While the immediate effect will be to assist program managers in evaluating and improving program performance, the ultimate benefits will accrue to the producing industry, the states, and the nation in the form of sustained or increased domestic oil production. This benefit depends also, of course, on the effectiveness of the technology being transferred.

The managers of the Technology Transfer program, and the larger federal oil and gas R&D programs, will be provided with a means to design and assess the effectiveness of program efforts as they are developed, tested and performed. The framework allows deficiencies in critical aspects of the program to be quickly identified, allowing for timely corrections and improvements. The actual process of developing the evaluation also gives the staff of the Oil R&D Program or Technology Transfer subprogram the opportunity to become oriented to the overall program goals. The structure and focus imposed by the evaluation paradigm will guide program staff in selecting activities which are consistent with achieving the goals of the overall R&D program.

A methodology for evaluating the content and processes of the technology transfer function must ensure an effective technology transfer program that remains focused on this critical mission. Presently, the goals of technology transfer efforts are stated in terms of relatively distant end results -- e.g., did oil production increase? Evaluation must provide a mechanism for identifying the logical chain of causality or linkage between a specific program element or effort and the end result. Further, evaluation must provide real opportunity for timely, mid-stream program refinements and improvements. With an R&D program focused on the near- and

mid-term, the associated technology transfer requires more intermediate mechanisms and measures of effectiveness. A practical evaluation methodology will allow for the rapid identification of structural and substantive program deficiencies and clearly illuminate areas of weakness. A well-constructed evaluation plan will suggest improvements and facilitate their implementation. It will also influence technology transfer mechanisms and substance to be compatible and consistent with the goals of the larger R&D program.

Through its implementation, the evaluation will establish causality between technology transfer processes and impacts on the environment outside the federal program. In the course of doing this, the targets of the transfer effort (operators, producers, service companies, and other technology transfer intermediaries, etc.) will be provided both the opportunity and the mechanism to offer their feedback on the effectiveness of the transfer mechanisms used and the content of the technology or information being transferred. Often the needs and expectations of those target audiences will generate essential suggestions and ideas for enhancing the entire transfer program. Having a consistent means to assess the effectiveness of technology transfer efforts across the program also allows managers to measure one technology transfer approach against another. The limited available resources can then be allocated to the most efficient or most needy approaches thereby maximizing effectiveness.

It is important to note that, while the evaluation methodology identifies areas for improvement, management must institute changes. The purpose of the methodology is to set standards, measure performances, and report on discrepancies between standard and performance. The standards used in the evaluation are developed in close concert with project management and staff. Deciding which actions are to be taken to correct an identified deficiency is the sole province of program management (although feedback generated by the system may help guide decisions for correcting deficiencies in structure or content). Thus

evaluation is a valuable tool in support of management activities.

APPROACH

To begin this work, the Compact and its consultant, ICF Resources Incorporated conducted a review of recent literature in the area of oil and gas technology transfer, and analyzed the Federal Oil R&D Program Implementation Plan. An extensive review of relevant DOE orders was also conducted to ensure establishment of a framework that is consistent with the appropriate departmental order and regulations. Based on the results of these efforts, a systems approach to evaluation was chosen as the methodology most adaptable and applicable to the technology transfer program. To assist in the performance of this work, ICF Resources Incorporated retained the services of Frank Morra and Associates Inc., a consultant with extensive experience in evaluations and evaluation methodologies. The resulting framework is structured using the same systems approach as was used in developing the Federal Oil R&D Program design. It is also internally consistent with DOE Order 5700.6C

("Quality Assurance") and DOE Order 1332.1A ("Uniform Reporting Systems").

In the absence of an established integrated federal program, a hypothetical technology transfer program was postulated for illustrative purposes. Figure 1-1 shows the technology transfer function in the context of the DOE/FE Oil R&D Program.

Figure 1-1 represents an abstraction of the Federal Oil R&D Program as a system. The system begins with a set of goals and constituencies (or "stakeholders") which define a set of needs and expectations for the program to address. Through the analysis function, which includes specific technology assessment functions, these inputs are translated into a series of specific program objectives. In the design element, a program of activities is developed to achieve these objectives. In the case of the Oil R&D Program, these activities include both a field demonstration and R&D program element. Each of these program areas can, of course, be further detailed in a work breakdown structure. Ultimately, through the performance of the

Figure 1-1. DOE/FE Oil Research Program

designated activities and functions, these R&D programs will yield products. These products may take many shapes and forms and have a variety of target audiences.

The evaluation function will examine the implementation of the program compared to the plan and will evaluate the outputs or products of the program. From a technology transfer perspective, however, this function evaluates specific R&D products to determine if they do what they are supposed to do and whether they are packaged and ready for dissemination through the technology transfer process. If not, they are returned to the R&D process. Otherwise the technology transfer process assumes responsibility for transferring the results to the target audience or client. These relationships also contain feedback loops for clients to respond to the R&D process. The technology transfer function is therefore integrated into the program as a whole rather than being an individual activity performed at the conclusion of each element of the R&D effort. This view is consistent with DOE specifications for management and operating support of the National Oil and Related Programs.

To be fully effective, DOE's technology transfer activity cannot operate in a vacuum. Figure 1-2 illustrates hypothetical functions and inter-relationships of the federal and non-federal technology transfer efforts. This view was used to construct a worked example using the framework contained in this volume. It assumes that DOE will continue to employ the methods previously used in the program. It also assumes that DOE will expand its role to use additional approaches, some of which are employed by other participants in the R&D and technology transfer environment but which are outside of the system that DOE fully controls.

The development of a framework for an evaluation methodology provides an essential *interim step* to the development of an effective and integrated oil and gas technology transfer program. Once the elements of this plan are defined, a more specific evaluation methodology can be developed. By maximizing the effectiveness of federal technology transfer efforts in the oil research program, the near-and mid-term goals of the oil research program can be more readily achieved.

Figure 1-2. Hypothetical Technology Transfer Program Elements

Chapter 2

THE EVALUATION PARADIGM

The purpose of this document is to describe a perspective or "paradigm" for the evaluation of the Technology Transfer elements of the Federal Oil Research Program. The paradigm has been designed to collect useful information needed to monitor the progress of the program and assure its contribution to the goals of the DOE Fossil Energy Research Program. Using a systems approach to evaluation, the paradigm seeks to provide information about the Technology Transfer Program to meet two purposes: assessment and improvement. Further, this information will be consistent with the requirements of DOE Order 5700.6C ("Quality Assurance") and DOE Order 1332.1A ("Uniform Reporting System").

The evaluation paradigm focuses on the program as a whole. It is not a model for judging the quality of research products or their acceptance by the marketplace (although both of these activities may take place within the scope of the general model). This approach is based on the following general principles:

- Evaluation is a constructive activity. Information must be collected to improve programs before valid information can be collected to assess them. Accordingly, the model stresses two phases: First, evaluation monitors the implementation of the program and achievement of intermediate milestones, thereby measuring the performance of the program relative to its plan. Then, measures the impact of the program relative to its stated goals.
- Like research, evaluation is both an art and a science. The work performed under this paradigm will be adapted and

changed as the program develops. It is virtually impossible to lay down a hard and fast evaluation plan prior to the startup of the program.

- Evaluation works best when there is broad participation in all evaluation activities, and when program staff function in an atmosphere where they feel the freedom to recognize setbacks, make revisions, and risk failure creatively. Therefore, this evaluation framework stresses the involvement of the staff and management of the Technology Transfer program in all phases of evaluation.

A SYSTEMS APPROACH TO EVALUATION

"Evaluation" is defined as the comparison of what is (performance) against an expectation of what should be (standard). If a difference is found between standard and performance, this difference is known as a discrepancy. Discrepancies may be positive (performance exceeds standard) or negative (performance fails to meet standard). While positive discrepancies are joyously welcomed, negative discrepancies generally cause concern. Negative discrepancies may be resolved in two ways: (1) an unrealistic standard may be reformulated or redesigned by management; or (2) management may exert controls to improve performance.

As discussed in Section 2.3 (below), the principles of evaluation discussed in this paper are inherently part of the general management function. In a complex program, management may choose to delegate the evaluation components to a specific individual known as *the evaluator*. This person may be a part of the staff

(i.e., an internal evaluator), or a person from outside the program (i.e., an external evaluator), or some combination of the two.

Within this paper, the evaluation role is clearly defined as that of a generator and interpreter of unbiased information about program performance relative to standards. Note that the evaluator identifies the discrepancy and management takes appropriate action. Thus, the role of the evaluator is to provide critical information in support of management decision-making. The activities of evaluation are related to the three components: developing standards, measuring performance, and identifying discrepancies. The evaluator may interpret discrepancies for management, but all action decisions are reserved for program management.

PROGRAM DESIGN AS A STANDARD FOR EVALUATION

Without a standard - some explicit idea of intent or expectation, or model of excellence - systematic evaluation is not possible. Clearly, the starting point for the formulation of the standard is the program's mission statement. However, standards are derived from the interpretation of the program's mission in light of subjective factors, such as experience, knowledge, and values. Of particular note is the fact that it is not possible to set standards that are absolutely comprehensive. Resource limitations always force decision makers to focus on some portion of available information and to overlook others. For example, one version of a standard may specify the distribution of a given number of units as a desirable outcome of technology transfer and consider changes in customer attitudes as irrelevant. Clearly, the formulators of such a standard have expressed a particular choice based on these subjective factors. Evaluation requires that someone or some group apply these factors to the breadth of information collection activities and determine the particular standard(s) which will be used to make the judgement.

Standards are used regularly in the evaluation of research programs. All too often,

however, such standards have one or more critical problems: (1) the standard is not made public; (2) the standard is not shared by all relevant parties; or (3) the standard is not sufficiently specific and comprehensive to be useful in judging or improving research programs. Items (1) and (2) are the exclusive province of management, while the evaluator makes a contribution to solving problem (3).

By adapting the techniques of systems analysis, it is possible to construct a standard that is adequate for use in evaluation. Such a standard defines the intent of the program by describing:

- The expected inputs, or that which will go into the program, such as people, products and resources;
- The program processes, or the activities and operations that will take place;
- The outputs (products and services) which will emerge from the program; and
- The impacts, or changes in behavior in the external environment which may be attributed to the program.

Discrepancy evaluation refers to such a standard as a program design. Once the program design has been judged adequate for evaluative purposes and validated by the program staff, it becomes the standard against which subsequent program performance may be compared.

THE STAGES OF EVALUATION

The evaluation paradigm postulates five "stages" of evaluation which parallel a program's natural development of planning, installation, operation and cyclical replanning:

- Design Evaluation;
- Input Evaluation;
- Process Evaluation;
- Output Evaluation; and
- Impact Evaluation.

Design Evaluation continues throughout the life of the program because the identification of discrepancies may result in replanning. Ideally, the first Design Evaluation cycle should precede program installation. The design of the program will be evaluated in terms of the strategic intentions of the program. Outside experts, program staff and other interested parties formalize and judge the substantive adequacy of program plans. From an evaluation perspective, the design will be the standard for all later stages of evaluation.

Design evaluation activities include the examination of: (1) the program's consistency with established theory; (2) the likelihood that the program will achieve the desired impacts within the time and resources available; (3) the internal consistency of the program; and (4) the compatibility of the program with its environment. The results of these efforts - including possible "drawing board" modifications - is codified in a formal program design document. In later cycles, these design evaluation activities will be repeated and actual program performance data will be another source of information that will contribute to the process.

In the next three stages of evaluation, performance is compared to the standard that is embodied in the program design. Input evaluation asks the question, "Has the program been installed as planned?", and determines whether necessary preconditions have been made and the program's activities have been set in motion. Process evaluation monitors the program's activities to determine whether the various components are working in harmony (according to the design) to create interim products that lead to the tangible results that are defined as the "outputs" of the program. Output evaluation builds on the results provided by input and process evaluation to determine the quality of the specific products of the program. It should be noted in this context that output evaluation refers to products of the technology transfer process, not those of the R&D process.

The fifth evaluation stage is impact analysis, which assesses the effects of the products on and

the acceptance of the products by the external environment. In this stage, the evaluators seek to determine whether the program has caused a change in the external environment. This is achieved by following a logical chain of causality which begins with introduction of the technology and ends, ultimately, with an effect on the level of domestic oil production. The information developed in this process is, in turn, used to modify the program to keep it on a course for successful achievement of its mission.

The six-step process of program development and assessment is cyclical in nature. All information generated from the program is used in program redesign; inputs, processes, and outputs are regularly monitored, and impacts are frequently assessed.

THE EVALUATION PLAN

Management can rarely afford to conduct comprehensive input, process, and output evaluation for all aspects of the program. Similarly, only a limited number of factors in the program's environment can be assessed for possible impacts. Resource limitations necessitate choosing specific areas for study. For this reason, an evaluation plan must be constructed which defines and selects those priority aspects of program operation which will be subject to evaluation. The choice of priority areas for evaluation is largely determined by the program plan, although the needs of the program's audience, the interests of staff and management, specific theoretical concerns, and other factors may enter into the decision. The evaluation plan identifies areas of evaluation concern. In the construction of the plan, the evaluator formulates evaluation questions (focused on inputs, processes, outputs, and impacts) which direct the systematic definition and collection of performance information. The evaluator also clarifies standards, selects measurement devices and plans their administration.

The construction of an evaluation plan directly follows the creation of a program design. In many ways, a program plan is incomplete

without a corresponding evaluation plan. Both of these documents are periodically revised as information is received from the measurement activities.

USES AND LIMITATIONS

This paradigm is intended to complement the activities of program management, and not to replace them. The model operates within a well-defined scope and there are certain things that it is not intended to do. The paradigm is not a needs assessment model - it cannot determine whether the program itself is "necessary". The paradigm is not intended to select from alternative programs eligible for installation, nor

to make value judgements about the standard. The model answers the question "Will the inputs buy the outputs?", and not "Why are you willing to pay the input price?" Discrepancy evaluation and the information it provides do not necessarily make decision-making rational. They do, however, give management the opportunity to make clear the basis upon which the decisions are made. The evaluator must ensure that the standard results from asking necessary and sufficient questions and that the information used to answer those questions is relevant and accurate. On the other hand, decision-makers set standards and must take action in response to deviation from these standards.

Chapter 3

FUNDAMENTALS OF PROGRAM DESIGN

A program design is a structured description of a program -- a plan. It organizes information in such a way that it becomes an operational map or blueprint that reflects the intent of a program. A design shows what is needed to do the job (inputs); what is going to be done (processes); what will result when the job is complete (outputs), and how the world will change when it gets the products (impacts). The program design corresponds to the Work Breakdown Structure [discussed in DOE Order 1332.1A, Ch. II,1,b,(1)], starting from the overall objective(s) or end product(s) in the statement of work and proceeding through successive levels to elements at the lowest level of detail required for effective management.

As programs increase in size and complexity, so too does the task of constructing program designs. Since design construction often takes considerable time and energy, one should consider the rationale for this work. Although there are many reasons for developing a program design, they all emanate from three basic perspectives:

- The program design is a necessary management tool;
- The program design is the cornerstone of the larger evaluation process; and
- A program design is required by DOE 1332.1A.

THE PROGRAM DESIGN IN MANAGEMENT

There are persuasive reasons for program management and staff to spend time documenting program intents. In one sense, simply putting a program's mission, objectives, and description down on paper has its own

rewards, but the most significant benefits arise when: (1) this is done in a form which readily demonstrates how a program is supposed to work; and (2) all parties essential to the program's success are involved in the design construction work.

- The program design facilitates clarification of and agreement on program goals and operation. Since the design represents a standard, it is subject to approval not only by staff, but other influential parties as well. The surfacing and resolution of possible conflicts can go a long way toward the construction of a feasible and agreed-upon program plan and ensuring its operational success.
- Program design is part and parcel of the planning process. The systematic information categories inherent in the design highlight possible gaps and inadequacies in conceptual organization of a plan before they can lead to problems.
- The program design serves as a basis for analyzing costs. According to DOE 1332.1A, budgets must be keyed to the Work Breakdown Structure. Thus, construction of a program design is also critical to management's responsibility in cost analysis.
- The program design permits assessment of plans before implementation. A well-documented design allows management to involve a wide range of experts and interested parties to assist in judging the program's adequacy and correct potential deficiencies before the program leaves the drawing board.

- The program design serves as an implementation coordination guide. Programs of greater complexity will benefit from the design process, particularly where program staff need to understand expected activities and obligations of a significant number of program elements or groups.
- The program design provides a sense of the whole. In a complex program, a design helps staff members understand how their individual activities relate to the larger effort. Furthermore, the making explicit of functional dependencies between program parts assists in coordination activities.
- The program design documents operations. The construction of a program design and its periodic updating as a result of management action based on evaluative feedback, provides a record of program development and progress which not only facilitates replication but also provides insights into the causes of program successes and failures.

In general, the program design makes possible a thorough and evaluation effort which, in turn, promotes systematic program improvement. This paradigm can be applied to the DOE Oil R&D Program. Briefly, the Oil R&D Program has been derived to serve the basic mission of *maximizing the economic producibility of the domestic oil resource*. The program focuses on reducing both technical and economic constraints on producibility from the mature domestic resource to realize its enormous potential benefits. The program addresses the real world constraints that include: (a) potential loss of access to the resource caused by the rapid pace of well abandonments; (b) the lead time required for RD&D before advanced technologies can be made available for widespread application, and (c) the necessity that oil extraction technology be environmentally sound.

The strategy for implementing this program involves selective focus on specific geologic classes of reservoirs which have the highest potential and greatest risk of abandonment. Specific program strategies include: (1) field work on selected reservoir classes; (2) targeted and discipline-oriented R&D to support the field work; (3) exploitation of synergies between the concurrent activities in common areas by industry and the states; and (4) focused technology transfer activities. There are three major lines of program activities including: (1) Analysis and Planning; (2) Field RD&D (with near- and mid-term projects based on criteria of access and potential); and (3) Supporting R&D including targeted development and engineering and basic discipline-oriented R&D. Technology transfer is a sub-system under both Field R&D and Supporting R&D activities.

THE PROGRAM DESIGN IN EVALUATION

Discrepancy evaluation is based on comparing performance to a standard. A program design serves as the formal representation of that standard. The standard represented by the program design is, in reality, a collection of smaller or more specific standards, each of which can be compared with performance to produce discrepancy information.

A design includes the objectives of the program. The design has input standards ("we will use these resources"), *process* standards ("in these ways"), *output* standards ("to yield these products"), and *impact* standards ("to make these changes in the world"). It is possible to collect performance information relative to each type of standard. For example, *input evaluation* verifies that the appropriate resources and preconditions are available. *Process evaluation* verifies that the program has been installed as planned. It also verifies that interim objectives are being met. *Output evaluation* verifies and measures the delivery of high quality products. *Impact evaluation* documents the changes outside the program which result from the availability of the products.

A program design's most basic contribution to the evaluation process is its description of the program standards in a form which makes them readily subject to monitoring. The program design is also a method for guiding the expenditure of limited evaluation resources. Rarely, if ever, can a program afford to monitor each and every aspect of the program. The design, however, by exposing the functional dependencies between program parts, highlights those basic points in program operation which are of critical importance to the success of the undertaking as a whole.

Sound management principles require that much information be collected, particularly financial data and time spent by employees. Law and executive orders also mandate the collection of other types of information (e.g., ethnic background of staff, environmental data, and the like). Much of this mandatory or "background" data is useful in the evaluation process and is collected as a matter of routine because it has been proven to be effective to the management process by decades of experience. However, the evaluation of the program may also require additional information that is of a "non-routine" or "special use" character. Development of this type of information is the province of the evaluator, and the program design is the tool for identifying that "non-routine" performance data which is most important to collect.

THE PROGRAM AS A SYSTEM

At a general level, the DOE Oil R&D Program may be thought of as a system using *inputs* (dollars, staff, equipment, etc.) in *processes* (experiments, field tests, analysis, data collection, etc.) to generate certain *outputs* (reports, data, software, new chemicals, improved technology, etc.). In turn, these outputs make *impacts* on the external world (increased use of new technology, increased domestic oil production, etc.). The program design that is needed for evaluation is organized around these four major information categories (i.e., inputs,

processes, outputs, and impacts) and their inter-relationships.

In order to discuss the program design procedures, a few brief concepts from systems theory must be introduced. Figure 3-1 shows the system in its most elemental form. The system is defined by a "boundary," which shows those activities within (under the control of) the program and those which are outside (not under the control of) the program, or in the environment. The definition of program boundaries is very important. For example, DOE's mission was for some years defined as "long-term, high-risk projects." This definition and its application in practice served as a definition of the Fossil Energy (FE) R&D program, and led to the choice of processes (or R&D activities) which fit within this boundary. Within the general system, things which come from the environment are known as *inputs*. That which is delivered from the program to the environment are known as *outputs*. The activities under program control which convert the inputs to outputs are known as *processes*. The changes in the environment that are the result of the availability of the outputs are known as *impacts*. The continuity of the system is maintained because exchanges in the environment (i.e. the "usefulness", or impact, of the products) assure the availability of inputs to the system. Through the *exchange process*, appropriate tangible products, or outputs, are accepted and have impacts which assure that inputs continue to flow. Thus, attainment of desired impacts is critical to the system's survival.

The system interface, or boundary, is the place where the system meets the environment, and is defined by the methods used to take resources from the environment (input interface) and the methods used to deliver the products from the system to the environment (output interface). For the FE Oil R&D Program, Technology Transfer activities are the methods primarily engaged in managing the output interface. The Technology Transfer function

should be seen as a sub-program (sub-system) of the DOE Oil R&D Program.

Systems are most useful when they are *adaptive*, including mechanisms for modifying themselves in order to maintain their viability. In many senses, the adaptive system (Figure 3-2) is much like a living organism. Adaptive systems have a control unit which monitors the three critical factors within the system boundary (i.e. inputs, processes, and outputs) as well as some mechanism for sensing impacts or changes in the environment (generically known as *sensors*). In general, the control function is the locus of management while the system process is the locus of personnel and equipment. On a day-to-day basis, management stands responsible for ensuring the adequacy of inputs, operating the process according to design and assuring the quality of outputs. However, over the long term,

management must also make decisions about the fundamental nature of the inputs, processes and outputs in order to ensure that appropriate impacts will occur, and that through the exchange process, the system itself will survive.

One variant of the adaptive system is the purposive system, or an entity which seeks not only to survive, but also to achieve specific impacts in the environment. For example, the mission of the DOE Oil R&D Program is to make a specific impact (increase cost-effective, environmentally sound domestic oil production). In order to achieve this goal, the program must not only survive, but it also must plan and redirect its activities to assure that changes in the environment are of the desired character. Within this evaluation paradigm, the Technology Transfer program is treated as a purposive system.

Figure 3-1. Elemental Form of the System

Figure 3-3 shows the system with the control process expanded to show the two major management or control functions. The first type of controls are *homeostatic controls*, or those which cause the system to remediate any discrepancies between actual and planned conditions, e.g., to keep the system running on a day-to-day basis. This form of control is based on the assumption that the standard is designed correctly (Do inputs meet specifications? Are staff in place and functioning correctly? Do products meet quality standards?). There are also *evolutionary controls* which are based on the assumption that the system may not be designed correctly. In this case, all questions are referenced to the environment (What kind of inputs are available? Is there a better process? Are the products in demand? Are there changes in the external environment that may be attributed to program outputs? Do the impacts yield exchanges which ensure survival of the system?).

Figure 3-4 outlines the basic operation of the homeostatic process. The control unit (management) makes reference to an

"abstraction" of the process, and is guided by this in decisions about inputs, processes and outputs. In practice, the abstraction is known by many terms: "the Book," "Standard Operating Procedure," "guidelines," etc. It may be used as a standard for making judgements about the adequacy of inputs, processes and/or outputs, (note that impact judgements are part of the evolutionary process). In essence, this abstraction of the process is the program design. Specifications for inputs, processes, and outputs are derived from the program design and must be met before the program moves forward. If the inputs do not meet specifications, then better inputs must be sought before moving to the process. If the process does not meet specifications, then the process must be reworked and the inputs must be reassessed. If inputs and processes meet the specifications and outputs do not, then the specifications may need to be revised. This assessment procedure is an important element of quality assurance.

DOE Order 5700.6C spells out the Quality Assurance requirements for Department of Energy programs. Section 9b of the order

Figure 3-2. The Adaptive System

illustrates the basic nature of this aspect of the control process, and this section conforms with it on a point-by-point basis.

- A Program Design is required (9b(1)), in which the organizational structure, functional responsibilities, levels of authority, and interfaces are discussed.
- Section 9b(2) calls for Standards (see also section 5) to be set for program operation which reflect both the program design and technical desiderata set by professional and environmental organizations.
- Section 9b(3) requires that management at all levels continuously compare performance to the standards and to take action to ensure that performance meets the standards.

Much of what is traditionally known as "evaluation" is involved in generating information about discrepancies between the standard (i.e. the design) and performance. However, as shown below, there is also a larger role for evaluation. Figure 3-5 shows the full structure of the system, including the evolutionary control function.

The role of the evolutionary function is to assure that the system remains compatible with the environment, and, in the case of purposive systems, effects changes in the environment. The control unit obtains information about the environment from "sensors." These may be as informal as the intuitions and casual contact between management and external agencies, or they may be very formal operations, such as market research functions. All share the common denominator of providing management

Figure 3-3. Control Processes in the Adaptive System

with information about the outside world. Of course, there is much more information available about the environment than can be collected or used. For practical purposes, some information is retained, and the rest is discarded. The net result of the choice of information yields an abstraction, or an analytically useful representation of the environment.

For example, the FE R&D program uses its Tertiary Oil Recovery Information System (TORIS) as an abstraction of the environment. TORIS can be used to answer questions about the potential impact of new technologies on domestic oil production. A considerable amount of effort is expended each year by DOE to assure that TORIS is a reliable abstraction of the domestic oil supply economy and to assure that TORIS is relevant to the operation of the program. The update efforts are the "sensors" which keep TORIS current, while redesign efforts ensure that it can analyze questions related to R&D projects. As an example of the latter, in the past few years, FE's Oil R&D mission expanded from tertiary recovery alone to also include advanced secondary recovery

processes. Accordingly, TORIS was also changed to include components related to these processes, such as capability to analyze the potential of infill drilling.

The operation of the control unit is evolutionary -- it is necessarily adaptive to the environment. The basis for control action is the identification of changes in the environment. The evolutionary component must constantly assess the probabilities that inputs may change or that new outputs may be demanded. This "change" may be quantified as discrepancy information between the "world as it is" and "that which is likely to be." A purposive system, such as the Oil R&D Program, must rely heavily on its abstraction of the environment.

The abstraction must be capable of generating a baseline forecast which describes the "world without the program," as well as forecasts which represent the impacts of the program as departure from the baseline. The analytical abstraction of the environment is of critical importance to the operation of a

Figure 3-4. Components of the Homeostatic Control Unit

purposive system and should have the following components:

- A method for estimating the full potential of the impact of the outputs on the environment, serving as a limit on expectations;
- A logical representation of the mechanism by which the outputs create the impacts required by the mission statement;
- Analytical consideration of the effect of additional variables (e.g., oil price) on the causal chain between output availability and impacts; and
- An explanation of the mechanisms in the environment by which outputs are exchanged for vital inputs to sustain the system's operations (these may or may not be the same mechanisms by which impacts are realized).

A number of research organizations, most notably the Gas Research Institute (via the Hydrocarbon Model) and the Oil R&D Program (via TORIS), manage program operations using a formal analytical abstraction to assure that their activities are targeted toward desired external impacts. In the context of the evaluation of the Technology Transfer model, the analytical abstraction of the environment may consist of extending TORIS to include *market penetration curves* for particular technology advanced targeted by the program. As shown in Figure 3-6, this type of curve plots time on the horizontal axis and market share on the vertical axis. In general, new technologies penetrate the market in the form shown by the curve. The initial innovation phase is marked by a small number of "pioneering" users. Next comes the period of rapid acceptance, when market share is gained very rapidly. Finally, the technology comes to dominate the market, with only a small number of "resistors." One only has to think of recent innovations such as video recorders, compact discs, or microwave ovens as practical applications of this theoretical curve.

Figure 3-5. Components of the Evolutionary Control Unit

The role of the evolutionary component is, therefore, to change the design of the system process to react to changes in the environment. As an example of this, TORIS showed a rather large target potential for unswept mobile oil-in-place. Recognizing that many fields were likely to be abandoned in the near future, the R&D program has been redesigned, in light of the TORIS estimates of potential, to look for promising ways of addressing this target in order to maintain domestic production. Accordingly, the R&D program was modified to include advanced secondary processes. Further, the program's near-term component is explicitly defined as the rapid transfer of currently available technologies to avoid premature abandonments, i.e., a "steepening" or acceleration of the market penetration curve.

Evaluation activities are also involved in the evolutionary component, in terms of generating discrepancy information about the environment and the program. Specifically, evaluation activities also include developing information which permits management to decide whether the program design is consistent with the

environment and, in the case of purposive systems, achieving desired changes in the environment.

MAJOR ELEMENTS OF A PROGRAM DESIGN

From the review of systems theory, it is clear that management requires a good abstraction of the program -- the program plan or design -- in order to exercise both its homeostatic and evolutionary functions. It might be argued that the program design is the foundation for effective management because it is the standard for developing discrepancy information for each function. As we have indicated, the program design is an analytically useful compilation of the inputs, processes, outputs, and impacts of the program (Figure 3-7). Each of these components may exist at various levels of detail. The basic system process can be composed of a number of sub-processes. The outputs of some sub-processes may also be inputs to others. Impacts, however, occur in the external environment and are not part of the description of a particular process. To reflect different levels and functional groupings of

Figure 3-6. Classical Market Penetration Curve

Technology Transfer Program		
Inputs	Processes	Outputs/Impacts
<ul style="list-style-type: none"> • Problem Diagnosing Workshops • New Technologies • Data • Reports & Analyses • Software 	<ul style="list-style-type: none"> • Outreach Activities • Problem Solving Workshops • Information/Data Dissemination • Training • Demonstrations 	<u>Outputs:</u> <ul style="list-style-type: none"> • Repackaged Reports/Analyses • Software • Referrals • Data/Information <u>Impacts:</u> <ul style="list-style-type: none"> • Attitude Change • Knowledge • Use of Technology • Improved Recovery

Figure 3-7. Major Information Categories for a Hypothetical Technology Transfer Program

inputs, processes, and outputs, the program design will usually organize a program into several components. A component is a "process" which has been analyzed, into its own inputs, (sub) processes, and outputs.

In large programs, it is likely that each "process" of each "component" will become a sub-component in its own right and that each sub-component will be analyzed into its own inputs, processes, and outputs. This sub-division can continue even further until a level of specificity is reached that is appropriate and meaningful to management.

At each level of analysis, it is possible to identify certain functional dependencies between components or sub-components. For example, a successful field test (component) may depend on

successful development of screening criteria (component) and development of new chemicals (component). The program design notes and recognizes such dependencies.

The next section provides further details for program description. It is important to remember that the design that will emerge as a result of these procedures will not be "cast in concrete." A design develops incrementally; it changes as implementation brings to light information of greater detail, and it changes as management exercises the "redesign" option for resolving discrepancies. This recycling is natural and beneficial. In research programs, information and new knowledge developed in the course of the program may also contribute to the redesign cycle.

Chapter 4

CONSTRUCTION OF A PROGRAM DESIGN

Program design and program planning are synonymous. This section highlights the basic elements of planning in order to create a standard (i.e., program design) for the purposes of evaluation. DOE Order 1332.1.A, Uniform Reporting Systems, requires that all programs (including Technology Transfer) have a program plan. The type of design required by the paradigm is drawn from the required Work Breakdown Structure (WBS), with additional modifications to show the inputs required by and the outputs delivered from each element of the WBS. This approach also applies well to private sector or non-federal research and technology transfer efforts that do not fall under the requirements of the DOE orders.

Although the statement of inputs, processes, and outputs may not be explicitly required, compliance with the Order will require formal, systematic, mission-oriented planning. Specifically, systematic planning requires the following major steps:

Step 1: *Establishment of Goals, Constraints and System Boundaries:* Goals and broad constraints are set by careful consideration of the environment. Goals and major objectives are defined as desired changes in the environment. Planning is virtually impossible without thinking through the chain of desired impacts and deciding what tangible outputs can influence this chain of events.

Step 2: *Analysis of Objectives:* A chain of logic which subdivides the goals and broad objectives into more concrete objectives, sub-objectives, and, ultimately, meaningful work packages. This

analysis is ultimately formalized into the work breakdown structure (WBS) which partitions the overall program into a series of manageable tasks which are hierarchically related to the ultimate goals of the project.

Step 3: *Process Analysis:* Starting with the lowest level in the WBS, "processes" are laid out as a series of precedence-related tasks. The definition of processes begins with their expected outputs (products or services) and leads to a statement of the work which is required to yield the outputs. During this analysis, several alternative strategies to accomplish the objective may be considered. The sequence of outputs from lower-level tasks becomes a chain of milestones, and the work required to yield them enters into the staffing plan. The process analysis is iterative. If the resource analysis (discussed below) shows that the total requirements of a given set of processes do not fit within the constraints, then planners must choose an alternative.

Step 4: *Resource Analysis:* The statement of processes and outputs serves as the basis for estimating the necessary "inputs" (staff, funds, material, etc.) that are necessary to accomplish the job. Input analysis provides an opportunity for assessing the feasibility of the processes, both in terms of assuring that the total resource requirement fits within the constraints and that the appropriate sequence of outputs from some processes are available as inputs to other processes.

Step 5: *Scheduling*: The statement of inputs, processes, and outputs from lower levels in the hierarchy are combined into an integrated schedule which shows the activities of each program element as well as the entire program as a whole. At this point, interactions between processes and critical events are identified and milestone dates can be established. The resource requirements and constraints can be integrated into an overall schedule, budget, and staffing plan.

Step 6: *Evaluation Planning*: All evaluation and monitoring activities are then added into the plan. This includes regular fiscal monitoring and staff accountability as well as special questions about the functioning of the processes, the quality of products and subproducts, and, ultimately, their impact on the environment.

Steps 1-6 are repeated until the program fits within its constraints and stated goals. Thus, "normal" planning, in compliance with DOE Order 1332.1A, requires consideration of all elements of the program design needed to serve as the standard for evaluation. This chapter provides a discussion of each of the first five steps. The next chapter treats Step 6, the evaluation and monitoring activities.

ROLES AND RESPONSIBILITIES

Prior to discussing the specifics of preparing the program design, it is necessary to look at the mix of personnel that is required for the design effort. The design construction process relies heavily on the cooperation of those conducting a program and those responsible for its evaluation. This holds true even in the case of internal evaluation, where a regular staff member is chosen to direct or facilitate a program's evaluation effort. In general, the planning process requires input from key managers and technical staff. There are two sets of skills that participants must bring to the design activity: process skills and technical skills. Process skills

are needed to explain the design's purpose to others, to gather design information, and to validate the finished product. Technical skills are needed to transform assorted program characteristics into the useful, detailed, descriptive document known as a program design or plan.

Written documents such as this place emphasis on technical procedures because they are most suited to this medium. Insofar as process considerations are concerned, the basic advice which can be offered is to involve as many interested groups and individuals in the work as possible. A standard (i.e., program design) is constructed, in the context of a the mission statement, on the basis of knowledge, experience, and values - all combining to produce a model, or abstraction, of how things "ought" to be.

GOALS, CONSTRAINTS, AND THE SYSTEM BOUNDARIES

The Federal Oil and Gas R&D Program, and its component Technology Transfer program, can be thought of as a purposive, adaptive system -- it is made up of a series of related input-process-output units that are designed to achieve certain changes in the external environment. Any given system, however, operates alongside of many other systems which combine to form the environment. The first task to be faced when constructing a program design is defining the *system boundary* -- differentiating between the specific elements to be included within the system and those which lie in the environment. The program's mission statement is critical to this activity. It is the point of reference for setting goals and establishing broad constraints, and it defines the desired impact of the program on its environment. Planning requires a logical analysis of the chain of impacts which relate the tangible products of the program to the ultimate goal.

Within this document, a hypothetical example will be developed which addresses one aspect of technology transfer. It is assumed that the mission of this hypothetical program is to

increase domestic oil production through the dissemination of new technology. The logical chain of desired impacts between the ultimate goal and the tangible outputs of the program is summarized below (Figure 4-1):

- (1) Domestic oil production is now in decline because (a) the U.S resource base is mature and large new fields are not being found; and (b) economic factors are causing operators to abandon existing wells at an increasing rate. Although nothing can be done about the geologic facts of the resource base, the rate of abandonment is governed by economic and technical factors.
- (2) The rate of abandonment is increasing because the rate and value of production from many existing wells is declining relative to the cost of operating them. Premature abandonment traps oil in the reservoirs which could be produced by emerging technologies.
- (3) Reversing the rate of abandonment, therefore, requires solutions which

(a) increase productivity; (b) lower costs; and/or (c) increase prices (note that option (c) is not within the mission of the R&D program).

- (4) The DOE Fossil Energy Oil R&D Program is charged with the mission of transferring existing technology or developing new information or technologies which contribute to sustaining or increasing production and/or reducing operating costs. However, these technological products must be brought from the laboratory to the field.
- (5) There is a natural process of acceptance of new technology which, absent federal and/or non-federal intervention, would require a relatively long time for the products of the Oil R&D Program to penetrate the market.
- (6) A variety of techniques are available to reduce the time required between product introduction and broad market acceptance.

For this example, it is assumed that a software package allowing users to characterize

Figure 4-1. Logical Chain of Impacts

their reservoir and operating environments, assess their producing options, and simulate process performance has been developed and is determined to be ready for transfer. Among several alternatives for transferring the software from the developer to users in the field, presentation of the software package at a focused technology workshop has been chosen. It is important to note that the alternatives developed for achieving a desired output are not mutually exclusive. Choosing one does not preclude using another approach as well, given sufficient resources. In fact, it is likely that a combination of approaches will be chosen for each R&D product to be transferred. For the purpose of this example, it is assumed that systematic problem identification, needs analyses, and technology assessments have already been conducted. Thus, the broad strategic plan for the hypothetical Technology Transfer program is to sustain or increase domestic oil production by reducing the rate of premature abandonments through the accelerated introduction of new and existing technologies, one of which is the described software package.

The boundary for the program is drawn with reference to the program's mission and intended span of control. The criterion is: processes over which the program has no control are placed outside the boundary. For example, the R&D program can have no control over the maturation of the domestic resource base, so efforts to increase production through discovery of giant fields is outside the boundary. A second type of boundary "edge" might occur on the output side. The R&D program may succeed in developing and commercializing a new chemical for use in field EOR processes. However, if this chemical also has benefits in the aerospace industry for non-oil related activities, activities related to commercialization for this latter use would lie outside the system. The rule for drawing the boundary is:

- If the program can control, by specification, command, or direction, a particular result, then the activities are within the system boundaries, and their products are known as "outputs" (e.g.,

"The polymer will maintain its properties in high salinity environments", "Employees must wear safety goggles", "Parts will be machined to a tolerance of 0.0001 mm"). Outputs can be "products" or "services rendered". With services, it is often difficult to differentiate clearly between the process and the output. Outputs are the observable result of the conversion of inputs by processes. They lay inside the system boundary.

- If the program can only achieve a desired result by influencing the free choice of individuals or institutions, the result is known as an "impact" (e.g., "Operators will have favorable attitudes about the polymer", "Polymer augmented waterfloods will increase by 10% per year", "The rate of abandonments will slow by 5%", "Domestic oil production will increase"). These impacts are changes in the environment resulting from the availability of outputs, and they lay outside the boundary.

The boundary, of course, is not a wall. Unplanned or uncontrollable interactions between the program and its environment are natural and generally inevitable. It is important to note that the boundary has been defined in terms of control. Sometimes programs may begin with global and largely uncontrollable goals, such as "improved social conditions" or "the rekindling of the human spirit." Although such aspirations may be admirable, the likelihood of their accomplishment through typical program processes alone is small. A boundary should represent those specific, tangible things for which a program truly intends to be held accountable.

In general, purposive systems such as R&D programs are designed to produce certain outputs, generally tangible in nature, which will achieve a certain impact, or change, once they have been passed into the environment. The program does not produce the impacts. Rather, it is the use of or exposure to the outputs by

others outside the system that will produce the impact. Both formal analytical abstraction of the environment (e.g., TORIS estimates or market penetration curves) and informal "understanding" of the relationship between outputs and impacts form the basis for reasoning that the outputs will have the desired impact.

Monitoring of the environment, done by the evaluator, provides evidence of impact. This evidence is the basis for the decisions which may lead to redesign. If the desired impacts are not found, then either the program or the analytical abstraction (or both) must be redesigned. The adjustment of the system is always necessary, even if the cause for lack of impact lies outside the program's control. For example, the program may have relied on forecasts that oil production would increase if a new polymer that would be economic at \$20/Bbl oil prices was introduced. Suppose that the product is available, and oil prices fall to \$15/Bbl. Suppose further, that oil production drops. In this case, the analytical abstraction could be correct and the product could meet specifications, but the program would not achieve the desired impact. The implications

for management are clear. Management would be best served if it made an attempt to redesign the polymer so that it is cost effective at the lower oil price.

At a general level, it is possible to represent a program's relationship to its environment as a statement of strategy. This broad statement identifies the *stakeholders* in the environment and their association to the process (Figure 4-2). Stakeholders are those people or entities who have, or perceive they have, a stake in the future success of the process. Stakeholders provide the resources or inputs necessary to the process. They also receive process outputs, hopefully leading to the desired impacts on the environment. This declaration of strategy should depict what the program needs from the environment, what outputs it seeks to produce, and which impacts in the environment will likely result from this availability of outputs. In essence, the result is a statement of raw feasibility for the program.

A more definitive system boundary will emerge as the design becomes more detailed, and

Figure 4-2. Statement of Strategy for a Hypothetical Technology Transfer Program

specific inputs, processes, and outputs are judged to be within or outside the program's span of control. As with all aspects of a program design, the boundary may change as a result of program operation and evaluative feedback. A system may decide to expand its scope to include some processes previously outside the boundary. For example, based on the need to prevent abandonment of wells in the near term, FE expanded the boundaries of its research program from tertiary recovery (and other long-term, high-risk technology) to include advanced secondary recovery and related geoscience. Alternatively, the purposive system may respond to its environment by discontinuing processes which yield outputs that do not achieve the desired impact. A periodic review of boundary questions should be conducted throughout the design construction and during the cyclic modification process.

ANALYSIS OF OBJECTIVES

The program design is based on a chain of logic that subdivides the ultimate goals and objectives of the program into more concrete objectives and sub-objectives. This analytical process continues until definitive work packages (processes), resources (inputs), and products (outputs) can be specified. This analysis partitions the overall program into a series of manageable tasks which are hierarchically related to the ultimate goals of the program.

After establishing the chain of logic which leads to the system boundary, construction of the design begins with the formal specification of the impacts of the program. This includes an objective definition of the desired change in the environment and a discussion of the analytical rationale for a linkage between program products and the change. This generally makes reference to the abstraction, or analytical model, of the environment, as discussed above. In the case of the FE Oil R&D Program, intended impacts might be stated in terms of the difference between a Base and Advanced Case TORIS run (or some fraction thereof). For the Technology Transfer program, impacts might be stated in terms of the various parameters of the market

penetration curve, as discussed above (e.g., "greater innovation phase" or "steeper acceptance phase"). The specification of impacts poses a considerable challenge and requires careful consideration of stakeholders, technologies, economic factors, regulatory and other constraints. The meticulous specification of impacts, done so that there are observable indicators of change, is an important element of evaluation to be discussed in the next chapter.

This analytical breakdown eventually leads to identifiable intermediate objectives. The intermediate objectives are the outputs which result from program-controlled processes. Intermediate objectives are passed from one element of the process to another, enabling the program to move forward in a logical chain of steps to hopefully cause the desired impacts in the environment. This sequence of intermediate objectives becomes a list of milestones for the program. The analytical breakdown is formalized into the Work Breakdown Structure (WBS) (Figure 4-3).

Most R&D programs seek to develop products. The Technology Transfer program seeks to bring those products from the laboratory to actual industry use. For the focused technology workshop example, the sequence of intermediate objectives could run as follows:

- Advertisements will be placed in appropriate publications and a targeted mailing will be conducted;
- Members of the target audience register for the workshop;
- Materials for the workshop are prepared; and
- The software package is presented to members of the target audience.

At this point, the objectives move outside the boundary of the program to potentially have impacts on the environment. The series of milestones allows program managers to assess the progress of the approach being used.

PROCESS ANALYSIS

Starting with the lowest level in the WBS, "processes" are laid out as a series of precedence-related tasks. Often, the definition of processes begins with their expected outputs (products or services) and leads to a statement of the work which is required to yield the outputs. The statement of work is frequently chosen from several alternatives which could be pursued to accomplish the objective. The sequence of outputs from lower-level tasks becomes a chain of milestones, and the work required to yield them enters into the staffing plan.

Process analysis is iterative and must pass the initial test of a resource analysis (discussed below). If a chosen set of processes does not fit within the constraints, then planners can redesign the process or choose another alternative. Although there are many alternatives available for the transfer of a software package, the hypothetical example assumes that planners have chosen to conduct a focused technology workshop as the technology transfer mechanism

(rather than other means, such as demonstrations at annual meetings, trial copies installed at resource centers, and articles in trade journals).

In general, processes are described in terms of event-sequences, or the intended interaction of people, materials, and equipment and the context in which the interaction takes place. The process descriptions in the WBS are required to be specific. They should be examined to make sure that they clearly describe who is doing what to whom, how, when, where, and for how long. The process description bears the burden of clearly describing how inputs will be transformed into outputs.

There is a need to strike some balance between "procedural" and "instructional/technical" detail. An over-emphasis on either can short-change an evaluation effort. For example, a design for a training session which contains nothing but an outline of the topics to be covered will tell little about where trainees or instructors come from and how they will interact with the materials. Similarly, the same activity

Figure 4-3. Partial Work Breakdown Structure for a Hypothetical Technology Transfer Program

could be described with great emphasis on the participants while leaving the actual training as a "black box". A balance between both types of information is essential to evaluation. Order 1332.1A requires that the WBS be made sufficiently specific to support effective management. If necessary, each component of the process should be further analyzed into sub-components which reflect sufficient detail to manage costs and time.

In the hypothetical example, each technology transfer "activity" is considered to be a subsystem with four major subcomponents. The components and their relation to the evaluation process are illustrated in Figure 4-4.

1.0 *Develop Prototype* -- The basic design for the technology transfer "activity" is created during the initial set-up. In general, planners find the best mechanism for transferring the technology.

2.0 *Adapt Prototype* -- Staff adapts the prototype to the specific site and audience to which it is targeted.

3.0 *Execute Process* -- The technology transfer activity is actually conducted at a specific site.

4.0 *Report to Higher Levels* -- Staff summarize the information from the process to produce recommendations for changes in the design of the activity or in the design of the product being transferred.

Using this flow of logic, it is possible to describe the steps or components to each process (Figures 4-5 through 4-8). Taken as a whole, the steps in the flow of logic depict the process' internal detail and inter-relationships. As required by the WBS, each block of activity should be analyzed to a point where appropriate staff and resources can be specifically defined. When describing the components of each block of activity, several considerations should be kept in mind:

- *Degree of Functional Importance:*
Each component should have about the same amount of critical influence on the success of the program. A rough

Figure 4-4. Logical Flow of Process Analysis

equality of time and staff demands should also be considered in defining components, although the most important factor is their functional equality in contribution to terminal objectives.

- *Overlap:* Components should be as distinct from one another as is reasonably possible. Similar processes should not be repeated from component to component.
- *Comprehensiveness:* All program processes should logically fit under one (and only one) block of activity.

Once the process has been analyzed to an appropriate level of detail, program planners can begin to assign staff and resources to a particular transfer mechanism.

ESTIMATION OF RESOURCES

The statement of processes and outputs is the basis for estimating the necessary inputs, staff,

money, material, etc., that are necessary to accomplish the job. Inputs are required to set processes into motion and keep them running. Some of the most common classes of inputs are:

- *Resources:* Though perhaps all inputs could be called resources, in the paradigm this term is reserved for those non-human tangibles, such as dollars, equipment, facilities, and services, which generally come from outside the boundary of a particular process.
- *Staff:* Staff are those individuals, either volunteer or salaried, who have recognized responsibility for actively supervising or conducting program processes. Input descriptions for staff should emphasize functional roles and responsibilities rather than names of particular persons.
- *Intermediate Objectives From Other Components:* The final class of "input" is the output from one process which serves as the input to other processes.

Figure 4-5. Program Design for the *Develop Prototype* Component

As program planners assign staff and resources to a particular process, it provides them the opportunity to assess the feasibility of the process. If the required staff time and/or resources are unreasonable or prohibitive, then the process may need to be reworked. This iterative characteristic of the process and resource analysis is an integral element to effective program planning. The process and resource analysis should be revisited until a feasible design results.

Once a feasible design has been established and staff and resources have been assigned, it is possible to examine each process in terms of an input-process-output/impact (IPO) description which summarizes the program process. The estimated inputs set the budget and standards for the cost accounting and time management functions of the program. The forms and requirements for representing staff allocation is treated with some length in DOE Order 1332.1.A.

SCHEDULING

Once process and resource analysis have been completed, it is possible to estimate the duration of the required activities. These sequenced activities can be linked with those from other planned processes to create an overall integrated schedule. In addition to the sequence and duration of tasks, constraints on staff and resources can also define the schedule. Various analytical methods, such as critical path analysis, can be applied to identify potential trouble spots allowing program planners to remediate them at an early stage of program design. The products (intermediate and final) which are depicted in the integrated schedule serve to define the milestones for the overall program.

DESIGN ADEQUACY CRITERIA

The concern at this point is with the adequacy of the description of the design as a basis for evaluation and not the conceptual or

Figure 4-6. Program Design for the *Adapt Prototype* Component

political adequacy of the program itself. A design should be a complete and accurate representation of the program at hand. It should be of sufficient technical soundness to serve as a foundation for the remainder of the discrepancy evaluation process. In order to assess technical adequacy, two criteria should be applied: comprehensiveness and internal consistency.

The first criterion addresses the completeness of the program design. Comprehensiveness can be assessed on two dimensions. The simplest of these is breadth (or inclusiveness). The second, depth (or level of specificity) is more complicated to assess. Under the paradigm, the comprehensiveness criterion has one additional function -- to ensure that each information category prescribed by the model's systems analytic framework has been satisfied. Potential comprehensiveness criteria questions include:

- Are all major program components included in the design?
- Are all essential objectives (outputs) specified?
- Is there at least one activity (process) specified for each objective?
- Are the resources (inputs) essential to the activities specified?
- Does the design indicate functional relationships between program components?
- Does the design specify time dimensions - the order and duration of major program activities?
- Are there performance standards that specify the changes expected in participants as a result of the program? Is there a description of the performance of participants before they begin the program?

Figure 4-7. Program Design for the *Execute Process* Component

- Are the dynamics of program operations detailed at a level of specificity which clearly describes how outputs are produced and how program components interrelate?
- Are descriptions of performance sufficiently concrete so that measurement is possible?

The second criterion, internal consistency, examines the logic of the relationships between various parts of the program design. Potential internal consistency criteria questions include:

- Are all program activities related to the stated objectives?
- Are all inputs related to the program processes?
- Are stated functional relationships between program components consistent? Does one component produce an output intended for a

second component, and does, in fact, that second component use it (and vice versa)?

- Are different program components anticipating use of the same limited resource (staff, equipment, money, etc.)?
- Are the time schedules of different program components coordinated with respect to input use or the achievement of intermediate objectives?
- Do the inputs, processes, and outputs specified in the design, and resource allocations among them, adequately reflect stated program goals and priorities?

The design effort required by DOE Order 1332.1.A provides the standard for evaluation. The next chapter provides the framework for the methodology to evaluate the Technology Transfer program.

Figure 4-8. Program Design for the Report to Higher Level Component

Chapter 5

OVERVIEW OF EVALUATION PLANNING

Formulation of the evaluation standard in the form of a program design should be closely followed by construction of an *evaluation plan*. The evaluation plan is a strategy for collecting performance information compare with the standard to identify discrepancies. Discrepancy information is used by management for program improvement. In the same way that a program design is a systematic and complete description of program activity, an evaluation plan is a systematic and complete description of intended evaluation activity, including its purposes, scope, methodology and worksteps.

PURPOSES SERVED BY THE EVALUATION PLAN

As discussed below, a systematic evaluation plan serves four purposes: (1) it states intentions publicly; (2) it organizes the complexity of the evaluation effort; (3) it facilitates and justifies resource allocation decisions; and (4) it serves as a "standard" for judging the evaluation itself.

- *Statement of Intentions:* Clearly, the evaluation has the potential for significant impact on program support and operations. As such, many individuals view evaluation with fear and suspicion. To help alleviate such fears, the evaluation plan provides a clear explanation as to why information is needed and how it will be used in a public document. More specifically, the evaluation plan should result from broad-based participation in the evaluation planning process, so that the evaluation becomes a useful rather than a threatening aspect of program operations for all concerned.
- *Organization:* As the size and complexity of a program increases, so

too does the necessity for the evaluation plan. Planning ahead guards against such common evaluation problems as bad timing and oversight. Planning also prevents the evaluator from being placed in the awkward position of trying to measure something that is over and done.

- *Resource Allocation:* An evaluation plan helps the staff allocate limited evaluation resources to high priority concerns. An evaluation plan shows how the evaluation activities will support the program and its information needs.
- *Standard:* An evaluation, like a program, should expect to be subject to systematic scrutiny. Criteria for judging the adequacy of an evaluation plan include: (a) theoretical basis; (b) external compatibility; (c) internal consistency; and (d) compatibility with the program environment.

All four concerns are discussed in detail in the following sections.

PLANNING FOR THE STAGES OF EVALUATION

Since the evaluation plan can be focused on "concerns", which are related to either inputs, processes, outputs, or impacts, the relationship between a program design and an evaluation plan should be very close. The evaluation plan will overlay the program design, and it will identify, measure, and document program parts of both functional and political importance. The evaluation plan shows that information collection will be purposeful and coordinated, while at the same time being directly related to program goals and operation.

The evaluation plan, like the program design, is subject to periodic revision. With the addition of performance information, a program design may be expanded. With the discovery of unsatisfactory discrepancy information, constructive activities to remove the discrepancy may be implemented and the program design modified. In each case, as the program design changes, so should the evaluation plan. Due to the cyclic nature of program development, construction of the evaluation plan must account for all five "stages" of evaluation.

As described below, the stages of evaluation correspond to the natural developmental programs - planning, installation, early operation, and cyclical replanning. The evaluation paradigm provides for activities in each of the five stages (Figure 5-1).

Stage 1: Design Evaluation

The technical adequacy of a design (whether the program was sufficiently well explicated in design format) must be assessed. The design

must be a complete and accurate representation of the program at hand, and it must be of sufficient technical soundness to serve as the foundation for the remainder of the discrepancy evaluation process. A systematic attempt to examine the substance, assumptions, and structure of a program prior to installation, particularly when conducted by experts in both content area and program environment, will almost inevitably bring about drawing board modifications which will add to program feasibility and success.

An individual designated with specific responsibility as an evaluator would be involved in Stage 1 evaluation only as a facilitator. As such, he or she would provide participants with criteria for judging substantive design adequacy, but does not actually make the judgements. As discussed below, there are three types of design adequacy questions which must be addressed within design evaluation activities: (1) theoretical consistency; (2) external compatibility; and (3) internal consistency.

Figure 5-1. Hypothetical Technology Transfer Activity Showing Evaluation Stages

Theoretical Consistency Design Adequacy Questions:

- Is the theoretical or conceptual base of the program specified?
- Do program activities and concerns reflect this theoretical base?
- Has relevant evidence from research literature been considered in planning the program?
- Are the theoretical principles embraced by the program generally accepted by the experts? If not, is there a rationale for program experimentation?

External Compatibility Design Adequacy Questions:

- What other institutional objectives are sacrificed by the allocation of resources to this particular program? Are the things "given up" of lower priority than the benefits to be provided by the program?
- Are needs being addressed by the program being met elsewhere?
- Are necessary facilities, media, and other tangible resources available for program use?
- How does program philosophy relate to prevailing community and/or professional attitudes?
- Are program objectives adequate to meet external standards?
- Do program staff and cooperating personnel have the time to be involved in the program? What other activities must they give up?
- Are the needs addressed by the program perceived to be "needs" by prospective participants?

Internal Consistency Design Adequacy Questions:

- Are program preconditions (administrative support, staff qualifications, etc.) likely to be met?
- Do inputs (facilities, staff, equipment, etc.) seem sufficient to support program activities?
- Are staff communication activities sufficient for program operation?
- Are program activities sequenced logically?
- Is there enough time allocated for each activity?
- Are desired outputs likely to be produced by program processes?
- Are any unintended (especially undesirable) impacts likely to be produced by program processes?

Application of the theoretical consistency criteria offers an opportunity to clarify and assess the theoretical principles and rationale on which the program is based. The external compatibility criteria serves to test program assumptions in a larger context by investigating a program's consonance with its general surroundings; this criterion also examines broader concerns, (such as duplicated or conflicting efforts, competing priorities, resource availability, and political constraints) by focusing on the program's impact on the environment and vice versa. The last criterion, internal consistency, is the most subjective of all: it inquires as to the extent that a program "appears" to be reasonable and workable.

The hypothetical technology transfer activity, shown in Figure 5-1, requires design evaluation activities at two points:

- As the "prototype" activity is being developed, experts will provide input

about the likelihood of success. In the example about disseminating a software product, management would want to assemble a team of experts on workshops, software distribution, and oil operators to assure that the prototype meets the criteria of theoretical consistency, external compatibility, and internal consistency.

- As the prototype is adapted to a specific site, management would want to review the adequacy of the adaptation in light of: (a) general principles articulated in the prototype design; (b) specific local conditions; and (c) experience from prior applications of the prototype.

In the former, the evaluation activities will most likely be very visible in terms of convening the panel of experts. In the latter, evaluation will gradually decrease in visibility as strategy and standards for the adaptation evolve with experience. In this case, evaluation (although ongoing) will come to be virtually indistinguishable from general management activity.

Stage 2: Input Evaluation

In its simplest form, input evaluation seeks to determine: (1) that required inputs are present at the time, in the places, and of quantity and quality prescribed in the program design; and (2) that planned processes have been set in motion. The most traditional form of input evaluation is fiscal monitoring (i.e., accounting information, timecards, etc.).

Beyond this, simple input evaluation lends itself readily to checklists, and discrepancies are easily detectable. Though simple, this process can be a critical element in getting programs off on the right foot.

Input evaluation of greater sophistication measures and reports on the extent to which design preconditions have been met. This kind of investigation is particularly important to replication programs where failure to meet preconditions is a frequent source of problems.

In the software workshop example from the hypothetical technology transfer program, input evaluation activities will focus on participants, presenters, and logistics using the adapted prototype design as the standard:

- The characteristics of the actual workshop participants will be measured relative to assumptions and preconditions inherent in the design (e.g., the software requires ownership or access to or willingness to acquire a 386 class computer. How many participants meet this criteria?).
- The characteristics of the presenter for the workshop will be verified (e.g., the design requires that the presenter have oilfield experience. Did this happen?).
- Logistics requirements may cover items like facilities, timing, travel distance, and others. Input evaluation would gradually evolve to checklists to make certain that all necessary activities take place at the correct time.

Input evaluation is expected to diminish in "visibility" (but not importance) as a distinct activity. As experience leads to the development of clear standards, input evaluation will come to be seen as part of general management through the development of checklists and standard operating procedure.

Stage 3: Process Evaluation

After input evaluation verifies that processes have indeed been set in motion, process evaluation monitors their continued operation and the sequential accomplishment of intermediate objectives as specified in the program design. Process evaluation uses discrepancy reports to clarify the relationship between program activities and the accomplishment of interim objectives and to identify intervening factors or variables. A precise record of the connections between program activities and interim effects makes a substantial contribution to the interpretation of the evaluative steps which ultimately follow.

Most evaluation plans should emphasize process evaluation during the early stages of program operation. Instrumentation during this stage of evaluation is difficult, because measuring devices will most likely have to be constructed. Subsequent evaluation cycles improve instrument development, however, since early feedback on program operations can be used to build instruments of increasing sensitivity and sophistication.

In the hypothetical example, process evaluation would take the form of structured observation of the workshop, perhaps even trying to investigate the mechanisms by which participants are influenced or the efficiency of specific materials or workshops activities. The first few workshops may be studied very thoroughly, with evaluation activities very visible. As experience leads to increased understanding of the dynamics of the workshop, process evaluation would diminish in visibility (but not importance) and would gradually become recognized as part of management's standard operating procedure.

Stage 4: Output Evaluation

The word "output" in this evaluation stage refers to end products only. In its simplest form, output evaluation merely checks to see that the products have in fact been delivered. Again, it is important to note that with "services" the distinction between process and output tends to become blurred.

If the end products are complex, output evaluation alone may produce ambiguous and inappropriate results. When applied to programs which have benefitted from formative evaluation, however, the results are not only interpretable, but generally positive, since previous evaluation stages (i.e., design, input, and process evaluation) provide for program improvement. On a more technical level, the designs themselves are more sophisticated, since the relationships between treatment, conditions, and effects discovered during process evaluation can often be translated into independent variables for later study of impact. As programs improve and more sensitive measures of impacts are developed, the

chances for success in meeting overall goals will be improved.

In the example from the hypothetical technology transfer program, the output is the delivery of a service (i.e., the workshop). Attainment of this "output" can be measured in several ways, for example:

- A simple count of the number of participants who stayed for the whole session
- A count of the participants who say that they heard "something new" at the session (i.e., the session was markedly different than staying home).

Output evaluation will also decrease in visibility as the program matures and studies establish criteria for assuring internal and external audiences that the services have indeed been delivered.

Stage 5: Impact Analysis

Impact analysis is the ultimate rational step in the process of program development. This final evaluation stage refers to some aspect of the environment (e.g. oil production) and the comparison of a baseline scenario with actual results. The baseline is an analytical construction which represents the "world without the program".

Effective impact evaluation requires a carefully constructed abstraction of the environment. This abstraction could be defined in a theoretical analysis or computer model which contains:

- *A method for estimating the full potential of the impact of the outputs on the environment, serving as a limit on expectations.* For example, TORIS analyzes the technical potential for oil recovery for a variety of current and advanced technologies in a very large set of actual oil reservoirs, creating an upside limit on the amount of recovery which may be obtained.

- A *logical representation of the mechanism by which the outputs stimulate or create the impacts required by the mission statement.* In the case of the Technology Transfer program, market penetration curves might be used to chart the progress of technology from the laboratory to widespread field acceptance. These curves should represent a "base case", or a world without focused DOE transfer activities and a series of alternate cases reflecting the success of various components of the Technology Transfer program. In addition, market research theory provides the basis for constructing advanced cases.
- *Analytical consideration of the effect of additional variables (e.g. oil price) on the causal chain between output availability and impacts.* TORIS is relatively unique as an analytical abstraction, because it considers many additional environmental variables, particularly price, regulation, and taxation, and their impact on potential recovery. DOE has recently developed the Crude Oil Policy Model which further extends the understanding of the linkage between technology availability and its usage in the marketplace.

The essence of impact evaluation is the examination of the causal chain to identify salient points which indicate critical events (e.g. presence on "fast" acceptance curve, rather than "slow") and the development of measures of these events. A critical area of work is to separate program effects from the effects of other variables such as oil prices and regulation.

In our example from the hypothetical technology transfer program, impact evaluation could be done at three or more points, including:

- Survey of attitudes after the workshop;

- Survey after software purchase as part of warranty registration; and/or
- Survey of all participants (or a sample thereof) six months or a year after the workshop.

The survey data would indicate changes in attitudes. Behavioral changes could be monitored through other public channels, such as application for drilling or workover permits. As the program matures, increasing emphasis would be devoted to impact evaluation.

THE EVALUATION DESIGN

The first section of the evaluation plan - the *evaluation design* - provides an overview of the conceptual structure of the intended evaluation effort. It shows what parts of a program will be subject to evaluation and explains, in general terms, how performance information will be sought and used. The basic components of the evaluation design are: (a) the *evaluation concerns*, or the major aspects of the program which will be subject to evaluation; (b) the *evaluation questions*, or a description the kind of performance information sought; and (c) the *source of information*, or a general description of where performance information will come from, and how it will be obtained.

Evaluation Concerns

In a purposive system, such as the Technology Transfer program, evaluation concerns are derived from the impacts, which are, in turn, derived from the program's mission statement. These are several points or areas within the program design which should be subject to evaluation. These general areas are called *evaluation concerns*, and they function as organizing principles for the remainder of the evaluation planning process. Evaluation concerns should reflect the program design, but there need not be a strict one-to-one correspondence to program components.

Figure 5-2. Developing Evaluation Concerns and Addressing Them with Evidence

The evaluation concern list begins with the mission statement, and is refined inductively by identifying elements that are more and more specific until they state questions which can be answered by collecting data. For the Technology Transfer program, the highest level evaluation concern would be:

Is the amount of economically producible domestic oil increasing?

In turn, this might be further analyzed into concerns such as:

- Do market conditions support an increase in production (with and without the technology)?
- Is production change related to deployment of the new technology in key areas in which it is applicable?
- Is the rate of abandonments slowing, particularly in areas where the technology is available?
- How many units of the new technology are being deployed?
- What influences operators to choose to deploy the technology?
- How many units are purchased/deployed in the absence of active technology transfer activities?
- How many units are purchased/deployed based on notification of availability?

This process (as illustrated in Figure 5-2) should be guided by the analytical abstraction, but a large component of brainstorming by staff and experts will also be required to organize the list of evaluation concerns into a hierarchical list which shows how the answer to each is logically related to the program mission statement. The list of evaluation concerns must eventually be "matched" with evidence that will deductively show attainment of the mission. Evaluation

planning is, therefore, largely a process of bridging the gap between program and mission by combine deductive and inductive reasoning.

Most of the time, it is possible to identify more evaluation concerns than evaluation resources can address. Some evaluation concerns can easily be postponed until a second cycling of the evaluation process, while others must submit to a priority ranking. The following are useful criteria relative to the selection of priority areas of evaluation concern:

- *Areas relating to components of central functional importance:* Often, a superficial glance at a design network, if not common sense, will show one or two program components that are at the heart of program operation. Logically, this means that the success of the program as a whole is heavily dependent on the success of this one component and on its specific outputs. Such components are prime targets for evaluation concern.
- *Areas that are problematic:* A second candidate for evaluation interest is the proven or anticipated "problem area." Such areas may be one or more of the following types:
 - Areas where design adequacy questions are unresolved
 - Areas undergoing development or experiment
 - Areas with a history of problems
 - Areas marked by staff disagreement.
- *Areas of direct concern to external evaluation audiences:* one of the main reasons most evaluations are conducted is to satisfy the evaluation information demands of external audiences, such as:
 - Funding agencies
 - Higher administrative levels
 - Professional associations
 - Regulatory agencies

— Community and assorted interest groups.

- *Areas of direct concern to internal evaluation audiences:* To insure program staff cooperation, an evaluation should produce information which is directly useful to all concerned. Not all evaluative feedback will be useful to everyone, but each major internal audience should be able to identify at least one part of an evaluation plan addressed to their needs.
- *Areas with time priority:* An obvious priority should be given to evaluation concerns which involve information needed by a fast-approaching deadline. Care must be taken, however, to avoid too many "crisis" evaluation concerns. The whole point of evaluation planning is to defuse such crises by making information collection a planned and methodical part of program operation.

Sometimes external information demands are documented and formal. Sometimes, they must be inferred and anticipated. In either case, all such audiences should be identified, and their information needs should be clarified and coordinated. The analysis of stakeholders, discussed in Section 4.2, is a starting point for developing strategies to meet external information needs. The evaluation concerns of external agencies should reflect needs of a significant and enduring nature.

Evaluation Questions

The next step in the construction of an evaluation design is the formulation of a set of evaluation questions for each evaluation concern. An evaluation question is used to direct the systematic collection of performance information, and is the basic building block of evaluation planning. An example of evaluation questions for "contact" activities in the hypothetical Technology Transfer program might be:

(1) Is the right target audience being reached?

(2) Do the recipients react appropriately to the message?

(3) Do the recipients seek further information about the technology?

(4) Do the respondents eventually accept and use the technology?

Evaluation questions must be specific enough to contain measurable concepts which can be investigated systematically, yet general enough to elicit information which is meaningful to decision makers. Taken together, the set of evaluation questions provides the operational definition of a particular evaluation concern. Like these concerns, evaluation questions must be prioritized using similar criteria as set before, plus the added consideration of cost. Some evaluation questions, though not of critical importance, are relatively cheap to answer. For others, the cost of collecting adequate performance information may be prohibitive. Evaluation questions should not be discarded until some time has been spent brainstorming about imaginative and inexpensive measuring techniques. Detailed analysis of evaluation questions clarifies each area of concern, and becomes a guide to the collection of performance information. The goal of evaluation questions is to develop a strategy for collecting information that will answer the question at reasonable cost.

In a purposive system, such as the Technology Transfer program, the evaluation questions must be derived from the mission statement. The intent is to reduce broad concepts to specific, measurable variables. Shown below is a brief example of this type of Evaluation Question Analysis:

Evaluation Question: In order to achieve a significant increase in the number of "innovators" on the market penetration

curve, it is necessary for workshop participants to have a favorable opinion of the new technology. Thus, it is necessary to answer the question, "Do the recipients of contact activities react appropriately to the message?"

Evaluation Question Analysis: General Concept: Does the message convey the benefits of the technology?

Specific Question: How many recipients received the message?

Specific Question: Do the recipients agree with the message?

Specific Question: Do the recipients plan to take action based on the message?

The final task in the evaluation question analysis is to determine a standard for each variable identified. In the case cited above, the evaluation plan may decide to conduct interviews of a sample of recipients and develop a detailed sampling plan and interview format.

The complexity of the analytic process depends on two factors: first, the relative specificity of the evaluation question; and second, the degree of thoroughness and objectivity with which the question must be answered. The intellectual exercise involved is not without a purpose. It feeds directly into the process of developing measuring instruments to collect performance data by reducing the concepts embodied in each evaluation question to measurable form. This task is perhaps the most demanding of the entire evaluation planning process. However, it is a necessary prerequisite to the development of measuring instruments and requires a thorough understanding of program operations and objectives.

The statement of an evaluation question implies a concept about which data is to be collected. For example, if the evaluation asks, "How adequate is the Technology Transfer Contact Component?", it seeks data about the concept "contact component". To do this,

"adequate" must be carefully defined in this context. A set of indicators, by which its presence, absence or quality can be determined, should be developed. The first step is referred to as *formulating dimensions* and the second as *specifying variables*.

The analytic process is hierarchical in nature, involving a systematic movement from the general to the specific. The first step in the process was taken when each evaluation concern was defined in terms of a set of evaluation questions. Now each evaluation question will be defined in terms of a set of variables. Each evaluation question was stated in more specific terms than its associated evaluation concern. The sum of evaluation questions defines the evaluation concern. A similar relationship holds between variables and evaluation questions. Thus, with each analytic step, the concept under examination is slowly narrowed, and activity moves to the statement of specific information needed.

Information Needs

Along with the identification of evaluation concerns and their associated evaluation questions, there is a discussion of the *information need*, or an explanation of (1) why the evaluation question is being asked; (2) what kind of information is sought; and (3) how, and by whom, it will be used.

A "source" of information, as used in an evaluation design is not a unidimensional concept. Rather, for any given measurement, several factors are involved:

- **Subject:** The person, organization, behavior or phenomenon about whom (or which) information is being collected;
- **Locus:** The person, organization, document, or artifact which will provide the desired information;
- **Mode:** The manner by which the information is to be collected (i.e.,

observation, document analysis, self-report, interview, etc.); and

- *Instrument:* The device by which the behavior or phenomenon is to be measured (i.e., questionnaire, checklist, etc.).

The process of determining what to measure and how to measure it are subject to a great deal of interaction. The question of "what" is dealt with by the specification of evaluation concerns and questions, and the analysis of evaluation questions into variables. The question of "how" is dealt with by generating a number of information collection possibilities for each evaluation question and then choosing those which yield the best information at the lowest cost.

The considerations involved in deciding upon a source of information are many. The first task, as noted above, is to brainstorm a number of information collection possibilities for each question. The second task is to pick and choose from among the possibilities generated. The following factors should be considered in this process:

- *Reliability and Validity:* Reliability means the degree to which information is consistent over time and method of measurement. Validity means that the information accurately reflects the phenomenon being measured. One can do much to insure the reliability and validity of the information by choosing modes which are direct (without long leaps of inference), unobtrusive (do not contaminate behavior), and objective. Sources of information which would not be considered credible by the audience(s) for evaluation results should be avoided. When possible, information should be validated by using more than one information source for each evaluation question. If instruments are to be developed, field testing and reliability/validity studies should be conducted.

- *Cost:* Before deciding on an information source, the cost of gathering, analyzing, and reporting information should be considered. How accessible is the source? How much computer/staff resources will be required to analyze the data? Can the results be easily summarized and understood? All available resources should not be squandered on one evaluation question. Gathering as much broad-based information for the evaluation effort as possible should be a goal. Already proven measurement tools may exist and should be sought. If possible, one instrument should be used to answer one or more evaluation questions. Care should be taken not to overwhelm sources, particularly if they stand to gain little from the evaluation exercise. Cost is not only a matter of finances. An effort should be made to ensure that the information collection will not disrupt program operations. Information that will reinforce existing informal evaluation processes should be chosen.

An evaluation design may need to be available before the evaluation planning process has been fully completed. The general rule of thumb when specifying the "source of information" is simply to begin with one's immediate thoughts. The specifics can be updated later as the planning process continues.

A statement of "information need" performs several functions. First, it provides a rationale for why any given evaluation question has been considered important enough to justify resources for the asking and answering. Second, it briefly explains what kind of information is sought. Third, it indicates how the information will be used and by whom.

Justifications for pursuing specific evaluation questions vary. Listed below are some of the common classes of rationales:

- *Record Keeping:* Evaluation and on-going management information

systems should be kept closely coordinated to avoid unnecessary overlap and program disruption. The two systems are not, however, the same. A record-keeping rationale is rarely sufficient unto itself to justify the inclusion of an evaluation question in a design. Most commonly, it is coupled with an external evaluation demand for the information, or a need for baseline data for a future time-series study.

- *Routine Monitoring:* This is similar to record-keeping, but it applies more specifically to input evaluation where the presence of inputs and the installation of processes are verified. Evaluation activities should make maximum use of accounting information, milestone achievement information, and staff time records.
- *Verification of Preconditions:* Some evaluation questions may be asked in order to verify the presence of critical preconditions or to validate their status as such. Such questions are particularly worth asking when program replication is planned or where there are disagreements over program boundaries.
- *Management Troubleshooting:* When evaluation questions refer to areas that are problematic, they should be justified by providing a brief explanation of what makes them so.
- *Functional Criticality:* When evaluation questions refer to areas of critical functional importance, major dependencies should be cited in the rationale statement.
- *Accountability:* The fact that information is needed or desired by an external agency or group provides a strong rationale for many evaluation questions.

The second function commonly served by a statement of "information need" is a brief description of the parameters which define the information to be sought. This more detailed restatement of the evaluation question serves as the basis for the "question analysis" task, which directly follows the evaluation design phase.

Last, but not least, the statement of information need should tell the reader the purpose for gathering the information. In broad terms, this is done by designating the "need" as formative or summative. This indicates whether an evaluation question is being asked for purposes of program improvement or program assessment. More specifically, the body of the statement of information need should clarify those decision situations, program modifications, or accountability needs to which the resulting data will be applied.

It is important to begin to specify the date at which the information must be available to establish a ballpark estimate of when discrepancy information will be available. The date may differ from one evaluation audience to another. If so, it should be noted. More specific report dates will be projected as evaluation planning proceeds. An example of the evaluation design is shown in Figure 5-3.

Dimensions, Variables, and Standards

The gap between a concept and an appropriate set of measurable variables can be small or large, depending upon both the initial specificity of the evaluation question and the precision of performance data required. To allow for a flexible number of analytic steps between questions and variables, a category called the dimension is posited. In brief, a dimension is a useful organizing principle which further defines an evaluation question.

For example, consider the concept "Adequate Contact Program". Suppose that the Technology Transfer program planned to use a mailed letter to contact independent operators and that the letter was intended to influence the reader to

attend a free workshop on a new software product. Some dimensions of the word "adequate" might spring to mind:

- An "adequate" mailed contact gets to the correct respondent;
- The respondent will, in fact, read the letter; and
- A percentage of respondents will take action based on the letter and attend the seminar.

This kind of analytic process should continue until measurable variables are specified. For the above dimensions, a number of measurement opportunities are possible:

- *Dimension:* An "adequate" mailed contact gets to the correct respondent.
- *Variables:* (1) Number of letters returned for incorrect address; and (2) total size of mailing.

- *Dimension:* The respondent will, in fact, read the letter.
- *Variable:* In a phone interview of a random sample of persons who received the letter, the respondent can remember some aspect of the letter. Results from the sample can be used to estimate the total number of persons who have read the letter.
- *Dimension:* A certain percentage of respondents will take action based on the letter and attend the seminar.
- *Variables:* (1) Count of seminar applications; (2) total number of letters known to have been received; and (3) total number of letters projected to have been read.

At what point a variable becomes measurable is somewhat problematic. In general, the preference is for objective measures, which

EVALUATION CONCERN	EVALUATION QUESTION	DESIGN REFERENT	INFORMATION NEED	SOURCE OF INFORMATION	DATE NEEDED
Factors Involved in Software Acquisition Decision	How did the operator find out about the software? What level of exposure did the operator receive?	Applies to effort as a whole.	Planners need to know the source of information on the software because if the focused technology workshop is not a strong factor, then the transfer strategy may need to be reworked. Knowing the type and source of exposure is important in planning the next workshops	Warranty cards and follow-up with users will provide the necessary information	N/A
	What was the role of computer specifications (i.e., memory, time, hardware) in the decision to acquire the software?	Applies to effort as a whole.	Prohibitive computer requirements could keep potential users from acquiring the software. If this is the case, the low level of software acquisition by operators provides little information regarding the effectiveness of the transfer effort	Interviews with a sample of mailing targets who did not attend the workshop and of attendees who did not acquire the software. Examination of computer requirements provides context	Before the next planned workshop

Figure 5-3. Evaluation Design for Components of Impact Evaluation

implies that a variable should meet the following criteria:

- *Specificity:* A variable must always be more specific than the evaluation question it helps to define. Within the context of the subject population, the variable must take on multiple values (it must be capable of "varying"). It should refer to a prescribed population, time span, and context. If any of these elements are missing, the dimensional framework may be incomplete.
- *Observability:* A knowledgeable disinterested party may easily distinguish levels of the variable given the definitions developed within the evaluation plan. An indicator is more easily measured when it refers to a tangible behavior or artifact. Briefly, an "attitude" may be hard to spot, but a smile is not.
- *Unidimensionality:* The particular value of the variable should be determined by changes in one underlying trait of the subject being measured. Basically, this translates into "simpler is better". The analysis should be reduced to the point where only one thing - a discrete behavior or artifact is changing. If several things are to be measured, set a dimension for each.
- *Suggests Standards:* It should be easy to attach a specific performance standard to each identified variable. A number scale, a fixed set of categories ("present"/"absent"), or clear methods of judgement are indicators that a variable is likely to be objective.

Once the analytic process is completed, variables must be tested for completeness. For each set of variables, one should ask: if information were received relative to each variable on the list, would it be possible to answer the evaluation question in a satisfactory

manner? If the answer is "yes", the derived variables are sufficient. If the answer is "no", then more ingenuity must be applied to fill in the remaining gaps.

The analysis of evaluation questions is, in many ways, a continuation of the standard-setting process that was begun in constructing the program design. This is formalized by attaching a standard, or specific level of acceptable performance, to each variable that has been formulated. In some cases, a program may say that it is interested in information for its own sake. However, this type of information is probably not relevant to the evaluation effort and implicit standards exist for all information. Thus, consistent with DOE Order 5700.6C ("Quality Assurance"), all standards should be made public.

At this stage in the evaluation planning process, measuring instruments may not yet exist. A first-cut evaluation plan merely paves the way for the selection or construction of such instruments by specifying the variables to be measured and by suggesting appropriate modes of measurement. The actual development of instruments would come later. As instrument development progresses, however, the evaluation plan should be updated. One way of doing this is to group variables in clusters around potential instruments. Initially, it may only be possible to associate the name of a proposed instrument with each variable that it will measure. Eventually, however, each variable should be matched to one or more specific items on an instrument. The standards will also have to be translated to reflect specific responses to any particular item.

Following the completion of an evaluation design, the next step in the evaluation planning process is to reduce the concepts embodied in each evaluation question to measurable form. This task is perhaps the most demanding of the entire evaluation planning process. It is a necessary prerequisite to the development of measuring instruments and requires a thorough understanding of program operations and objectives. An example of this process is shown in Figure 5-4.

THE EVALUATION WORKPLAN

The last section of the evaluation plan is the *evaluation workplan*. The workplan lays out in some detail how the evaluation will actually be implemented: the measurement instruments to be used, where they will come from, how they will be administered, and how the resulting data will be analyzed and reported. Unlike previous evaluation documents which are organized around evaluation question, the workplan is organized around instruments - both existing and planned. Although instruments do not have to be fully developed to be recognized in a workplan, the relevant evaluation question analysis should be completed. The documentation of an evaluation workplan should be based on evaluation task analyses and planning decisions about the selection, development, and testing of instruments, the collection processing and analysis of data, and the assignment of staff responsibilities and time lines.

An evaluation workplan should contain the following categories of information related to

each instrument to be administered during the evaluation:

- Instrument Status
- Evaluation Questions Addressed
- Administration Schedule
- Administrator (s)
- Respondents
- Sampling Procedure
- Data Analysis Procedure
- Data Analyst(s)
- Date at which report(s) will be available

Each of these information categories is discussed below.

The *instrument status* information indicates the source and availability of the each particular instrument. The following aspects should be treated:

- *Source*: If the instrument is being developed internally, the staff responsible for the work and the dates at which drafts and final copies will be available should be indicated. If the

Evaluation Question: What is the role of exposure to the software?
Concern: Factors involved in software acquisition decision

DIMENSIONS	VARIABLES	STANDARDS
Source of Exposure	Media Brochure/Description Friends Focused Technology Workshop	Technology Transfer Would Be The Most Effective Source
Type of Exposure	Hear Recommendation Read About Software See Demonstration of Software Have Hands-On Experience	Type of Exposure Should Be That Used In The Workshop
Locus of Exposure	Own Machine Someone Else's Machine (Not At Workshop) Machine At Workshop	Type of Exposure Should Be That Used In The Workshop

Figure 5-4. Analysis of an Evaluation Question for an Impact Evaluation Concern

instrument is standardized or available through a professional clearinghouse, the dates of order and anticipated receipt should be noted.

- *Pilot Tests:* The dates and conditions of pilot reliability/validity studies should be noted, particularly for instruments which are under development.
- *Revisions and Adaptations:* The dates of any planned or completed modification efforts should also be noted.

The workplan should give a table or map which cross-references between the *evaluation questions addressed* and the instruments. This will show how the measurement phase will provide answers to the evaluation questions.

The *administration schedule* should be addressed by giving both the dates and any special conditions for administration. Along with this schedule, the staff resources required to administer (Administrators) the instruments should be delineated. In addition, the subject population (*respondents*) should also be carefully identified.

If the instrument is to be administered to a sample, rather than the whole population, the *sampling procedure* should be carefully identified.

The *data analysis procedure(s)* should be identified. For quantitative data, the statistical procedures which will be used should be identified. For non-quantitative data, the analytic methods which will be used in their interpretation should be described as thoroughly as possible. The *data analyst(s)* should be identified in terms of the personnel and hour commitment required.

Finally, a projection of the *dates at which the reports will be available*, should be made to ensure that timely discrepancy information is available for program management decisions.

ASSESSING THE ADEQUACY OF THE PLAN

Like a program design, an evaluation plan should be subjected, either formally or informally, to an adequacy review. Ideally, program staff will have been involved in the evaluation planning tasks, especially in the identification and prioritization of evaluation concerns and questions. Broad-based participation when assessing the adequacy of the evaluation plan is also encouraged, and particularly if the planning process has not previously provided for representative input. Below are listed some criteria which may be used to judge the adequacy of the evaluation plan:

Theoretical Validity

- Is the evaluation plan balanced? Does it meet both formative and summative needs? Does the plan include evaluation questions which are input- and process-related as well as output-related and impact-related?
- Does the evaluation plan have legitimate emphases? Does it focus on program parts of critical functional importance? Does it reflect priority information needs? Are there valid rationales for the concerns and questions chosen?
- Will the evaluation plan produce credible information? Are there methods for assuring reliability and validity? Will projected analytic procedures be appropriate to the data?

Institutional Consistency

- Does the evaluation plan address the information needs of representative internal audiences?
- Does the evaluation plan meet the information needs of all significant external audiences?
- Are evaluation procedures described publicly?

- Are standards for each evaluation question publicly described?

Internal Consistency

- Are evaluation concerns logically related to the program design?
- Are evaluation questions logically related to the evaluation concerns? Are evaluation questions more specific than the evaluation concerns?
- Are sources of information logically related to the evaluation questions?
- Are sources of information accessible? Will the information that is produced be likely to answer each evaluation question to the satisfaction of all audiences?
- Are available resources sufficient to implement the evaluation as planned?
- Are the time lines both realistic and functional? Will discrepancy information be available to the various decision-making audiences at the appropriate time in their program review cycles?

Compatibility with Program Environment

- Does the plan make judicious use of formal and informal program evaluation procedures already in existence?

- Will the measurement procedures be non-disruptive to normal program operation?

- Does the plan make use of talents and resources in the program's immediate environment?

CONCLUSION

A first-cut evaluation design is a very important document. Carefully done, it will serve as the foundation for long lasting program evaluation. Parts of the design will, of course, be subject to modification (recycling) with the passing of time. As the program changes and develops and as more sophisticated measurement techniques emerge, the evaluation should also evolve. However, the evaluation plan should also have components which remain stable in order to provide longitudinal data for time-series studies. Given the importance of the document and the broad strategy it represents, it is a wise idea to supplement the evaluation design with a broad statement of rationale. Such a statement treats the evaluation design as a whole, rather than question-by-question, and specifies the assumptions upon which it is based. This is a place to justify not only the design's emphases, but also its intentional omissions.

APPENDIX A: A WORKED EXAMPLE FROM A HYPOTHETICAL TECHNOLOGY TRANSFER PROGRAM

DOE Order 1332.1.A, Uniform Reporting Systems, requires that all programs (including Technology Transfer) have a program plan, including a Work Breakdown Structure (WBS). The framework presented in this volume incorporates the design requirements within an evaluation methodology. This approach also applies well to private sector or non-federal research and technology transfer efforts that do not fall under the requirements of the DOE orders. The worked example of the hypothetical Technology Transfer program contained in this appendix uses the framework to outline an evaluation.

The paradigm requires six steps for systematic program planning:

- Step 1: Establishment of Goals, Constraints and System Boundaries: Goals and broad constraints are set by careful consideration of the environment. Goals and major objectives are defined as desired changes in the environment. Planning is virtually impossible without thinking through the chain of desired impacts and deciding what tangible outputs can influence this chain of events.
- Step 2: Analysis of Objectives: A chain of logic which subdivides the goals and broad objectives into more concrete objectives, subobjectives, and, ultimately, meaningful work packages. This analysis is ultimately formalized into the work-breakdown structure (WBS) which partitions the overall program into a series of manageable tasks which are hierarchically related to the ultimate goals of the project.
- Step 3: Process Analysis: Starting with the lowest level in the WBS, "processes" are laid out as a series of precedence-related tasks. The definition of processes begins with their expected outputs (products or services) and leads to a statement of the work which is required to yield the outputs. During this analysis, several alternative strategies to accomplish the objective may be considered. The sequence of outputs from lower-level

tasks becomes a chain of milestones, and the work required to yield them enters into the staffing plan. The process analysis is iterative. If the resource analysis (discussed below) shows that the total requirements of a given set of processes do not fit within the constraints, then planners can choose another alternative. The designs are not "cast in cement". If it is not going to work, then the process can be changed.

- Step 4: Resource Analysis: The statement of processes and outputs is the basis for estimating the necessary "inputs", staff, money, material, etc., that are necessary to accomplish the job. Input analysis provides an opportunity for assessing the feasibility of the processes, both in terms of assuring that the total resource requirement fits within the constraints and that the appropriate sequence of outputs from some processes are available as inputs to other processes.
- Step 5: Scheduling: The statement of inputs, processes, and outputs from lower levels in the hierarchy are combined into an integrated schedule which shows the activities of each program element as well as the entire program as a whole. At this point, interactions between processes and critical events are identified and milestone dates can be established. The resource requirements and constraints can be integrated into an overall schedule, budget, and staffing plan.
- Step 6: Evaluation Planning: All evaluation and monitoring activities are then added into the plan. This includes regular fiscal monitoring and staff accountability as well as special questions about the functioning of the processes, the quality of products and subproducts, and, ultimately, their impact on the environment.

The example is presented in the sections that follow.

A.1 GOALS, CONSTRAINTS, AND SYSTEM BOUNDARIES

The first step in program design is the analytical breakdown of the ultimate goal of the program into its component objectives and subobjectives. This exercise continues until the objectives fall within the control of the program (within the system boundary). Figure A-1 illustrates the results of this analytical process.

Figure A-1. Logical Chain of Impacts

A.2 ANALYSIS OF OBJECTIVES

Once inside the program boundary, the chain of logic further subdivides objectives into increasingly manageable components. The process continues until meaningful work packages are discernible. The results of this process are eventually formalized into the Work Breakdown Structure (WBS) (Figure A-2).

A.3 PROCESS ANALYSIS

At the lowest levels of the WBS, processes are laid out a series of precedence-related tasks. As shown in Figure A-2, program managers have several technology transfer options from which to choose. For this example, it is assumed that a focused technology workshop was chosen as the mechanism for transferring the software package. Selection of this mechanism, however, does not preclude using others at the same time. Figure A-3 illustrates the flow of the components of the processes. Note that at each

component management has a control option based on the discrepancy information provided by the stages of evaluation. Figures A-4 through A-7 present the designs for the components of the process.

Figure A-2. Partial Work Breakdown Structure for a Hypothetical Technology Transfer Program

Figure A-3. Hypothetical Technology Transfer Activity Showing Evaluation Stages

Figure A-4. Program Design for the *Develop Prototype* Component

Figure A-5. Program Design for the *Adapt Prototype* Component

Figure A-6. Program Design for the *Execute Process* Component

Figure A-7. Program Design for the *Report to Higher Level* Component

A.4 RESOURCE ANALYSIS

Once the processes have been specified to a sufficient level of detail it is possible to allocate staff and resources. Resource analysis provides an opportunity to assess the feasibility of processes simply by asking, "do we have the resources to do this?" If the answer is "no", then the process may need to be reworked. The results of the resource analysis are presented together with processes, outputs, and impacts in an input-process-output/impact (IPO) table (Table A-1).

Table A-1 Input-Process-Output/Impact Description for the Focused Technology Workshop		
INPUT	PROCESS	OUTPUT/IMPACT
1.1 Receive Software Package from Program Working dialogue between R&D organizations and workshop organizers. Software package which has been tailored to the needs of producers. Workshop organizing staff with knowledge of reservoir formations and producing conditions, operators, and their needs, and the technical proficiency necessary to learn the package.	Verify that software package comes complete with instructions, description, a demonstration disk, and training where necessary.	Workshop organizers are trained to use and teach others to use the package.
1.2 Learn and Review Features and Applications of Software Package Workshop organizing staff. Software package.	Evaluate software package to determine to which operators it best applies, and what needs it best addresses. Evaluate reservoir and producing characteristics featured in package.	Profile of targeted reservoir types, producing conditions, and operators the software package best addresses.

Table A-1 (Continued)
Input-Process-Output/Impact Description
for the Focused Technology Workshop

INPUT	PROCESS	OUTPUT/IMPACT
<p>1.3 Determine Target Audience and Create Contact Lists</p> <p>Profile from 1.2.</p> <p>List of active operators.</p> <p>Workshop organizing staff.</p>	<p>Categorize operators by type, size, and region.</p> <p>Assess the general needs of the operators to see if significant needs are met by the package.</p> <p>Develop a contact list of appropriate operator personnel.</p> <p>Assess level of computer literacy/use to determine if adequate for software package. This information can be acquired through census data or marketed data.</p> <p>Construct list of contacts who are likely to be interested in the software package.</p>	<p>A list of both operators and individual contacts who would be most interested in the package, organized by region, and categorized by type and size.</p>
<p>1.4 Develop a Prototype Workshop Concept and Activity Plan</p> <p>Profile from 1.2.</p> <p>Available budget for workshop.</p> <p>Workshop organizing staff.</p>	<p>Develop workshop tone and style, whether formal, interactive, etc., and select accommodating presentation style.</p> <p>List topics to be discussed in conjunction with/in addition to the software package itself.</p> <p>Assess length of time needed to present materials and need for breaks in between presentations.</p> <p>Compare budget to cost of workshop and make adaptations to workshop.</p> <p>Construct an assessment form to be filled out by workshop attendees and other software package users.</p>	<p>Prototype workshop including duration of workshop, topics covered, discussion time (if any), breaks, etc.</p> <p>Style and tone of workshop and presenters (formal/interactive).</p> <p>Preliminary, but more detailed, workshop budget.</p> <p>General assessment forms.</p>

Table A-1 (Continued)
Input-Process-Output/Impact Description
for the Focused Technology Workshop

INPUT	PROCESS	OUTPUT/IMPACT
<p>1.5 Identify Workshop Notification Options</p> <p>Detailed information on various outreach tactics used in similar workshop or technology transfer operations.</p> <p>Staff experienced in various marketing strategies.</p> <p>Profile from 1.2.</p> <p>Contact list from 1.3.</p> <p>Oil and gas focused publications.</p> <p>Workshop organizing staff.</p>	<p>Assess effectiveness of previously used tactics and develop specific tactics to be used. Tactics should reflect general audience.</p> <p>Prepare presentation and demonstration for use in seminars, meetings, conferences, symposia, trade shows, resource centers, etc.</p> <p>List publications which are candidates to which an ad and/or press release is to be sent.</p> <p>Prepare format of ad and press release. The piece should introduce the workshop and the software package. Workshop details can be filled in after planning is completed.</p>	<p>An overall marketing plan for the software package.</p> <p>A plan of promotional tactics for the workshop.</p> <p>List of organizations and publications which could be contacted about the workshop.</p> <p>Format for ads and/or press releases prepared for distribution.</p> <p>List of potential meetings, conferences, and symposia to participate in and/or where workshop and software package can be advertised.</p>
<p>2.1 Define Region</p> <p>Profile from 1.2.</p> <p>Contact list from 1.3.</p> <p>Workshop organizing staff.</p>	<p>Compare software package profile to characteristics of regions in U.S. Select regions with similar reservoir and producing conditions, operator profile, and operator needs.</p> <p>Evaluate contact list and locate regions with greatest target audience and develop regional contact list.</p> <p>Within a selected region, choose location that is central, convenient to get to, and has necessary accommodations.</p>	<p>Defined region and specific location where workshop will be located.</p> <p>Regional contact list.</p>

Table A-1 (Continued) Input-Process-Output/Impact Description for the Focused Technology Workshop		
INPUT	PROCESS	OUTPUT/IMPACT
2.2 Determine Specific Target Audience Contact list from 2.1. Records of attendees from similar workshops or conferences. Financial statistics of region's operators. Workshop organizing staff.	Review contact list for specific contacts who fit criteria of having needs that are addressed by software package, and if possible, who have a P.C. or access to one. Determine previous operator involvement in similar workshops or conferences. Review operators' ability to both afford the software package and attend the conference. Construct a narrowed down contact list for the region, although region as a whole will be exposed to workshop promotion. Estimate percentage of targeted audience that will attend workshop.	Specific contact list. Approximation of size of audience.

Table A-1 (Continued)
Input-Process-Output/Impact Description
for the Focused Technology Workshop

INPUT	PROCESS	OUTPUT/IMPACT
<p>2.3 Adapt Prototype Workshop Activities to Region</p> <p>Prototype from 1.4.</p> <p>Workshop organizing staff.</p> <p>Schedule of holidays, other conferences, meetings, symposia or notable regional activities.</p>	<p>Adapt topics of discussion, worked examples and areas of focus to specific operator profile and operating conditions.</p> <p>Hire presenters that are suited to needs.</p> <p>Adapt assessment form if necessary.</p> <p>Adapt tone and style if it is not appropriate for region.</p> <p>Adapt preliminary schedule to personality of expected attendees, (Favor long or short lunches, with or without activity, etc.)</p> <p>Choose date that does not conflict with holiday or other occasion.</p> <p>Select exact location with facilities, and reserve space.</p> <p>Finalize budget for workshop.</p>	<p>Schedule of events for workshop including specific items and activities.</p> <p>Final assessment form.</p> <p>Final budget.</p> <p>Workshop date and exact location.</p>
<p>2.4 Compare and Select Promotion Options</p> <p>List of organizations and publications from 1.5.</p> <p>List of meetings, conferences, and symposia from 1.5.</p> <p>Workshop organizing staff.</p>	<p>Evaluate distribution, subscriber profiles, and cost of ad for publication in region to determine which ones to advertize in or submit press releases to.</p> <p>Examine content of and audience for meetings, conferences and symposia in region to determine which ones to participate or advertise in.</p>	<p>List of publications, organizations and meetings to promote workshop in.</p>

Table A-1 (Continued)
Input-Process-Output/Impact Description
for the Focused Technology Workshop

INPUT	PROCESS	OUTPUT/IMPACT
<p>3.1 Advertise/Promote Workshop</p> <p>Format for ad, press releases, and presentation from 1.5.</p> <p>Contact list from 2.2.</p> <p>List from 2.4.</p> <p>Workshop organizing staff.</p>	<p>Finalize ads, press releases, and presentations with location, date, time, and final details of workshop, specific to region.</p> <p>Decide which organizations and publications receive press releases and which receive ads.</p> <p>Send organizations and publications appropriate piece on software package and workshop.</p> <p>Contact organizers of conferences, symposia and meetings to arrange for exposure to and presentation of package.</p> <p>Attend selected meetings to advertize workshop and package.</p> <p>Notify contacts about workshop through personal letters.</p>	<p>Wide media exposure.</p> <p>Operators, producers and other potential software package users are exposed to software package and have received information on the workshop.</p>
<p>3.2 Identify Resources Necessary for Workshop</p> <p>Estimate of audience size from 2.2.</p> <p>Schedule from 2.3.</p> <p>Budget from 2.3.</p> <p>Workshop organizing staff.</p>	<p>Estimate the number or amount of staff and materials needed for the workshop audience. These include presenters and hosts, software packages, demo packages, notebooks/user materials, attendee assessment forms, on-site marketing materials, PC's for hands-on use, electrical and audio-visual materials, and presentation materials such as problem sets, case studies or worked examples, slides and handouts.</p> <p>Estimate resources needed to train presenters.</p> <p>Identify catering needs.</p>	<p>Detailed list of exactly what is needed for workshop.</p> <p>Catering needs.</p>

Table A-1 (Continued)
Input-Process-Output/Impact Description
for the Focused Technology Workshop

INPUT	PROCESS	OUTPUT/IMPACT
<p>3.3 Arrange Logistics</p> <p>Logistical needs identified in 3.2.</p> <p>Workshop staff.</p>	<p>Specify use of space and seating style in chosen location, taking into consideration size, electrical equipment, and facilities.</p> <p>Hire and schedule hosts.</p> <p>Train presenters.</p> <p>Hire caterer.</p> <p>Contact travel and lodging facilities if arrangements are to be made for staff and/or attendees.</p>	<p>Logistics worked out.</p>
<p>3.4 Prepare Workshop Materials</p> <p>List of materials needed from 3.2.</p> <p>Workshop staff.</p>	<p>Contact suppliers of various materials and arrange for pick up or delivery of materials.</p> <p>Form "check list" of needed materials and keep track of which ones are received.</p> <p>Arrange backup options for essential materials.</p>	<p>All workshop materials.</p>

Table A-1 (Continued)
Input-Process-Output/Impact Description
for the Focused Technology Workshop

INPUT	PROCESS	OUTPUT/IMPACT
3.5 Conduct Workshop All workshop inputs.: - Staff (presenters, hosts) - Caterers/food - Software packages - Demo packages - Notebooks/user materials - Attendee assessment forms - On-site marketing materials - PC's for hands-on use - Electrical and audio-visual materials - Presentation materials (problem sets, case studies or worked examples, slides and handouts)	Organize and distribute materials. Conduct workshop: - Greeting - Introduction of problem - Introduction of product - Where product is used in operation and its benefits. - Worked example 1 - Discussion - Worked example 2 - Discussion - Worked example 3 - Discussion - Conclusions/summation as to usefulness and cost effectiveness - Attendee assessment of workshop and product	Impact: Exposure to and knowledge of software package. Transfer of technology to producers. Workshop format trial. Output: Assessment forms.
3.6 Prepare and Distribute Workshop Report Presenters and staff who attended or worked at workshop. List of attendees. Workshop organization staff.	Have personnel prepare written assessment of workshop. Have experts prepare summary of their presentations. Prepare profile of attendees. Have discussion leaders record summaries and results from discussions. Prepare general summary and results of workshop incorporating all above summaries and assessments.	Synthesized summary of the results of the workshop.

Table A-1 (Continued)
Input-Process-Output/Impact Description
for the Focused Technology Workshop

INPUT	PROCESS	OUTPUT/IMPACT
<p>3.7 Distribute to Attendees</p> <p>List of attendees.</p> <p>Summary of workshop results from 3.6.</p>	<p>Distribute workshop results to attendees.</p>	<p>Impact:</p> <p>Exposure to and knowledge of software package.</p> <p>Transfer of technology to producers.</p>
<p>4.1 Assimilate and Analyze Evaluation Information</p> <p>Assessment forms from attendees from 3.2.</p> <p>Assessment forms from presenters and staff.</p> <p>Staff qualified to synthesize assessment results into a summary document.</p> <p>Workshop organizing staff.</p>	<p>Gather and synthesize all assessment forms into a summary document.</p> <p>Conduct interviews with attendees where more information is needed.</p> <p>Examine and address areas for improvement. Problems are either resolved by staff, will be improved upon in later workshops, or will be addressed by researchers and/or software package developers.</p>	<p>Summary document prepared from assessment forms and containing a section addressing problems and highlighting successes.</p>
<p>4.2 Distribute to Technology Transfer Program Managers and Planners</p> <p>List of technology transfer program managers and planners.</p> <p>Summary document from 4.1.</p>	<p>Distribute summary assessment results to the Technology Transfer program management.</p>	<p>Impact:</p> <p>Technology Transfer program management receives information for input into replanning future efforts.</p>
<p>4.3 Distribute Summary Assessment to R&D Program Managers and Planners</p> <p>List of Oil R&D program managers and planners.</p> <p>Summary document from 4.1.</p>	<p>Distribute summary assessment results to the oil R&D program management.</p>	<p>Impact:</p> <p>Oil R&D program management receives information for redesigning the software and for planning future R&D efforts.</p>

A.5 SCHEDULING

The statement of inputs, processes, outputs, and impacts from lower levels of the WBS hierarchy can be combined into an integrated schedule. At this level, interactions between processes and critical events are identified and milestone dates can be established. Since only one worked example is presented here, no integrated schedule is shown. For this hypothetical Technology Transfer program, the integrated schedule would include data from any alternative technology transfer mechanism implemented in addition to the focused technology workshop.

A.6 EVALUATION PLANNING

Finally, evaluation and monitoring activities are added to the program design. Evaluation concerns and the associated evaluation questions are presented below. The evaluation questions associated with impact evaluation concerns are further analyzed, and an evaluation design table has been prepared for those questions.

Table A-2
Evaluation Concerns and Questions

Design Evaluation Concern #1:
Is the prototype workshop likely to succeed?

(1) Evaluation Question	Does the prototype use techniques known to convince people to acquire useful software?
(2) Evaluation Question	Is the prototype design complete? Does it cover all aspects of the workshop?
(3) Evaluation Question	Is the prototype design appropriate to the population of oil operators and producers?
(4) Evaluation Question	Is the prototype design cost effective? (Will it consume more resources than available? Is it cheaper than one-on-one contacts?)
(5) Evaluation Question	Is the prototype sufficiently flexible to be adapted to specific markets? (Does the form and content of the workshop impose undue constraints on staff or facilities? Does form and content limit the type of participant?)
(6) Evaluation Question	What assumptions are made in the prototype about staff, participants, facilities, curriculum, and/or materials? Are they realistic?
(7) Evaluation Question	What are the important, measurable characteristics of the target population that are necessary/useful in planning workshops?

Table A-3 Evaluation Concerns and Questions	
Design Evaluation Concern #2: How should the prototype workshop be targeted toward a specific audience?	
(1) Evaluation Question	Is there evidence or expert judgement to indicate that the target audience is materially different from the audience assumed in the prototype? Is the software relevant to this group?
(2) Evaluation Question	How does the target audience differ from the audience assumptions used in developing the prototype? If "yes", does the difference impact staff, participants, facilities, curriculum, and/or materials?
(3) Evaluation Question	Can the workshops be adapted/redesigned to fit within the constraints of the specific target population while also remaining consistent with the program goals? ...and stay within reasonable cost boundaries?
(4) Evaluation Question	Is the adapted workshop likely to succeed? (See analysis of Concern #1)

**Table A-4
Evaluation Concerns and Questions**

**Evaluation Concern #3:
Was the workshop effective as delivered?**

Input Evaluation Concern #3A: Were the workshop inputs consistent with the design?	
(1) Evaluation Question	How many people got the mailing? Accepted the invitation? Showed up?
(2) Evaluation Question	How many of those who showed up fit the design profile (type of reservoir, computer equipment, etc.)?
(3) Evaluation Question	Were facilities available and suitable at time(s) required? Materials? Presenter?
Process Evaluation Concern #3B: Were the workshop activities consistent with the design?	
(1) Evaluation Question	Were all topics required by the design actually covered in the session? What was left out? Was anything substituted?
(2) Evaluation Question	Did the participants appear to have "interest" in all aspects of the workshop?
(3) Evaluation Question	Did the staff perform their duties consistent with the design? If not, why did they depart from the plan?
Output Evaluation Concern #3C: Was the service (i.e., workshop) delivered to the participants?	
(1) Evaluation Question	How many (what percentage) of participants stayed for the entire session? Did any miss parts of the session?
(2) Evaluation Question	How many (what percentage) of participants appeared to be paying attention during each part of the session?

Table A-5 Evaluation Concerns and Questions	
Impact Evaluation Concern #4: What influences the operator to acquire the software?	
(1) Evaluation Question	What is the perceived level of benefit that the operator expects as a result of acquiring the software? Was it acquired with a specific use in mind or for some general reason (e.g., intellectual curiosity)? Did the nature of the software suggest a use, or did a need cause a search for the software?
(2) Evaluation Question	How did the operator find out about the software (i.e., the workshop, technical article, word-of-mouth, other means)? What level of exposure did the operator receive (brochure, demonstration, hands-on experience and training, etc.)?
(3) Evaluation Question	What was the deciding factor, or "clincher", in the decision to acquire the software?
(4) Evaluation Question	What was the role of computer specifications (memory/time/hardware) in the decision to acquire the software?

Table A-6
Evaluation Question Analysis for Concern #4

Impact Evaluation Concern #4:
What influences an individual to acquire the software?

DIMENSION	VARIABLES	STANDARD
(1) Evaluation Question: What is the role of benefits?		
Perceived benefits	<ul style="list-style-type: none"> • Practical application available • Intellectual satisfaction • Keeping up-to-date 	Mission indicates that user should buy software for a practical use
Achieved benefits	<ul style="list-style-type: none"> • In wells owned by others • In own operation 	Seeing benefits directly correlated with attitude toward software
(2) Evaluation Question: What is the role of exposure to the software?		
Source of exposure	<ul style="list-style-type: none"> • Media • Brochure/Description • Friends • Technology transfer workshop 	Technology transfer workshop would be most effective source
Type of exposure	<ul style="list-style-type: none"> • Hear recommendation • Read about software • See demonstration of software • Have hands-on experience 	Type of exposure should correspond to that used in the workshop
Locus of exposure	<ul style="list-style-type: none"> • Own machine • Someone else's machine (not at workshop) • Machine at workshop 	Type of exposure should correspond to that used in the workshop
(3) Evaluation Question: What was the "clincher" in decision?		
Factor	<ul style="list-style-type: none"> • Cost • Benefits • Exposure 	Workshop design assumes exposure most important, benefits second, cost third
Time	<ul style="list-style-type: none"> • Time after initial exposure needed to make decision 	No standard -- but this information is needed to plan the follow-ups from the workshop
(4) Evaluation Question: Role of computer specifications?		
Computer requirements of software	<ul style="list-style-type: none"> • Memory requirements • User friendly/need expertise • Hardware requirement 	Minimal computer requirements (i.e., small memory needs, user-friendly system)
Computing capabilities of potential user	<ul style="list-style-type: none"> • Computer equipment • Memory/hardware capabilities • Technical skill (computer know-how) 	Computer literate, personal computer owners

Table A-7

An Evaluation Design for Impact Evaluation Concerns and Questions

Evaluation Concern	Evaluation Question	Design Referent	Information Need	Source of Information	Date Needed
Factors Involved in Software Acquisition by Operators	What is the perceived level of benefit that the operator expects as a result of acquiring the software? Was it acquired with a specific use in mind? Did the nature of the software suggest a use, or did a need cause a search for the software?	Applies to effort as a whole.	The role of benefits provides some proof of causality between the workshop and acquisition. If a need caused the user to seek the software, the presentation at a workshop would have little to do with acquisition. On the other hand, if the presentation suggests the use, then the workshop was very effective.	The operators who acquire the software will be the source of information. The evaluation form from the workshop should elicit some of this information. Phone follow-up by staff with software users will also be necessary.	Data should be gathered as soon as possible after the workshop. There will be lag time, however, to allow the operator to use the software before follow-up is conducted.
	How did the operator find out about the software? What level of exposure to the software did the operator receive?	Applies to effort as a whole.	Planners need to know the source of information on the software because if the focused technology workshop is not a strong factor, then the transfer strategy may need to be reworked or rethought. Knowing the type of exposure and where it took place could also be important in replanning the next round of focused technology workshops.	The information will come from warranty cards, received when acquiring the software, which must be returned in order to receive a warranty and future upgrades. Phone follow-up with users three to six months after acquisition will also provide information.	N/A As information is received, however, any necessary adjustments to strategy and workshop planning should be made.

Table A-7 (Continued)
An Evaluation Design for Impact Evaluation Concerns and Questions

Evaluation Concern	Evaluation Question	Design Referent	Information Need	Source of Information	Date Needed
	What was the deciding factor, the "clincher", in the decision to acquire the software?	3.5 3.6	Information on the deciding factor (i.e., exposure, benefits, cost) provides essential input into the appropriateness of the strategy. If the deciding factor had little to do with the exposure, the strategy may need to be replanned. Data on how long after exposure it takes the operator to acquire the software will help plan follow-up efforts.	Information will come from warranty cards and follow-up with users conducted by staff.	N/A It should be done in enough time to make the answers meaningful to future planning efforts.
	What was the role of computer specifications (i.e., memory, time, hardware) in the decision to acquire the software?	Applies to effort as a whole.	Prohibitive computer requirements could keep potential users from acquiring the software. If this is the case, low level of software acquisition by operators provides little information regarding the effectiveness of the transfer effort.	Interviews with a random sample of mailing targets who did not attend the workshop and of attendees who did not acquire the software will provide the information. Examination of computer requirements will provide context.	Before the next planned workshop.

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