Recommended Methods for Evaluating the Benefits of ECUT Program Outputs

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March 1986

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RECOMMENDED METHODS FOR EVALUATING
THE BENEFITS OF ECUT PROGRAM OUTPUTS

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FOREWORD

The Energy Conversion and Utilization Technologies (ECUT) Program of the U.S. Department of Energy (DOE) conducts research to increase energy conversion efficiency and to enhance the capability to use alternative, non-critical fuels. ECUT's activities ensure that a scientific and technical knowledge base is available for industrial, transportation, utility, and residential/commercial energy users, thereby supporting the U.S. commitment to advancing energy technologies. This sustained commitment is necessary if the U.S. is to continue to lead the world in technological innovation and industrial productivity.

To fulfill these objectives, ECUT positions itself at the leading edge of technology, monitors the results of basic research, and focuses this basic knowledge on problem areas that prevent using these research results in actual applications. ECUT fills the gap between basic science and engineering applications through applied research and exploratory development.

Since the beginning of the ECUT Program the performance of individual research outputs has been reviewed each year. However, the broader benefits of ECUT program outputs, such as research results, models, software, etcetera, have not been evaluated. The purpose of this study therefore is to identify and/or develop the most appropriate methods for measuring the benefits that result from ECUT-sponsored R&D.

EXECUTIVE SUMMARY

The research conducted for the Energy Conversion and Utilization Technologies (ECUT) Program in the U.S. Department of Energy (DOE) results in a variety of beneficial effects, including increased technical knowledge, stimulation of industrial research, encouragement of innovative concepts. As part of the Pacific Northwest Laboratory (PNL) Systems Analysis Project, the research described in this report was conducted to explore the feasibility of measuring these beneficial effects.

OBJECTIVE

This study was conducted to define and develop techniques that could be used to assess the complete spectrum of positive effects resulting from ECUT Program activities. These techniques could then be applied to measure the benefits from past ECUT outputs. In addition, the impact of future ECUT outputs could be assessed as part of an ongoing monitoring process, after sufficient time has elapsed to allow their impacts to develop.

APPROACH

Developing the approach for evaluating ECUT benefits involved several steps. First, literature on R&D benefit evaluation, scientific communication and technical information transfer was reviewed. From this review, an evaluation strategy was developed based on the concept of measuring program output impact. Techniques for implementing this strategy were proposed. Then selected ECUT program outputs were used as case studies to assess the feasibility of using some of these techniques. Based on these case studies, modifications and limitations of the proposed techniques were discussed, and recommendations for implementing an ECUT benefit evaluation were developed.

FINDINGS

The results of this process are described below.

Literature Review

The literature review revealed several issues that should be addressed when evaluating the benefits of ECUT program outputs. These issues are listed below:

- There is frequently a long gestation period between research outputs and technological innovations.
- The utilization of scientific and technical information is a non-linear, complex process, which makes it difficult to evaluate the relative importance of different sources of information.
- Measuring economic benefits, either direct or indirect (i.e., spin-offs), requires detailed economic information on a case-by-case basis.
- Bibliometric methods measure the impact of a particular research output at a specific point in time; this impact is a function of quality level, relevance to current needs, and success of information transfer.

Case Studies

A major goal of this project was to determine whether cost-effective techniques could identify a significant share of the "ultimate" users of ECUT-sponsored research outputs so that these users could be contacted and surveyed concerning research utilization.

To achieve this objective, three case studies were conducted on particular research outputs in combustion engine, materials, and tribology research. The major insights resulting from these case studies are summarized below:

- Technical reports are not likely to be referenced in the refereed literature. Thus, indications of utilization of technical reports are limited to requests for copies (to NTIS, authors, and ECUT) and distribution lists.

- Requests for documents can be identified through NTIS. Request information from professional societies is more limited. However, information on the ultimate users of these documents is difficult to obtain from either source.
- Researchers themselves perform a great deal of information transfer by responding to requests for reprints, software, samples, etc. However, they generally are unable to provide detailed information on the requests received.
- Clear evidence of research impact (in the form of reprint requests, NTIS orders, citations to articles, etc.) usually can be found after two years.

CONCLUSIONS

Benefits evaluation should stress identifying specific users of ECUT-funded research through reprint requests, references to articles, etc, because bibliometric indicators (e.g., number of articles, citations, requests for documents/reprints) alone do not adequately measure the benefits of a program as diverse as ECUT. A meaningful evaluation of the benefits can be made through combining bibliometric techniques with knowledge gained from interviewing users of ECUT outputs.

User-specific information from public and quasi-public sources (e.g., NTIS, Science Citation Index,^(a) professional societies and journals) is limited and will not by itself provide a cost-effective mechanism for identifying ECUT beneficiaries. As an alternative, greater emphasis should be placed on utilizing requests made directly to the researchers. Based on the results from this project, ECUT-funded researchers probably would find providing information on past requests burdensome since it is unlikely that they have complete and organized records of such inquiries. Therefore, to permit cost-effective

(a) Science Citation Index is a registered trademark of the Institute for Scientific Information.

surveying of future users of ECUT research output, a reporting system should be implemented that would allow the researcher who received the request to notify ECUT.

This study indicates that no single comprehensive technique exists for measuring ECUT benefits. Because of the generic applied nature of ECUT funded research, simply using economic payback criteria (which are used to measure applied research) or pure bibliometric techniques (used to assess basic research) would be inappropriate. At best, measuring ECUT benefits will consist of painting in portions of an evolving canvas of research impact. The ability to follow and document the "trail" of utilization will vary substantially. Thus bibliometric comparisons (e.g., based on number of reprints, citations) of research impact, either over time or among research topics, should not be attempted unless supplemented with information gained through surveys of ECUT output users and analyses of referencing articles. For example, it would be a mistake to use only bibliometric techniques to answer the question: "Is research performed two years ago having more or less benefit than research performed four years ago?"

However, even incomplete understanding can be useful. Analyzing the benefits of ECUT-funded research can give greater insight into the mechanisms of successful research transfer and utilization and thus improve program effectiveness. Because only a minority of the outputs (probably 20%) are likely to be "big winners", identifying the sectors of the economy affected by these selected outputs can give insight into a significant portion of total ECUT program benefits.

RECOMMENDATIONS

The recommendations resulting from this study can be summarized as follows:

1. A standardized reporting system should be instituted that ECUT-funded researchers could use to record requests for specific article reprints, conference papers, software, samples, etc., so that future users of ECUT outputs could be more easily identified.

2. A data-base management system to inventory past and future ECUT research outputs and impacts should be developed. Such a system could be developed using existing software and a microcomputer.
3. Citation information on ECUT publications should be gathered from the Scientific Citation Index to aid in identifying research utilization.
4. A sample of identified users of ECUT publications should be surveyed, both to test the survey instrument and to estimate the survey response rate.
5. An actual benefit evaluation should be delayed until adequate user information is available to combine with bibliometric indicators to permit a balanced evaluation.

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1.0 INTRODUCTION

The results of research conducted for the Energy Conversion and Utilization Technologies (ECUT) Program in the U.S. Department of Energy (DOE) provide a variety of beneficial effects, including increased technical knowledge, stimulation of industrial research, fostering of innovative concepts, and spin-off development of new businesses.

Historically, DOE's conservation efforts have been assessed in terms of energy savings. However, while barrels of oil saved is an appealing indicator of ECUT's benefits, three factors make it difficult to measure ECUT benefits in these terms. First, because much of ECUT's work occurs at the very beginning of the development process, measures of energy saved are almost always projections of future savings rather than actual savings. Such estimates must be based on a number of uncertain assumptions, e.g., future energy prices, technology substitution rates, comparative cost. Second, technologies will almost inevitably require R&D beyond the ECUT-sponsored effort (public, private sector, or both) before commercialization. In instances where a commercialized product traceable to ECUT can be identified, the issue of ECUT's relative share of credit remains. Third, because some of ECUT's outputs result in productivity increases and other benefits, it is difficult to convert these benefits back to oil saved.

For these reasons, measuring the benefits of ECUT efforts should focus on the impact of specific ECUT program outputs. "Impact" of a program output here refers to its actual influence on surrounding R&D activities at a given time (Martin and Irvine 1983). These indicators should be based primarily on ECUT's defined program goals:

- Expand the technology base available to the private sector for development of improved energy systems and devices; and
- Evaluate new or innovative concepts for improved efficiency or alternative fuel use in energy systems or utilizing devices.

Indicators of the benefits of ECUT's outputs should primarily reflect impacts that address these goals. In short, indicators are proxies used to evaluate how ECUT is achieving its objectives.

1.1 OBJECTIVE

Conducted by Pacific Northwest Laboratory (PNL),^(a) this work is intended to define and develop techniques to assess the complete spectrum of positive effects resulting from ECUT Program activities. The work is designed to produce an inventory of past ECUT outputs, a series of impact measurement techniques, and a set of recommendations for using and interpreting these techniques for specific types of ECUT outputs and research utilization mechanisms. These techniques could then be applied retrospectively to past ECUT outputs. In addition, the impact of future ECUT outputs could be assessed as part of an ongoing monitoring process, after sufficient time has elapsed after their production to permit the identification of impacts.

1.2 RELATION TO RATE PROJECT APPRAISAL

This work is intended to complement the project appraisal analysis provided by PNL's Research Application/Technology Evaluation (RATE) process. The objective of RATE is to evaluate the quality of both current research being funded by ECUT and proposed research, and assess its relevance to both private sector needs and energy savings opportunities. Therefore, RATE's focus is inherently oriented toward the present and future. Information from the RATE process can thus be utilized for near-term program planning and project selection.

In contrast, the techniques to evaluate the benefits of ECUT outputs outlined in this report are retrospectively oriented: past outputs are examined and their utilization is tracked and assessed. The insights gained from analyzing benefits of past outputs can serve to document ECUT impact and to provide a better understanding of effective technology transfer mechanisms.

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1.3 APPROACH TO THE PROJECT

Evaluating the benefits of R&D expenditures is not an easy task. It is particularly difficult for ECUT because of the generic applied nature of the research and the types of functions ECUT provides. In order to develop techniques appropriate to ECUT, an extensive literature search was performed to identify prior research in benefit estimation. The relevance of this literature was assessed in terms of the outputs listed in ECUT program documents (DOE 1983, DOE 1984, Witze 1981) and the comments of ECUT program managers. Techniques with potential utility to ECUT were then identified and three case studies were selected to represent the wide range of ECUT research efforts. Software requirements for implementing a comprehensive analysis of ECUT program impacts were examined. Based on this research, recommendations for utilizing the impact measurement techniques were developed.

1.4 OVERVIEW

Section 2 contains a review of literature that addresses measuring the benefits of R&D. Section 3 describes a suggested approach for developing techniques which can be used to identify and measure the impact of ECUT Program outputs. Section 4 presents a preliminary analysis of ECUT research output transfer. Section 5 presents three case studies that apply some of these techniques to selected ECUT outputs. Section 6 presents the study conclusions and recommendations. Appendix A provides an inventory of ECUT outputs, and Appendix B provides a software specification document.

2.0 METHODS FOR MEASURING R&D BENEFITS--LITERATURE REVIEW

Interest in measuring the impact and effectiveness of R&D is not new, and has encompassed several different constituencies and needs. This interest has generated several basic approaches which address related, but often distinct, issues. Many of the differences among these approaches are apparent in the focus of the study: the specific innovation or project, specific scientist or engineer, particular firm or research facility, industrial sector, or even nation. Other differences concern methodologies. The literature describing these different approaches was reviewed to find previous work that might apply to ECUT's situation. Literature representing approaches relevant to evaluating ECUT program outputs is discussed below. The section concludes by summarizing the implications of key findings from these studies for measuring ECUT benefits.

2.1 SOURCES OF SUCCESSFUL INNOVATION--RETROSPECTIVE STUDIES

Retrospective analysis of the sources of successful innovations has potential relevance to the measurement of ECUT benefits. Four of the more significant studies of retrospective analysis are discussed below.

To assess the contribution of basic research, the Department of Defense study HINDSIGHT (DOD 1969) examined research discoveries or breakthroughs that led to the successful development of twenty specific weapons systems. These research events were categorized as either Science or Technology events. Of 710 research events examined, 91% were categorized as Technology events and 9% as Science events; most of the latter consisted of "directed," as opposed to "non-directed," scientific research. This could be interpreted as indicating that basic research had very little impact on the technology development exemplified by these weapons systems. However, this study imposed an arbitrary cutoff point of 20 years in tracing research events. The study stated:

"... less than 16% of the technologically oriented R&D events were traced to a post-1935 science base. The other 84% came directly from the application of nineteenth-century unified theory, were the results of empirical research, or appeared as invention not needing scientific explanation."

While not directly relevant to ECUT, this study clearly demonstrates the sensitivity of retrospective studies of technological developments to the time horizon selected. This sensitivity is also demonstrated by two similar studies commissioned by the National Science Foundation (NSF) that used a longer time frame to establish the antecedents of particular innovations: TRACES (Technology in Retrospective and Critical Events in Science) (IIT 1968) and a Battelle Columbus Laboratories (BCL) study, Interactions of Science and Technology in the Innovative Process (8MI 1973). Both studies categorized research events as either non-mission oriented, mission oriented or development. "Non-mission oriented" roughly corresponds to the non-directed scientific research mentioned above, "mission oriented" to directed scientific research, and "development" to technology events. The TRACES study found that a much higher proportion (70%) of research events were non-mission oriented than did HINDSIGHT. Furthermore, 80% of the non-mission research was completed 15 years prior to the innovation and 45% at least 30 years prior. The BCL study sampled a larger number of innovations than TRACES and had somewhat different findings. Non-mission oriented research was responsible for 34% of the significant events, mission oriented research for 38%, and development for 26%.

Another retrospective study, which used a somewhat different approach, was an analysis of thirty successful innovations reported in Gibbons and Johnston (1974) and Johnston and Gibbons (1975). The study examined the origins and characteristics of information inputs utilized in solving technical problems. The study found that scientific information made an important contribution to the innovations. More important, from ECUT's perspective, the authors concluded that interactions between basic and applied research, and between internal and external sources of information, are very complex, making policy criteria for public research support difficult to identify. In addition, they found that basic research infrastructure in universities and government laboratories contributes to commercial innovation in ways beyond simply providing firms with exploitable discoveries.

2.2 SCIENTIFIC AND TECHNICAL INFORMATION UTILIZATION

Studies of the information utilization patterns of scientists and engineers represent another research approach relevant to ECUT. Studies in this area are distinguished by a focus on the activity patterns of individual researchers and engineers (Rosenbloom and Wolek 1970) rather than the sources of particular inventions or innovations. Many of the findings in this field are discussed in Allen (1977).

A key finding for measuring the impact of ECUT outputs is that scientists and engineers have very different patterns of information utilization. Specifically, most engineers rely on a limited number of personal contacts within their companies for technical information. The average engineer reads very few refereed journals, instead utilizing trade journals and contacts within his or her firm to satisfy most information needs. However, Allen found that a small number of individuals within R&D organizations do maintain significant outside contacts and read more extensively. These "gatekeepers" often know one another and form a network for transferring information within their companies. The implication of these findings is that a program to track the impact of a particular ECUT output should take into account the type of document in which the technical information is conveyed and the desirability of identifying the "ultimate" user of the information.

2.3 VALUE OF FEDERAL R&D--ECONOMIC ANALYSIS

Economic analysis of the benefits resulting from federal R&D expenditures is a third research approach relevant to ECUT. According to Link (1982), very little is known about the effects of federal R&D spending, especially on the industrial sector--the largest single recipient of federal support. Economic analyses by Griliches (1973 and 1980), Link (1981), and Terleckyj (1974 and 1980) found that the direct return to federally-financed R&D on measured productivity growth is much less than for privately-financed R&D. However, Griliches (1964) found federal return on investment in agriculture to be quite substantial, greater than 300%. Link (1982) suggests that federal expenditures may indirectly affect productivity by changing the returns to private R&D. Specifically, he provides some empirical evidence that federal funding lowers

the marginal cost of private R&D, thus encouraging additional private R&D investment. This view is supported by Mansfield and Switzer (1984) in a study of the effect of federal support on company-financed, energy-related R&D. They found that, in about one-third of the projects studied, federally-financed R&D projects led to further R&D, for which the firm invested its own funds.

Russell and Vroman (1981) studied some of the methodological issues involved in measuring the economic benefits of nonmedical applications (spin-offs) of biomedical research. Specifically, benefits of new innovations consist of the extra satisfaction gained by consumers (consumers' surplus) from the new product, product improvement, or reduction in price resulting from the invention, and the "economic rents" received by the producers of the innovation. Particularly relevant to ECUT is their finding that all methods for estimating economic benefits require a case study approach, i.e., that each innovation should be studied separately and in detail.

2.4 CORPORATE POST-PROJECT R&D EVALUATION

Another research approach evaluated for possible relevance to ECUT involves the post-project evaluations utilized by corporate R&D managers to improve research effectiveness. Collier and Gee (1973) suggested that R&D should be evaluated in terms of the amount of business opportunity created, where opportunity is defined as the size of the market for which the product is both technically and economically adequate. Porter (1978) found that, on average, estimates of the potential value of corporate research at Mobil Research & Development Corporation agreed with actual values realized. However, he also found a bias toward underestimating large values and overestimating small values. Mobil found that over time the value of completed research exceeds research cost several times, with wide fluctuations from year to year. Patterson (1983), using a somewhat different measurement technique, found similar yearly fluctuations, in part because 80% of the economic benefits came from only 20% of the reported accomplishments.

These methodologies are not directly relevant to ECUT because they address near-term applied corporate research. Estimating payoffs in these instances is much easier than estimating the benefits of ECUT-sponsored research. However,

two findings relevant for ECUT do emerge from these studies. First, benefits resulting from applied research are partly stochastic, with wide variation in payoffs from particular research projects. Second, research with potentially large benefits may be underestimated when first completed.

2.5 EVALUATIVE BIBLIOMETRICS

A large body of research has evolved in the last 15 years to understand scientific progress and identify research specialties by examining scientific publications (Narin 1976). This research approach, evaluative bibliometrics, is the fifth research tradition examined for ECUT. In this approach, the number of publications produced (by an individual, department, or even nation) is taken as a measure of the amount of scientific output produced. References among scientific publications play a key role in this type of analysis. References are used to define the network of researchers working in a particular specialty. In addition, the number of citations^(a) received by specific articles is used as a measure of their "quality" or importance.

It is important to note that this type of analysis became cost-effective with the establishment of the Science Citation Index, a data base which enables the relatively easy identification of reference networks among publications and the counting of citations received. While quite extensive in terms of the number of journals, the Index tends to favor journals that report on basic research. More significantly for ECUT, it does not include DOE or NTIS published documents.

Bibliometric techniques are subject to several criticisms, well summarized by Martin and Irvine (1983). There are two basic difficulties. First, not all publications are of equal significance, so measuring the number of articles produced may give a misleading impression of the amount of scientific progress. Second, the number of citations received varies with research specialty and type of journal in which an article appears. Furthermore, the context of the citation is not revealed (Chubin and Moitra 1975), so interpretation of article

(a) The convention is adopted that a later document references an earlier document and an earlier document receives citations from later documents (Price 1970).

quality, based on citations received, is problematic. For example, a widely cited article may contain incorrect information but may have stimulated several additional articles which refuted its findings. Despite these limitations, "publish or perish" is still a reality for university researchers and thus research will continue to generate publications. In addition, NSF has used citation analysis to assess funding of chemistry departments and it has been utilized in promotion and tenure decisions (Wade 1975).

A more recent area of research analyzes technology through patents (Campbell and Nieves 1979, Campbell and Levine 1984, Narin, et al. 1984). Much of the methodology, and therefore many of the methodological criticisms concerning bibliometrics, is very similar. For example, the rate of patenting per R&D dollar spent has been shown to vary considerably among industries, in that industries with high levels of government-funded R&D tend to produce fewer patents per R&D dollar (Scherer 1983). Furthermore, not all highly cited patents are commercially important. However, Carpenter, et al. (1981) found that inventions associated with winners of the Industrial Research and Development Magazine's annual awards for outstanding innovations do tend to receive more citations than randomly selected patents.

Martin and Irvine (1983) make important conceptual distinctions which help overcome some of the past criticisms of evaluative bibliometrics. They distinguish between the quality, importance, and impact of publications, stating:

" 'Quality' is a property of the publication and the research described in it. It describes how well the research has been done, whether it is free from obvious error, how aesthetically pleasing the mathematical formulations are, how original the conclusions are, and so on. But quality is still relative rather than absolute . . . it is not intrinsic to the research, but is something judged by others who, with differing research interests and social and political goals, may not place the same estimates on the quality of a given paper

The 'importance' of a publication refers to its potential influence on surrounding research activities - that is, the influence on the advance of scientific knowledge it would have if there were perfect

communication in science However, there are 'imperfections' in the scientific communications system, the result of which is that the importance of a paper may not be identical with its impact.

The 'impact' of a publication describes its actual influence on surrounding research activities at a given time. While this will depend partly on its importance, it may be affected by such factors as the location of the author, and the prestige, language, and availability of the publishing journal"

Importance is a function both of the research described in a particular publication and of the specialty involved. Science is filled with examples of research that was "before its time;" Barbara McClintock's (Lewin 1983) Nobel Prize winning work on corn genetics is one recent example. In technology, a particular invention may remain uncommercialized for years until a change in factor prices (e.g., energy costs) or a national emergency (e.g., embargo on natural rubber) makes it more attractive (Rosenberg 1976).

Martin and Irvine (1983) maintain that evaluative bibliometric techniques measure research impact, not quality or importance, and as long as that distinction is understood most of the criticisms of this approach are moot. Impact can be measured, but only for a given point in time, because the quality and importance of a particular scientific article (or invention) can vary over time.

This conceptual scheme, although developed to assess basic research progress, is very relevant to measuring the impact of ECUT outputs, particularly written outputs (reports, articles, software). The impact of a particular ECUT output is a function of its quality, its relevance to current private sector needs (e.g., energy-intensiveness), and the success of the technology transfer achieved. Therefore, attempts to evaluate the impact of past ECUT outputs will inevitably involve measuring the influence of all these factors simultaneously, at a given time.

2.6 SYNTHESIS--IMPLICATIONS FOR ECUT IMPACT ASSESSMENT

This literature review raises several issues that need to be addressed when evaluating the benefits of ECUT program outputs. First, the benefits of ECUT's past research, because it is neither basic research nor directly applied research, will be difficult to evaluate. Second, the benefits of basic research are rarely evaluated on a case-by-case basis, except from the retrospective analysis of successful innovations. Finally, corporate applied research is usually tied to clear commercial objectives, making timely (i.e., within 3 years) evaluation of economic impact much easier. Specific issues are listed below:

- There is frequently a long gestation period between research outputs and technological innovations.
- The utilization of scientific and technical information is a non-linear, complex process, which makes it difficult to evaluate the relative importance of different sources of information.
- Scientists and engineers have very different patterns of information utilization. Therefore, the type of document and ultimate user must be considered in evaluating benefits.
- Measuring economic benefits, either direct or indirect (i.e., spin-offs), requires detailed economic information on a case-by-case basis.
- The payoff from applied research is partly stochastic, with a minority of the research projects generating most of the benefits.
- Research with potentially large benefits may be underestimated when first completed.
- Bibliometric methods measure the impact of a particular research output, which is a function of quality, relevance to the current needs, and success of information transfer. These approaches measure impact at a given point in time.

3.0 METHODS FOR EVALUATING ECUT IMPACT--A SUGGESTED STRATEGY

In this section the findings from the literature review are used to develop an approach for evaluating the impact of ECUT program outputs. As described below, the approach also involves performing three case studies to test the techniques and thereby develop final recommendations for the ECUT Program. Indicators of the benefits of ECUT's outputs should primarily reflect impacts which address the goals of the ECUT program. In short, indicators are proxies used to evaluate how well ECUT is achieving its objectives.

3.1 DESCRIPTION OF APPROACH

Different facets of the ECUT Program produce different kinds of measurable results, requiring several types of measures. Therefore, the past outputs (published reports, workshops, computer models, patents, etc.) of the ECUT Program should be inventoried. These outputs can be examined to identify the area addressed (materials, combustion, etc.), and the specific research utilization mechanism(s) which transferred the output (NTIS, distribution list, journal article, workshop, patent, etc.). From this information, various output utilization identification techniques can be developed. Then, indicators can be defined and developed which measure: 1) the level of demand or impact generated by the output, 2) the sector of the economy utilizing the output (e.g., transportation, buildings, manufacturing) and 3) where possible, the specific nature of the impact.

Fundamentally, this approach tries to identify a series of events based on the utilization of specific ECUT outputs. The transfer mechanisms associated with specific outputs are analyzed and an attempt is made to identify the users of the output. The number of users, the types of users, and their utilization of the output is documented and evaluated to assess the output's impact (see Figure 3.1).

This approach will produce: 1) an inventory of past ECUT outputs, 2) preliminary software design to support impact measurement data-base needs, 3) a

FIGURE 3.1. Description of Approach

series of impact measurement techniques, and 4) recommendations on using and interpreting these techniques for specific types of ECUT outputs and research utilization mechanisms.

3.2 SELECTED MEASUREMENT TECHNIQUES

Because of the varied nature of ECUT Program outputs, bibliometric analysis (number of citations received or NTIS copies requested), content analysis (review of articles or patents which reference ECUT outputs), and follow-up surveys were examined for their applicability to specific ECUT outputs. Citations received can be used to measure impact for articles in journals covered by the Science Citation Index. The number of requests to NTIS for specific ECUT-derived reports or reprint requests to a particular author and/or engineering society for ECUT-derived meeting presentations also can be used.

However, bibliometric analysis need not be an end in itself. This approach is not intended to provide a comprehensive use of evaluative bibliometrics to measure ECUT Program benefits. Rather, it is an attempt to use bibliometric analysis techniques to structure a cost-effective search to assess the utilization of ECUT efforts.

For example, bibliometric studies have found that the average number of citations an article will receive varies considerably across scientific disciplines. Bibliometric data on journals which have contained ECUT-derived research were obtained (see Figures 3.2-3.4) to identify the average number of citations these articles received within two years of publication.

Figure 3.2 contains citation information on articles published in Combustion Science and Technology. It reveals that articles published in 1979 received an average of about one citation one year after publication and 2.4 citations after two years. By contrast, Figure 3.3 shows that 1979 articles published in Plasmid received about five citations one year after publication and nine citations after two years. Each line on the figures represents citations to articles published in a specific year. Therefore, similar information can be obtained for articles published in other years.

These data can be used as a standard against which ECUT articles can be measured; not to see if ECUT research is above or below average, but rather to identify which ECUT research outputs have attracted significant attention. The significant outputs can then receive priority for more intensive investigation to determine ECUT impact. The journal citation data can also provide some insight into the length of time it will take to find indications of the impact of future ECUT outputs.

When a frequently cited journal article based on ECUT-funded research is identified, the articles referencing it can be obtained and reviewed. The nature of the contribution of the cited article to the referencing articles can then be assessed. In some instances the individuals that ordered specific NTIS documents or reprints can be identified and contacted to provide more in-depth information on utilization and benefit. Figure 3.5 contains a sample survey form that could be used to obtain this type of information.

3.3 DATA-BASE MANAGEMENT NEEDS

The type of approach outlined above would involve acquiring and analyzing data on many different types of outputs and transfer mechanisms. The complexity and variability of the data needed to identify and analyze the impact of

AIAA JOURNAL

ACTA ASTRONAUTICA

COMBUSTION AND FLAME

COMBUSTION SCIENCE AND TECHNOLOGY

FIGURE 3.2. Citation Information--Combustion Research Articles

JOURNAL OF COMPUTATIONAL PHYSICS

JOURNAL OF FLUIDS ENGINEERING

PHYSICS OF FLUIDS

PROGRESS IN ENERGY AND COMBUSTION SCIENCE

FIGURE 3.2. (contd)

BIOTECHNOLOGY/BIOENGINEERING

BIOTECHNOLOGY LETTERS

ANNALS OF NEW YORK ACADEMY OF SCIENCE

PLASMID

FIGURE 3.3. Citation Information--Catalysts/Biocatalysts Articles

FIGURE 3.4. Citation Information--Materials Articles

Article/Report Title

1. How did you learn of this document?
2. Did you pass along this document to someone else in your organization?
☐Yes
☐No
3. The information contained in this document was used as:
☐background information (to keep informed of developments)
☐input for applied research
☐input for product development
☐other
4. The information contained in this document was:
☐not useful
☐generally useful
☐very useful
☐critically important
5. Was this document used and/or referenced in other reports or publications?
☐yes
☐no
If yes, how many?
Specify (OPTIONAL)
6. Your organization is in what sector of the economy?
☐BUILDING CONSTRUCTION
☐FOOD & KINDRED PRODUCTS
☐LUMBER & WOOD PRODUCTS
☐PAPER & ALLIED PRODUCTS
☐CHEMICALS & PRODUCTS
☐PETROLEUM & COAL PRODUCTS
☐RUBBER & PLASTIC PRODUCTS, NEC
☐LEATHER & LEATHER PRODUCTS
☐STONE, CLAY & GLASS PRODUCTS
☐PRIMARY METAL INDUSTRIES
☐FABRICATED METAL PRODUCTS
☐MACHINERY, EXCEPT ELECTRICAL
☐ELECTRICAL, ELECTRONIC MACHINERY
☐TRANSPORTATION EQUIPMENT
☐SCIENTIFIC INSTRUMENTS & RELATED PRODUCTS
☐OTHER

IF WILLING TO BE CONTACTED (OPTIONAL) --
NAME TELEPHONE

FIGURE 3.5. Sample Survey Form

specific ECUT outputs suggest the need for a sophisticated data-base management system. Although this type of system is not required for the analysis of a few case study examples, a more extensive retrospective analysis of past and future ECUT outputs would require a system capable of storing a significant amount of data. Such a system would need to store data records of variable length and type and a data structure to link outputs to impact information.

The analysis of software requirements involved several steps. First, a general description of the software needs was developed; it is summarized under General Software Requirements. This description was used as a starting point in the compilation of a program specification document which contains more detailed requirements for the software. This document is included as Appendix B to this report.

A preliminary version of the program specification document was used to compare commercial data-base management packages and programming languages. This comparison was made in order to select that software development package which matched most closely with the software needs as described in the program specification document. It resulted in the choice of one software development package which will be used to develop a data base of ECUT outputs and analysis tools if an analysis of all ECUT outputs is undertaken.

An account of each step in the software selection process is given on the following pages. A description of the software's proposed features is also provided.

General Software Requirements

Full analysis of the impact of ECUT outputs will require a relatively sophisticated system of computer programs and data files. To describe and analyze ECUT outputs and their impacts, the data files associated with this system must be able to store six different types of information:

- a description of an ECUT output
- a list of workshop attendees
- a reprint request

- a survey form
- a description of a reference to an ECUT output
- the in-house analysis of the reference.

Besides being able to store separate types of information, the system must also be able to accommodate differences within one single type. For instance, in the collection of records (entries) describing ECUT outputs, those records describing journal articles need space to store the page numbers in the journal where the article appears, while a meeting presentation record should contain a space for the society hosting the meeting.

Computer programs written to process these data files must be able to retrieve and manipulate information in many ways. Because the analysis will include a variety of impact measures such as counts and crosstabulations, the programs must be able to calculate each of these measures. For some tasks, a program may need to retrieve all of the records in one information category, e.g., to count survey forms by research area (combustion, materials, heat transfer, etc.), all of the survey forms must be scanned. For other tasks, disparate types of records making up the 'impact trail' of one ECUT output must be retrieved, involving a scan of the records in each information category. Additional programs must provide for initial data entry, and for formatting of data for output reports.

Program Specifications

The program specification document describes in detail the required capabilities of the ECUT impact analysis software. It was compiled for several reasons. First, it provided a basis with which to compare commercially available software development packages for the needs of the analysis of ECUT output impacts. Following the selection of a commercial software package, the specifications have been refined to further describe the software's capabilities. Finally, if a full-blown analysis of all ECUT outputs is undertaken, this document will serve as a guide to the programmer(s) implementing the software.

The specifications began as the list of six types of information shown above. A description of the data associated with each type of information was

developed, and the possible links making up impact trails were specified. Once this was completed, specifications for the required analysis tools and computer outputs were added.

The program specification document is included as Appendix B of this report.

Comparison of Commercial Software Packages

A comparison of several commercially available data-base management packages and programming languages was undertaken in order to find one which met the requirements of the analysis of ECUT impacts. Before this comparison was made, the general software requirements and specifications were reviewed. A list of programming features needed in the chosen software development package resulted from this review. It was determined that the package chosen needed to have the following features:

- a way to organize a record of information into items (fields), and the ability to store the fields, intact, in a file;
- a feature allowing similar records to have some different fields;
- a method whereby variable amounts of space can be reserved for text information;
- the ability to track the impact trail of an ECUT output through different types of records.

Software development packages available for minicomputers (Digital Equipment Corp. VAX) and microcomputers (IBM PC) were investigated. They can be classified as data-base management systems for minicomputers, data-base management systems for microcomputers, or high-level programming languages available for both types of computers. The capabilities of two minicomputer data-base management packages, two microcomputer data-base management packages and three programming languages were explored. A summary of some of their features is given in Table 3.1.

The data-base management systems, in general, have advantages in that record structures are easily programmed, and that records are automatically

TABLE 3.1. Comparison of Software Development Package Features

	Data-base Management Systems				Programming Languages		
	Minicomputer Datatrieve	Rdb	Microcomputer dBase	Rbase	FORTRAN	Pascal	C
Record Structures (groups of fields) in computer memory	Yes	Yes	Yes	Yes	No	Yes	Yes
Record Structures in files	Yes	Yes	Yes	Yes	No	Yes	No
Variable Fields in Records	No	No	No	No	Yes	Yes	No
Allocation for text as needed	No	Yes	Limited	No	No	Yes	Yes
Tracking of Impact Trails Through Records	Yes	Yes	Yes	No	Limited	Yes	Yes

stored on file in those structured formats. In addition, they usually offer sophisticated data entry and editing features. Their ability to do numerical manipulation is often limited, however. Each of the data-base management systems investigated has drawbacks. The Rbase package is incapable of handling the tracking of output's impacts. Datatrieve does not allow memory or file space for text information to be allocated as it is needed. None of the packages would allow different fields in the same structure (to allow, for example, journal articles and workshops to be stored in a file of ECUT outputs). If that requirement were relaxed, only Rdb meets all of the requirements. Rdb is a fairly new minicomputer package, however, and users at PNL have reported problems in using both the variable memory allocation feature and the report-writing facility used to format printed output. And while space for text can be reserved as needed in the dBaseIII packages, it cannot be printed in a report or accessed by commands from a program file.

High-level programming languages tend to offer more flexibility than commercial data-base management packages. Specifically, the allowed types and formats for data are less restrictive, and high-level languages offer greater

power in performing mathematical calculations. Taking advantage of this additional flexibility, though, often entails a greater initial effort in structuring data files and providing data entry capabilities.

The three programming languages surveyed were FORTRAN, C, and Pascal. The first two did not meet all of the requirements. FORTRAN does not allow record structures to be implemented either in internal memory or in files. The C language does allow for record structures in the computer's memory, but becomes clumsy in handling those structures in external files.

Only the Pascal programming languages met all requirements. Its capabilities are uniquely suited to the requirements of this software. Specifically, Pascal programs can be written that will:

- organize data into record 'structures'
- link related information with tree and list structures
- handle files of records with different lengths and contents.

Record structures in Pascal allow complex information to be stored and retrieved as a unit, then manipulated in smaller units. Further, the same record structure may be used to store related but different information, for example, journal articles and ECUT-sponsored workshops, both of which are ECUT outputs. These record structures are used to organize information both in external disk files and in the computer's internal memory, where actual processing will take place.

Records following the same or different structures can be linked together in additional ways, such as the lists mentioned above. These linking structures, which allow data in internal memory to be connected in ways that are not possible in a disk file, will be used to follow the impact trail of ECUT outputs.

For these reasons, the Pascal programming language has been chosen for the development of the impact analysis software. As shown by the software comparison, Pascal's capabilities meet the analysis requirements, while the other options explored as implementation tools do not. To summarize, the other high-level languages do not allow data to be organized in files of record structures. Most commercial data-base management packages offer record structuring

and linking features of some sort, but cannot efficiently handle records of variable information. Pascal was chosen because it offers all of these features.

Hardware Requirements

An IBM-PC (or IBM-PC compatible microcomputer) would be used to develop the impact analysis software and to store the data base of ECUT outputs. A hard disk drive would be used to store the large amount of information involved; use of a hard disk would also result in faster file access. In addition, the PC would be equipped with a math processor (8087 chip) to speed calculations for the various measures of output impacts.

Software Description

Any computer software that allows for data storage and manipulation must accomplish several tasks. These include:

- data entry/editing
- data storage
- retrieval
- analysis
- output.

In this software description, plans for accomplishing each of these tasks are described in turn.

Data Entry/Editing. Information would be entered into the output analysis system at the computer console. Because several kinds of information would be involved, users would make an initial choice as to which type of information is to be entered. There would be a separate input screen for each of the record types listed earlier. Each input screen would give appropriate prompts for each field and indicate the maximum amount of space reserved for the storage of that field. The data input routines would also verify the information a user has entered before it is stored on disk. Verification is particularly important for fields such as a survey ID number, which may later be used as the key by which records are linked.

Data Storage. Each of the six types of information would be stored in a separate file, along with the key fields necessary to link records at a later

time. One file, for instance, would be used to store all of the survey form records. The records in a file would not always be identical, however: the file of ECUT outputs would contain some entries for journal article outputs, some entries for NTIS reports, and additional entries for each of the other types of outputs. Pascal allows these variable records to be stored in the same file. When it is necessary to read information from the file into memory, the program would be able to distinguish each type of record and automatically allocate the appropriate fields to store the information in the computer's memory while it is being processed.

Retrieval. The ECUT output impact data would need to be retrieved from its storage files for several reasons, including analysis, display or editing of records onscreen, and output reports. Depending upon the task chosen by the user, the computer would retrieve data in one of two ways, as shown in Figure 3.6. For some tasks, one or more entire files would be read from the disk

FIGURE 3.6. Two Methods of Information Retrieval

file into memory. For example, the count of survey forms by research area would require access to all survey forms stored in the 'survey form file.'

Other tasks require that one record be retrieved from each of several files. For instance, if the user wants to review the impact trail of one ECUT output before entering the in-house analysis, he or she might want to see the description of the output, a reprint request, a survey form and a description of a reference made to the output. If a user makes this kind of request, the program would search the necessary files, retrieve the records associated with a given output, and use a linking structure to organize them for processing.

Output. For analysis of output impacts, the software must be able to perform the calculations which lead to various counts and crosstabulations. The user would select an analysis measure from a list on the screen. When a choice is made, the software would retrieve data in the appropriate format, perform the calculations and show results either on the screen or in a printed report.

Output may include the entire contents of a record or records, partial contents of many records, and analysis measures such as crosstabulations. Depending upon the type of output requested and the user's choice of output device, calculated measures and/or data retrieved from storage would be formatted into a printed report or displayed on the screen.

When the contents of records are displayed onscreen, a screen format similar to those employed for data entry would be used. For printed versions of record contents, a set of standard output reports would provide appropriate hardcopy. Analysis results would use similar formats for screen display and printed reports; a report title, date and page numbers would be added if a printed version of the analysis results is requested.

4.0 RESEARCH OUTPUT TRANSFER--PRELIMINARY ANALYSIS

As part of the development of a methodology for evaluating ECUT benefits, a preliminary analysis of research output transfer was conducted. Requests for ECUT documents in the National Technical Information Service (NTIS) distribution systems were examined. In addition, a small, informal survey of combustion researchers was conducted to estimate their awareness of ECUT sponsorship of specific research outputs.

4.1 NTIS DOCUMENT REQUESTS

The NTIS is one important mechanism by which ECUT research output in the form of technical reports is distributed. The research outputs listed in Appendix A were reviewed to identify those documents that would be in the NTIS system. Request information for 38 ECUT documents supplied by NTIS was obtained through the cooperation of NTIS staff and the data were analyzed.

The documents were divided into the six research areas listed below:

- Engine Combustion
- Thermal Sciences
- Closed-Cycle Systems
- Direct Heating and Conversion
- Materials
- Technology Planning/Systems Analysis.

The analysis of requests for these documents is summarized in Table 4.1. On average each ECUT document was requested 7.55 times. Of course, some documents received no requests while one document received 37 requests. The standard deviation (7.92) of number of requests indicates considerable variation in the number of requests a particular document will receive. It is important to note that the request data have not been standardized for differences in publication date. Some documents have been in the NTIS system for about three years while others only one year. This can lower the number of requests received for those documents offered relatively recently by NTIS. The relatively high rate of requests per document in the Technology Planning category probably reflects

TABLE 4.1. NTIS Document Request Statistics

Research Area	Total Requests	Number of Documents	Average Per Document	Variance	Standard Deviation	Maximum	Minimum
Engine Combustion	68	13	5.23	34.02	5.83	23	0
Thermal Science	36	7	5.14	8.41	2.90	10	0
Closed-Cycle Systems	49	5	9.80	100.96	10.05	29	2
Direct Heat and Conv.	14	1	14.00	0.00	0.00	14	14
Materials	6	1	6.00	0.00	0.00	6	6
Technical Planning	114	11	10.36	101.14	10.06	37	2
TOTAL	287	38	7.55	62.7	7.92	37	0

the broader audience for the type of information contained in such documents. More technically-focused research areas are likely to be of interest to a smaller technical community.

Because the suggested approach involves surveying identified users of ECUT-sponsored research, it was important to estimate the usefulness of NTIS document order information as a technique for identifying specific users. If most requests for documents only specify an organization name or the library of an organization, it will probably be difficult to discover the "ultimate" user of the document. For this reason, requests were divided into the three categories listed below:

1. Libraries, Information Acquisition Departments, or Information Scientists (presumably ordering for someone else)
2. Individuals (with or without company affiliation, but not identified as a member of Category 1)
3. Other Organizations (Companies, Embassies, etc. with no individual specified).

The results, shown in Table 4.2, reveal that about 70% of the document requests were from unnamed individuals or from individuals requesting the document for another person. Since one-half of the individual requests were for technology planning documents (e.g., conservation research opportunities), only about 15% of the total requests might have come from users interested in the results of technical research funded by ECUT. These results suggest that attempts to identify and survey all three categories of NTIS document

TABLE 4.2. NTIS Requester Profile

<u>Research Area</u>	<u>Library or Information Specialist</u>	<u>Individual Requester</u>	<u>Other Organizational Request</u>
Engine Combustion	38	14	16
Thermal Science	25	8	3
C-C Systems	29	15	5
Direct Heat and Conv.	8	2	4
Materials	2	2	2
Technical Planning	52	44	18
TOTAL	154	85	48
PERCENT	53.7%	29.6%	16.7%

requesters would be very difficult and time-consuming. An alternative would be to limit survey attempts to individuals identified through requester information provided by NTIS. However, this would involve only a sample of the requester population.

4.2 COMBUSTION RESEARCH SURVEY

A survey form was developed consisting of a listing of publications and meeting presentations of ECUT-sponsored combustion research. This survey form was sent to a small number of combustion researchers at Battelle Columbus Laboratory (BCL). For each output, the researcher was asked if he or she was familiar with it. If familiar with the output, the survey respondent was asked if he or she was aware that ECUT had funded the research. The results of this survey are shown in Table 4.3. In cases where the research output was known, over four-fifths of the respondents indicated no awareness of ECUT funding (one respondent specifically noted on the survey form next to several publications that ECUT funding was not acknowledged). The survey results also suggest that technical journals, technical society publications, and presentations at conferences account for at least two-thirds of the research information transfer mechanism for these researchers.

TABLE 4.3. Awareness of ECUT Funding for Combustion Research

Were You Aware That This Research Received ECUT Funding?

	<u>Yes</u>	<u>No</u>	<u>Total Responses</u>
Count	15	74	89
Percent	16.9%	83.1%	100%

5.0 THREE CASE STUDIES TO DEMONSTRATE EVALUATION METHODS

A major goal of this project was to determine whether cost-effective techniques could be found to identify a significant share of the "ultimate" users of ECUT-sponsored research outputs so that they could be contacted and surveyed concerning research utilization.

To achieve this objective, three case studies of particular research outputs were conducted. These three case studies examined research outputs in each of the three ECUT priority research areas:

- engine combustion
- materials
- tribology.

The results presented here represent a snapshot of how a small sample of ECUT research outputs have been transferred. The research outputs were selected based on discussion with ECUT HQ Project Managers, and cover a range of diverse output types and output transfer mechanisms.

5.1 CASE STUDY I: COMBUSTION ENGINE RESEARCH

The CONCHAS-SPRAY computer software is a research and development tool to model reactive flows with fuel sprays. The software was distributed through three different mechanisms:

- magnetic tape from Los Alamos
- magnetic tape from national Energy Software Center
- technical report containing code listing from NTIS.

The technical report published by Los Alamos and distributed by NTIS is:

Cloutman, L. D., et al. May 1982. CONCHAS-SPRAY: A Computer Code for Reactive Flows with Fuel Sprays. Los Alamos Laboratory Report LA-9294-MS.

Results

Magnetic tapes were provided by Los Alamos to 28 different organizations or institutions. The information supplied from Los Alamos to PNL contained only a list of those organizations to which tapes had been sent. The types of

recipients are shown in Table 5.1. Conversation with Butler^(a) indicated that more specific information (i.e., name of requesting individual, date request received) is difficult to obtain. By contrast, the National Energy Software Center (NESC) has more complete requester information, but will release the information only to the software author. The NESC reports having received a total of 5 requests. The NTIS reported 23 requests for the technical report. Figure 5.1 shows the time delay for requests to NTIS for the technical report. The delay is calculated from the date of publication of the Los Alamos report to the date of request receipt by NTIS. The figure shows a slow steady flow of requests to NTIS for over three years with a peak of requests about two years after initial Los Alamos publication. A search of the Science Citation Index (SCI) data base revealed no citations to Technical Report LA-9294-MS.

Discussion

An important finding of this case study is that about five times more tapes were distributed by Los Alamos than by the National Energy Software Center. While this one example is not conclusive, it is consistent with the pattern of the author playing a significant distribution role in other types of research outputs (see Sections 5.2 and 5.3).

LA-9294-MS was one of the most often-requested of the 38 ECUT documents for which data were obtained from NTIS (see Section 4.1). The distribution of

TABLE 5.1. CONCHAS-SPRAY Tapes Sent by Los Alamos

<u>Number</u>	<u>Organization</u>
1	National Energy Software Center
11	Private Companies (6 automotive)
9	Universities
7	Other Government Agencies and Research Laboratories

(a) Private communication with T. D. Butler, Los Alamos National Laboratory, August 1985.

FIGURE 5.1. Requests to NTIS for LA-9294-MS (DE82-17385).

requests over time suggests that even for popular documents, requests will be received at a relatively low but steady pace, peaking two to three years after initial publication.

5.2 CASE STUDY II: MATERIALS

The two outputs selected for this case study represent a portion of research into ductile long-range ordered (LRO) alloys by ECUT-funded researchers. These materials show promise in high-temperature structural applications and may reduce the need for strategic minerals currently required for such applications. The outputs listed above focus on one alloy composition - $(\text{Fe}, \text{Co}, \text{Ni})_3\text{V}$:

1. Liu, C. T. 1984. "Physical Metallurgical and Mechanical Properties of Ductile Ordered Alloys $(\text{Fe}, \text{Co}, \text{Ni})_3\text{V}$." International Metals Review 29:(3)168-194.

2. Liu, C. T. and N. S. Stoloff. August 1984. Development and Characterization of Ductile Long-Range Ordered (LRO) Alloys (Fe, Co, Ni)₃V for High Temperature Structural Use. ORNL-6032, Oak Ridge National Laboratory, Oak Ridge Tennessee.

Although ECUT-funded research outputs on other LROs have been published, specifically on aluminides, these outputs have generally appeared later in the referenced literature. The results below give some indication of the minimum time required to observe subsequent articles which reference a given article. The outputs selected are probably as recent as possible to find evidence of referencing articles in SCI. These two outputs were also selected to examine contrasting user identification techniques, namely references from subsequent articles, requests to NTIS, and requests to the author.

Findings

A referencing article search of the SCI data base revealed a total of seven citations from later journal articles to the ECUT-funded article. No citations from journal articles to the technical report ORNL-6032 were found. However, examining the bibliography of the cited article as well as the referencing articles suggests that technical reports are infrequently referenced in the journal literature.

Of the seven citations received by Liu (1984), three were from articles in which Liu was author or coauthor (i.e., these represented "self-citations"). Two additional articles included Stoloff (coauthor of technical report ORNL-6032), and one article was coauthored by Braski--an Oak Ridge colleague of Liu's. These six articles were all published in 1984, the same year as the cited work. The one additional referencing article was published in 1985 by Japanese researchers. Thus, most of the referencing literature represents related work by a small group of researchers--Liu, Stoloff, Braski, and Schulson. The Japanese researchers, presumably outside this core group, represent the first indication of research expanding upon the work of these individuals. This suggests that there will be a lag of at least one year for researchers in the larger technical community to publish work that references articles describing ECUT-supported work.

Several of the articles acknowledge Liu's role in providing alloy samples for analysis. Conversation with Liu^(a) confirmed this role. Indeed, in materials research this may be an especially significant benefit which may be underestimated when using bibliometric techniques of impact assessment.

The NTIS has received a total of six requests for ORNL-6032. This report has been available from NTIS for a much shorter period of time than the document LA-9294-MS examined above. The number of requests received in the same time period (0 to 12 months) is comparable for the two documents (see Figure 5.2). It is not possible to determine if this report will become one of

FIGURE 5.2. NTIS Requests for ORNL-6032 (DE84-016750)

(a) Private communication, C. T. Liu, Oak Ridge National Laboratory, August, 1985.

the more frequently requested ECUT documents in the NTIS system. However, if the time lag in requests received is consistent with that observed in the first case study, it is likely that additional requests will be received in the next 18 months.

Liu reports receiving 74 requests for reprints of Inv. Met. Rev. 29(3):168-194 and about 20 requests for ORNL-6032.^(a) He had no specific information on the requesters. He did indicate that most requests did not come from libraries, in contrast to requests to NTIS.

Discussion

The search of the SCI data base revealed no references to technical report ORNL-6032. Examining the articles that referenced Liu (1984) uncovered few references to any technical reports, which is consistent with Brearley's (1973) observation that some journal editors will not allow technical reports to be referenced on the grounds that they are not generally available. Instead, journal editors may require that such references be made to "unpublished work" or "private communication." Such references were observed in some of the articles analyzed. Without information from the author, it is almost impossible to determine if such reference to an "unpublished work" is really to a technical report describing ECUT-funded work.

The data analyzed in this case study suggest that most references to journal articles published within about one year of the cited work will probably consist of self-citations or citations from close research colleagues. It will generally be necessary to wait about 18 months after article publication to utilize SCI to identify researchers in the larger technical community who have referenced ECUT-funded research outputs.

This case study indicates the need to track distribution of alloy samples as part of an overall ECUT benefits evaluation effort. It also illustrates the important role the researcher can play in technical report distribution.

(a) Private communication, C. T. Liu; Oak Ridge National Laboratory, November, 1985.

5.3 CASE STUDY III: TRIBOLOGY

The two research outputs selected from tribology research for this case study were:

1. Hsu, S. M., C. S. Ku and R. S. Lin. 1982. "Relationship Between Lubricating Basestock Composition and the Effects of Additives on Oxidation Stability." SAE Reprint 821237, Society of Automotive Engineers, Warrendale, Pennsylvania.
2. Ku, C. S. and S. M. Hsu. 1982. "Thin-Film Oxygen Uptake Test for the Evaluation of Automotive Crankcase Lubricants." ASLE No. 82-LC-1D-1, presented as an American Society of Lubrication Engineers (ASLE) paper at the ASME/ASLE Lubrication Conference, October 5 through 7, 1982, Washington, D.C. Also published in Lubrication Engineering 40:(2):75-83.

The output describes tribological research findings, the second, a tribological research method.

Findings

Discussion with Hsu^(a) indicated that he has given out approximately 85 copies of the SAE paper and 700 copies of the ASLE paper in the last three years. He could provide no requester-specific information. He did state that he felt many of the requests were from overseas, attributing this to the more common practice in the U.S. of photocopying material directly.

Discussion with a representative of SAE^(b) revealed that Hsu's paper had been published in Special Publication 526, Base Oils for Automotive Lubricants. A total of 605 copies of this publication has been ordered. No requester-specific information is available. Of course, it is not possible to determine if requesters of the special publication were specifically interested in Hsu's article. The SAE also provides copies of individual articles from such special publications, but has no system for tracking even the number of these requests.

(a) Private Communication, S. M. Hsu, National Bureau of Standards, August, 1985.

(b) Private communication, Ginger Joe, Society of Automotive Engineers, September 1985.

Discussion with a representative of ASLE^(a) indicated that no information is available to track requests for individual papers. Finally, search of the SCI data base uncovered no references to either paper.

Discussion

These results point out the limitations in tracking potential users of ECUT-funded research through requests to professional societies for specific published papers. In addition, the important role of author distribution is dramatically illustrated by the approximately 700 copies of ASLE No. 82-LC-1D-1 distributed by the author.

The absence of citations to such a widely distributed paper is puzzling. Hsu^(b) indicated that lubrication is a field with considerable trade secrecy. Reluctance of industrial researchers to publish their results may be the cause of this lack of citations.

5.4 INSIGHTS FROM CASE STUDIES

The results from the case studies indicate that identifying users of ECUT research outputs is difficult. Public and quasi-public sources of information (e.g., SCI, NTIS, technical societies) have limited ability to provide assistance in this task. An important finding from these case studies is the large role that researchers themselves play in distributing reprints, computer software, samples, etc. Unfortunately, researchers are unlikely to keep records of such requests in a form easily usable for the process of ECUT benefit evaluation. The major insights from these case studies are summarized below:

- Technical reports are not likely to be referenced in the refereed literature. Thus, indications of research utilization in technical reports are limited to requests for copies (to NTIS, authors, and ECUT) and distribution lists.

(a) Private communication, representative, American Society of Lubrication Engineers, September 1985.

(b) Private communication, S. M. Hsu, National Bureau of Standards, August, 1985.

- Researchers themselves provide a great deal of the information transfer, by fulfilling requests for reprints, software, samples, etc. For example, Los Alamos researchers have distributed about five times as many copies of CONCHAS-SPRAY as the National Energy Software Center.
- Researchers generally are unable to provide detailed information on the requests they have received.
- Clear evidence of impact (reprint requests, NTIS orders, citations to articles, etc.) will be available after two years, in most cases.
- The National Energy Software Center releases full request information only to the author of the software.

6.0 CONCLUSIONS AND RECOMMENDATIONS

This section contains the conclusions of the research on ECUT benefit evaluation techniques and recommendations for future implementation of ECUT benefit measurement.

6.1 CONCLUSIONS

Benefit evaluation should stress an impact assessment approach that attempts to identify specific users of ECUT-funded research. Bibliometric indicators (e.g., number of articles, citations, requests for documents/reprints) by themselves do not provide an adequate basis for measuring the benefits of a program as diverse as ECUT. However, bibliometric indicators can be combined with an analysis of particular program outputs through examination of referencing articles and/or surveys. A meaningful evaluation of the benefits derived from ECUT program activities can be obtained by combining bibliometric techniques with knowledge gained from specific users of ECUT outputs.

The work to date indicates that no single comprehensive technique exists for measuring ECUT benefits. Because of the generic applied nature of ECUT-funded research, simply using economic payback criteria (which are used to measure applied research) or pure bibliometric techniques (used to assess basic research) would be inappropriate. At best, measuring ECUT benefits will consist of painting in portions of an evolving canvas of research impact. The ability to follow and document the "trail" of utilization will vary substantially. Thus, bibliometric (e.g., number of reprints, citations) comparisons of research impact, either over time or among research topics, should not be attempted unless supplemented with information gained through surveys of ECUT output users and analysis of the content of referencing articles. For example, it would be a mistake to use bibliometric techniques alone to answer the question: "Is research performed 2 years ago having more or less benefit than 4-year old research?"

However, even incomplete understanding can be useful. Analyzing the benefits of ECUT-funded research can give greater insight into the mechanisms of

successful research transfer and utilization and thus improve program effectiveness. Because only a minority of the outputs (probably 20%) are likely to be "big winners," identifying the sectors of the economy affected by for these selected outputs can give insight into a significant portion of total ECUT program benefits.

An important advantage of this strategy is that existing computer software and hardware can be used to implement a data-base management system for evaluating ECUT output benefits.

The survey of combustion researchers at Battelle-Columbus Laboratories suggests that the benefits of ECUT-funded research may not be known by researchers utilizing its results because ECUT support is not acknowledged. Thus, ECUT may not be receiving proper credit for its efforts.

Attempts to identify the citations received by specific ECUT outputs in the SCI data base were hampered by incomplete bibliographic information on several ECUT outputs. For example, to unambiguously identify references to a journal article requires the article's author, volume number, issue number, pages, and date. Therefore, tracking citations to ECUT outputs via SCI will require obtaining such complete information to be successful.

Finally, benefit is a function of effective research transfer. The limited data analyzed here, as well as literature on scientific and technical information transfer, suggest that emphasis should be placed on those transfer mechanisms most likely to reach users of ECUT funded-research. Specifically, journal and society publications and conference presentations should be stressed as mechanisms for information transfer to researchers. Data tables, materials characterization information, etc., are more effectively transferred to engineers via books, technical reports, and society special publications (i.e., topical publications).

6.2 RECOMMENDATIONS

Greater emphasis should be placed on utilizing direct requests to the researchers. The research conducted in this project indicates that user-specific information from public and quasi-public sources (e.g., NTIS, Science

Citation Index, professional societies and journals) is limited and will not provide a cost-effective mechanism for identifying ECUT beneficiaries. Such requests are more likely to be from the immediate research community of the researcher. In addition, it is more likely that the researcher will have some idea of why the request was made and how the research output is being utilized.

Finally, to permit cost-effective surveying of future users of ECUT research output, a reporting system should be implemented which would allow the researcher to notify ECUT of any output requests. Based on the research in this project, ECUT-funded researchers currently would find a request for user information burdensome since they are unlikely to have complete and organized records of such previous inquiries.

The recommendations can be summarized as follows:

1. Institute a standardized reporting system that ECUT-funded researchers can use to record requests for specific article reprints, conference papers, software, samples etc., so that future users of ECUT outputs could be more easily identified.
2. Develop a data-base management system to evaluate the impact of ECUT outputs on an ongoing basis. This data base can be developed on a microcomputer using the Pascal programming language.
3. Gather citation information on ECUT publications from the Science Citation Index to further track the utilization of ECUT research results.
4. Survey a sample of identified users of ECUT research outputs to test this survey instrument and to estimate survey response rate.
5. Delay benefit evaluation until adequate information on users is available to combine with bibliometric indicators to permit a balanced evaluation.

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APPENDIX A

INVENTORY OF ECUT OUTPUTS: 1976-1984

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ENGINE COMBUSTION TECHNOLOGY RESEARCH

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APPENDIX B

PROGRAM SPECIFICATION DOCUMENT

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PROGRAM SPECIFICATION DOCUMENT

This appendix contains the software specification document that has been developed as an aid to defining and planning the software needs for an analysis of the impacts of ECUT outputs.

The first step in developing this document was the definition of the data that would be required to analyze ECUT impacts. A list of the six types of information involved (described in Section 3.4) was used as a starting point. From this list, a detailed description of each data type was made. The mechanisms and process by which an ECUT output has an impact were incorporated in the software specification document by adding the possible links between record types that make up an impact trail. Once the data needs were defined, a list of indicators by which the impacts could be tabulated and analyzed was developed and added to the specifications. Finally, required output reports were specified.

The program specification document has several uses. Initially, it was used to help define the database and analysis tools needed to perform an analysis of the impacts of ECUT outputs. It was also used as a basis with which to compare commercially available software development packages, and to choose a package with which the impact analysis software can be implemented (see Section 3.4 of this report). Finally, if software is developed to enable a full-blown analysis of the output impacts, the program specification document will be expanded for use as a detailed design of the computer programs. In this role, it will serve as a valuable guide to the programmer(s) implementing the software, and will ensure that the implementation proceeds smoothly in a cost-effective manner.

The program specification document is organized in three major sections. The first contains descriptions of the record types required, the second lists and defines the indicators needed, and the third covers output reports. Figure B.1 shows the organization of the specification document in detail.

1. INPUT DATA/RECORD TYPES
 - 1.0 INPUT DATA/RECORD TYPES SUMMARY
 - 1.1 REFERENCE TO ECUT ARTICLE/DOCUMENT/PATENT
 - 1.1.1 JOURNAL ARTICLE TYPE
 - 1.1.2 REPORT TYPE
 - 1.1.3 MEETING PRESENTATION TYPE
 - 1.1.4 PC SOFTWARE TYPE
 - 1.1.5 NON-PC SOFTWARE TYPE
 - 1.1.6 PATENT TYPE
 - 1.1.7 BOOK ARTICLE/CHAPTER TYPE
 - 1.1.8 OTHER TYPE
 - 1.2 SURVEY FORM
 - 1.3 REQUEST FOR ECUT DOCUMENT/REPRINT
 - 1.3.1 RESPONDENT
 - 1.4 ANALYSIS OF REFERENCING DOCUMENT
 - 1.5 ECUT OUTPUT
 - 1.5.1 JOURNAL ARTICLE TYPE
 - 1.5.2 REPORT TYPE
 - 1.5.3 MEETING PRESENTATION TYPE
 - 1.5.4 PC SOFTWARE TYPE
 - 1.5.5 NON-PC SOFTWARE TYPE
 - 1.5.6 PATENT TYPE
 - 1.5.7 BOOK ARTICLE/CHAPTER TYPE
 - 1.5.8 OTHER TYPE
 - 1.5.9 ECUT-SPONSORED WORKSHOP TYPE
 - 1.6 WORKSHOP ATTENDEE
2. INDICATORS
 - 2.1 COUNT INDICATORS
 - 2.2 CROSSTABS INDICATORS
 - 2.3 LAG AND OTHER INDICATORS
3. OUTPUT REPORTS
 - 3.0 OUTPUT REPORTS SUMMARY
 - 3.1 LIST OF ALL OUTPUTS
 - 3.2 ABSTRACTS BY INDUSTRY

FIGURE B.1. Key to Software Specification Document

The section dealing with record types defines the types of information that the ECUT output database will need to incorporate. It is further categorized into subsections for each of the six major types of data. Where one type of data may contain different information, each of the possibilities is described. For instance, under the ECUT output data type, each kind of ECUT output is described separately.

The indicators described in the second section of the specifications have been divided into three categories: counts, crosstabs, and lag indicators. In the final section, each output report is described separately.

1. INPUT DATA/RECORD TYPES
1.0 INPUT DATA/RECORD TYPES SUMMARY

Instructions: Make a summary entry for each type of record that you envision needing. If the record contains the same fields, it is one record type, no matter how many places it might be used (for example, the "survey form" record might be the same for both NTIS requests and journal articles, so this would be entered as one record type). Use sequential numbers in the "RECORD TYPE" column so that each summary entry can be keyed to a detail page. Use an additional summary page if you need to. Then fill out a detail page for each summary entry.

<u>RECORD TYPE</u>	<u>DESCRIPTION (in a sentence or phrase)</u>
1	Reference to ECUT article/document/patent
2	Survey form
3	Request for ECUT document/reprint
4	Analysis of referencing document
5	ECUT output
6	Workshop attendee

1. INPUT DATA/RECORD TYPES
 1.1 INPUT DATA/RECORD TYPES DETAILS

Instructions: Fill out a detail page for each entry made in the record type summary. Please be sure to copy the "RECORD TYPE" number used in the summary to this page. Then fill out the rest of the page. Your field names do not have to follow any particular conventions, and should succinctly say what the data item is. When specifying the field types for each field, try to use the following categories: Alpha Code, Numeric Code, Numeric, Text, Date, and Logical. If the field does not fall into one of these categories, you may call it what you like. In the LENGTH/FORMAT column, enter a field length for Code and Text fields. For Numeric fields, enter a format (i.e., decimal with 3 places) and the envisioned range of the numbers to be stored in the field (i.e., <100). For Date fields, please enter the format that you prefer. Logical fields need no entries in the LENGTH/FORMAT column.

RECORD TYPE (from Summary): 1

CONTENTS/PURPOSE: Bibliographic information to identify a referencing document sufficient to produce a PNL style reference.

What other record types might this record be linked with?

5, 4, 2

-----FIELDS-----		
NAME	TYPE	LENGTH/FORMAT
TITLE	Text	35
AUTHOR 1...n	Text	30/last name, FI, MI
DOCUMENTID	Text	20
TYPE	Numeric code	1/0=Unknown, 1=Journal Article, 2=Report, 3=Meeting Presentation, 4=PC software, 5=Non-PC software, 6=Patent, 7=Book article/chapter, 8=Other

Depending upon the value of the TYPE field, an additional record is provided to store remaining reference information. These are described as Record Types 1.1 through 1.8.

1. INPUT DATA/RECORD TYPES
1.1.1 INPUT DATA/RECORD TYPES DETAILS

Instructions: Fill out a detail page for each entry made in the record type summary. Please be sure to copy the "RECORD TYPE" number used in the summary to this page. Then fill out the rest of the page. Your field names do not have to follow any particular conventions, and should succinctly say what the data item is. When specifying the field types for each field, try to use the following categories: Alpha Code, Numeric Code, Numeric, Text, Date, and Logical. If the field does not fall into one of these categories, you may call it what you like. In the LENGTH/FORMAT column, enter a field length for Code and Text fields. For Numeric fields, enter a format (i.e., decimal with 3 places) and the envisioned range of the numbers to be stored in the field (i.e., <100). For Date fields, please enter the format that you prefer. Logical fields need no entries in the LENGTH/FORMAT column.

RECORD TYPE (from Summary): 1.1

CONTENTS/PURPOSE: Journal article type.

What other record types might this record be linked with?

-----FIELDS-----		
NAME	TYPE	LENGTH/FORMAT
JOURNAL	Text	30
VOLUME	Text	10
NUMBER	Text	2
PAGES	Text	9: -
DATE	Date	MMDDYYYY - - - -

1. INPUT DATA/RECORD TYPES
1.1.2 DATA/RECORD TYPES DETAILS

Instructions: Fill out a detail page for each entry made in the record type summary. Please be sure to copy the "RECORD TYPE" number used in the summary to this page. Then fill out the rest of the page. Your field names do not have to follow any particular conventions, and should succinctly say what the data item is. When specifying the field types for each field, try to use the following categories: Alpha Code, Numeric Code, Numeric, Text, Date, and Logical. If the field does not fall into one of these categories, you may call it what you like. In the LENGTH/FORMAT column, enter a field length for Code and Text fields. For Numeric fields, enter a format (i.e., decimal with 3 places) and the envisioned range of the numbers to be stored in the field (i.e., <100). For Date fields, please enter the format that you prefer. Logical fields need no entries in the LENGTH/FORMAT column.

RECORD TYPE (from Summary): 1.2

CONTENTS/PURPOSE: Report type.

What other record types might this record be linked with?

-----FIELDS-----		
NAME	TYPE	LENGTH/FORMAT
ORGANIZATION	Text	30
CITY	Text	20
STATE	Text	2
DATE	Date	MMYYYY

1. INPUT DATA/RECORD TYPES
1.1.3 DATA/RECORD TYPES DETAILS

Instructions: Fill out a detail page for each entry made in the record type summary. Please be sure to copy the "RECORD TYPE" number used in the summary to this page. Then fill out the rest of the page. Your field names do not have to follow any particular conventions, and should succinctly say what the data item is. When specifying the field types for each field, try to use the following categories: Alpha Code, Numeric Code, Numeric, Text, Date, and Logical. If the field does not fall into one of these categories, you may call it what you like. In the LENGTH/FORMAT column, enter a field length for Code and Text fields. For Numeric fields, enter a format (i.e., decimal with 3 places) and the envisioned range of the numbers to be stored in the field (i.e., <100). For Date fields, please enter the format that you prefer. Logical fields need no entries in the LENGTH/FORMAT column.

RECORD TYPE (from Summary): 1.3

CONTENTS/PURPOSE: Meeting presentation type.

What other record types might this record be linked with?

-----FIELDS-----		
NAME	TYPE	LENGTH/FORMAT
OCCASION	Text	50
SOCIETY	Text	30
CITY	Text	20
STATE	Date	2
BEGINDATE	Date	MMDDYYYY
ENDDATE	Date	MMDDYYYY

1. INPUT DATA/RECORD TYPES
1.1.4 DATA/RECORD TYPES DETAILS

Instructions: Fill out a detail page for each entry made in the record type summary. Please be sure to copy the "RECORD TYPE" number used in the summary to this page. Then fill out the rest of the page. Your field names do not have to follow any particular conventions, and should succinctly say what the data item is. When specifying the field types for each field, try to use the following categories: Alpha Code, Numeric Code, Numeric, Text, Date, and Logical. If the field does not fall into one of these categories, you may call it what you like. In the LENGTH/FORMAT column, enter a field length for Code and Text fields. For Numeric fields, enter a format (i.e., decimal with 3 places) and the envisioned range of the numbers to be stored in the field (i.e., <100). For Date fields, please enter the format that you prefer. Logical fields need no entries in the LENGTH/FORMAT column.

RECORD TYPE (from Summary): 1.4

CONTENTS/PURPOSE: PC software type.

What other record types might this record be linked with?

-----FIELDS-----		
NAME	TYPE	LENGTH/FORMAT
ORGANIZATION	Text	30
CITY	Text	20
STATE	Text	2
DATE	Date	MMYYYY
VERSION	Text	10

1. INPUT DATA/RECORD TYPES
1.1.5 DATA/RECORD TYPES DETAILS

Instructions: Fill out a detail page for each entry made in the record type summary. Please be sure to copy the "RECORD TYPE" number used in the summary to this page. Then fill out the rest of the page. Your field names do not have to follow any particular conventions, and should succinctly say what the data item is. When specifying the field types for each field, try to use the following categories: Alpha Code, Numeric Code, Numeric, Text, Date, and Logical. If the field does not fall into one of these categories, you may call it what you like. In the LENGTH/FORMAT column, enter a field length for Code and Text fields. For Numeric fields, enter a format (i.e., decimal with 3 places) and the envisioned range of the numbers to be stored in the field (i.e., <100). For Date fields, please enter the format that you prefer. Logical fields need no entries in the LENGTH/FORMAT column.

RECORD TYPE (from Summary): 1.5

CONTENTS/PURPOSE: Non-PC software type.

What other record types might this record be linked with?

-----FIELDS-----		
NAME	TYPE	LENGTH/FORMAT
ORGANIZATION	Text	30
CITY	Text	20
STATE	Text	2
DATE	Date	MMYYYY
VERSION	Text	10

1. INPUT DATA/RECORD TYPES
1.1.6 DATA/RECORD TYPES DETAILS

Instructions: Fill out a detail page for each entry made in the record type summary. Please be sure to copy the "RECORD TYPE" number used in the summary to this page. Then fill out the rest of the page. Your field names do not have to follow any particular conventions, and should succinctly say what the data item is. When specifying the field types for each field, try to use the following categories: Alpha Code, Numeric Code, Numeric, Text, Date, and Logical. If the field does not fall into one of these categories, you may call it what you like. In the LENGTH/FORMAT column, enter a field length for Code and Text fields. For Numeric fields, enter a format (i.e., decimal with 3 places) and the envisioned range of the numbers to be stored in the field (i.e., <100). For Date fields, please enter the format that you prefer. Logical fields need no entries in the LENGTH/FORMAT column.

RECORD TYPE (from Summary): 1.6

CONTENTS/PURPOSE: Patent type.

What other record types might this record be linked with?

-----FIELDS-----		
NAME	TYPE	LENGTH/FORMAT
ASSIGNEE	Text	25
FILEDATE	Date	MMDDYYYY
ISSUEDATE	Date	MMDDYYYY
CITY	Text	20
STATE	Text	2

1. INPUT DATA/RECORD TYPES
1.1.7 DATA/RECORD TYPES DETAILS

Instructions: Fill out a detail page for each entry made in the record type summary. Please be sure to copy the "RECORD TYPE" number used in the summary to this page. Then fill out the rest of the page. Your field names do not have to follow any particular conventions, and should succinctly say what the data item is. When specifying the field types for each field, try to use the following categories: Alpha Code, Numeric Code, Numeric, Text, Date, and Logical. If the field does not fall into one of these categories, you may call it what you like. In the LENGTH/FORMAT column, enter a field length for Code and Text fields. For Numeric fields, enter a format (i.e., decimal with 3 places) and the envisioned range of the numbers to be stored in the field (i.e., <100). For Date fields, please enter the format that you prefer. Logical fields need no entries in the LENGTH/FORMAT column.

RECORD TYPE (from Summary): 1.7

CONTENTS/PURPOSE: Book article/chapter type.

What other record types might this record be linked with?

-----FIELDS-----		
NAME	TYPE	LENGTH/FORMAT
PUBLISHER	Text	30
CITY	Text	20
STATE	Text	2
DATE	Date	MMYYYY (sometimes only YYYY)
EDITOR1...n	Text	30/last name, FI, MI
EDITION	Numeric	1
BOOKTITLE	Text	50

1. INPUT DATA/RECORD TYPES
1.1.8 DATA/RECORD TYPES DETAILS

Instructions: Fill out a detail page for each entry made in the record type summary. Please be sure to copy the "RECORD TYPE" number used in the summary to this page. Then fill out the rest of the page. Your field names do not have to follow any particular conventions, and should succinctly say what the data item is. When specifying the field types for each field, try to use the following categories: Alpha Code, Numeric Code, Numeric, Text, Date, and Logical. If the field does not fall into one of these categories, you may call it what you like. In the LENGTH/FORMAT column, enter a field length for Code and Text fields. For Numeric fields, enter a format (i.e., decimal with 3 places) and the envisioned range of the numbers to be stored in the field (i.e., <100). For Date fields, please enter the format that you prefer. Logical fields need no entries in the LENGTH/FORMAT column.

RECORD TYPE (from Summary): 1.8

CONTENTS/PURPOSE: Other type.

What other record types might this record be linked with?

-----FIELDS-----		
NAME	TYPE	LENGTH/FORMAT
COMMENT	Text	50/free text to accommodate miscellaneous information

1. INPUT DATA/RECORD TYPES
1.2 INPUT DATA/RECORD TYPES DETAILS

Instructions: Fill out a detail page for each entry made in the record type summary. Please be sure to copy the "RECORD TYPE" number used in the summary to this page. Then fill out the rest of the page. Your field names do not have to follow any particular conventions, and should succinctly say what the data item is. When specifying the field types for each field, try to use the following categories: Alpha Code, Numeric Code, Numeric, Text, Date, and Logical. If the field does not fall into one of these categories, you may call it what you like. In the LENGTH/FORMAT column, enter a field length for Code and Text fields. For Numeric fields, enter a format (i.e., decimal with 3 places) and the envisioned range of the numbers to be stored in the field (i.e., <100). For Date fields, please enter the format that you prefer. Logical fields need no entries in the LENGTH/FORMAT column.

RECORD TYPE (from Summary): 2

CONTENTS/PURPOSE: Survey information to analyze use of ECUT outputs.

What other record types might this record be linked with?

1, 3, 6

-----FIELDS-----		
NAME	TYPE	LENGTH/FORMAT
RESPONDENT	Text	30/last name, FI, MI
TITLE	Text	35
LEARN	Text	35
TRANSFER	Logical	
USE1	Logical array	1/1=background, 2=applied research, 3=product development, 4=other
SURVEYID	Numeric	3/integer
REFERENCED	Logical	
NREFERENCE	Numeric	1/integer
REFERENCE1...n	Text	80/title, author, date, document
SECTOR	Numeric	2/SIC codes
TELEPHONE	Text	13(____)____ - ____
COMMENT	Text	100

1. INPUT DATA/RECORD TYPES
1.3 INPUT DATA/RECORD TYPES DETAILS

Instructions: Fill out a detail page for each entry made in the record type summary. Please be sure to copy the "RECORD TYPE" number used in the summary to this page. Then fill out the rest of the page. Your field names do not have to follow any particular conventions, and should succinctly say what the data item is. When specifying the field types for each field, try to use the following categories: Alpha Code, Numeric Code, Numeric, Text, Date, and Logical. If the field does not fall into one of these categories, you may call it what you like. In the LENGTH/FORMAT column, enter a field length for Code and Text fields. For Numeric fields, enter a format (i.e., decimal with 3 places) and the envisioned range of the numbers to be stored in the field (i.e., <100). For Date fields, please enter the format that you prefer. Logical fields need no entries in the LENGTH/FORMAT column.

RECORD TYPE (from Summary): 3

CONTENTS/PURPOSE: Information to identify provider of document/copy and when request was made; also requestor information (where possible) to permit direct survey mailing or phonecall.

What other record types might this record be linked with?

5, 2

-----FIELDS-----		
NAME	TYPE	LENGTH/FORMAT
TITLE	Text	35
REQUESTID	Text	10
PROVIDER1	Numeric Code	1/1=NTIS, 2=ECUT, 3=Author, 4=Journal, 5=Society, 6=Software Center
PROVIDER2	Text	30/Name of provider (for providers 3, 4, 5)
DATE	Date	MMDDYYYY
CONTACT	Text	50/Name, phone number
TAG	Logical	1

1. INPUT DATA/RECORD TYPES
 1.3.1 INPUT DATA/RECORD TYPES DETAILS

Instructions: Fill out a detail page for each entry made in the record type summary. Please be sure to copy the "RECORD TYPE" number used in the summary to this page. Then fill out the rest of the page. Your field names do not have to follow any particular conventions, and should succinctly say what the data item is. When specifying the field types for each field, try to use the following categories: Alpha Code, Numeric Code, Numeric, Text, Date, and Logical. If the field does not fall into one of these categories, you may call it what you like. In the LENGTH/FORMAT column, enter a field length for Code and Text fields. For Numeric fields, enter a format (i.e., decimal with 3 places) and the envisioned range of the numbers to be stored in the field (i.e., <100). For Date fields, please enter the format that you prefer. Logical fields need no entries in the LENGTH/FORMAT column.

RECORD TYPE (from Summary): 3.1

CONTENTS/PURPOSE: Respondent: If respondent to survey has provided name, etc., it will be stored here.

What other record types might this record be linked with?

-----FIELDS-----		
NAME	TYPE	LENGTH/FORMAT
REQUESTOR	Text	30/Last name, FI, MI
ORGANIZATION	Text	30
ADDRESS	Text	30
CITY	Text	20
STATE	Text	2
ZIP	Text	5
PHONE	Text	13/() -

1. INPUT DATA/RECORD TYPES
1.4 INPUT DATA/RECORD TYPES DETAILS

Instructions: Fill out a detail page for each entry made in the record type summary. Please be sure to copy the "RECORD TYPE" number used in the summary to this page. Then fill out the rest of the page. Your field names do not have to follow any particular conventions, and should succinctly say what the data item is. When specifying the field types for each field, try to use the following categories: Alpha Code, Numeric Code, Numeric, Text, Date, and Logical. If the field does not fall into one of these categories, you may call it what you like. In the LENGTH/FORMAT column, enter a field length for Code and Text fields. For Numeric fields, enter a format (i.e., decimal with 3 places) and the envisioned range of the numbers to be stored in the field (i.e., <100). For Date fields, please enter the format that you prefer. Logical fields need no entries in the LENGTH/FORMAT column.

RECORD TYPE (from Summary): 4

CONTENTS/PURPOSE: Information on in-house (PNL,ECUT) evaluation of a referencing document's use of an ECUT output.

What other record types might this record be linked with?

1

-----FIELDS-----		
NAME	TYPE	LENGTH/FORMAT
EVALUATOR	Text	30/Last name, FI, MI
TITLE	Text	35
DOCUMENTID	Text	20
USEDFOR	Logical Array	4/1=Background, 2=Applied Research, 3=Product Development, 3=Other
USES	Logical Array	4/1=Uses data, 2=Uses methodology, 3=Uses software, 4=Other
FLAG	Logical	1/T-important use, mention
SECTOR	Numeric Code	2/SIC
COMMENT	Text	200/Abstract-description of referencing document and nature (context) of reference

1. INPUT DATA/RECORD TYPES
1.5 INPUT DATA/RECORD TYPES DETAILS

Instructions: Fill out a detail page for each entry made in the record type summary. Please be sure to copy the "RECORD TYPE" number used in the summary to this page. Then fill out the rest of the page. Your field names do not have to follow any particular conventions, and should succinctly say what the data item is. When specifying the field types for each field, try to use the following categories: Alpha Code, Numeric Code, Numeric, Text, Date, and Logical. If the field does not fall into one of these categories, you may call it what you like. In the LENGTH/FORMAT column, enter a field length for Code and Text fields. For Numeric fields, enter a format (i.e., decimal with 3 places) and the envisioned range of the numbers to be stored in the field (i.e., <100). For Date fields, please enter the format that you prefer. Logical fields need no entries in the LENGTH/FORMAT column.

RECORD TYPE (from Summary): 5

CONTENTS/PURPOSE: Bibliographic and subject information on ECUT outputs.

What other record types might this record be linked with?

1, 3, 6

-----FIELDS-----		
NAME	TYPE	LENGTH/FORMAT
TITLE	Text	35
AUTHOR1...n	Text	30/Last name, FI, MI
DOCUMENTID	Text	20
AREA	Numeric Code	1/1=Combustion, 2=Thermal Sciences 3=Materials, 4=Catalysts/ Biocatalysts, 5=Tribology, 6=Systems Analysis, 7=Other
TYPE	Numeric Code	1/1=Journal Article, 2=Report, 3=Meeting Presentation, 4=PC software, 5=Non-PC software, 6=Patent, 7=Book article/chapter, 8=Other, 9=ECUT sponsored workshop

Depending upon the value of the TYPE field, an additional record is provided to store remaining reference information. These are described as Record Types 5.1 through 5.9.

1. INPUT DATA/RECORD TYPES
 1.5.1 INPUT DATA/RECORD TYPES DETAILS

Instructions: Fill out a detail page for each entry made in the record type summary. Please be sure to copy the "RECORD TYPE" number used in the summary to this page. Then fill out the rest of the page. Your field names do not have to follow any particular conventions, and should succinctly say what the data item is. When specifying the field types for each field, try to use the following categories: Alpha Code, Numeric Code, Numeric, Text, Date, and Logical. If the field does not fall into one of these categories, you may call it what you like. In the LENGTH/FORMAT column, enter a field length for Code and Text fields. For Numeric fields, enter a format (i.e., decimal with 3 places) and the envisioned range of the numbers to be stored in the field (i.e., <100). For Date fields, please enter the format that you prefer. Logical fields need no entries in the LENGTH/FORMAT column.

RECORD TYPE (from Summary): 5.1

CONTENTS/PURPOSE: Journal article type.

What other record types might this record be linked with?

-----FIELDS-----		
NAME	TYPE	LENGTH/FORMAT
JOURNAL	Text	30
VOLUME	Text	10
NUMBER	Text	2
PAGES	Text	9:
DATE	Date	MMDDYYYY - - - - -

1. INPUT DATA/RECORD TYPES
1.5.2 INPUT DATA/RECORD TYPES DETAILS

Instructions: Fill out a detail page for each entry made in the record type summary. Please be sure to copy the "RECORD TYPE" number used in the summary to this page. Then fill out the rest of the page. Your field names do not have to follow any particular conventions, and should succinctly say what the data item is. When specifying the field types for each field, try to use the following categories: Alpha Code, Numeric Code, Numeric, Text, Date, and Logical. If the field does not fall into one of these categories, you may call it what you like. In the LENGTH/FORMAT column, enter a field length for Code and Text fields. For Numeric fields, enter a format (i.e., decimal with 3 places) and the envisioned range of the numbers to be stored in the field (i.e., <100). For Date fields, please enter the format that you prefer. Logical fields need no entries in the LENGTH/FORMAT column.

RECORD TYPE (from Summary): 5.2

CONTENTS/PURPOSE: Report type.

What other record types might this record be linked with?

-----FIELDS-----		
NAME	TYPE	LENGTH/FORMAT
ORGANIZATION	Text	30
CITY	Text	20
STATE	Text	2
DATE	Date	MMYYYY

1. INPUT DATA/RECORD TYPES
1.5.3 INPUT DATA/RECORD TYPES DETAILS

Instructions: Fill out a detail page for each entry made in the record type summary. Please be sure to copy the "RECORD TYPE" number used in the summary to this page. Then fill out the rest of the page. Your field names do not have to follow any particular conventions, and should succinctly say what the data item is. When specifying the field types for each field, try to use the following categories: Alpha Code, Numeric Code, Numeric, Text, Date, and Logical. If the field does not fall into one of these categories, you may call it what you like. In the LENGTH/FORMAT column, enter a field length for Code and Text fields. For Numeric fields, enter a format (i.e., decimal with 3 places) and the envisioned range of the numbers to be stored in the field (i.e., <100). For Date fields, please enter the format that you prefer. Logical fields need no entries in the LENGTH/FORMAT column.

RECORD TYPE (from Summary): 5.3

CONTENTS/PURPOSE: Meeting presentation type.

What other record types might this record be linked with?

-----FIELDS-----		
NAME	TYPE	LENGTH/FORMAT
OCCASION	Text	50
SOCIETY	Text	20
CITY	Text	20
STATE	Text	2
BEGINDATE	Date	MMDDYYYY
ENDDATE	Date	MMDDYYYY

1. INPUT DATA/RECORD TYPES
1.5.4 INPUT DATA/RECORD TYPES DETAILS

Instructions: Fill out a detail page for each entry made in the record type summary. Please be sure to copy the "RECORD TYPE" number used in the summary to this page. Then fill out the rest of the page. Your field names do not have to follow any particular conventions, and should succinctly say what the data item is. When specifying the field types for each field, try to use the following categories: Alpha Code, Numeric Code, Numeric, Text, Date, and Logical. If the field does not fall into one of these categories, you may call it what you like. In the LENGTH/FORMAT column, enter a field length for Code and Text fields. For Numeric fields, enter a format (i.e., decimal with 3 places) and the envisioned range of the numbers to be stored in the field (i.e., <100). For Date fields, please enter the format that you prefer. Logical fields need no entries in the LENGTH/FORMAT column.

RECORD TYPE (from Summary): 5.4

CONTENTS/PURPOSE: PC software type.

What other record types might this record be linked with?

-----FIELDS-----		
NAME	TYPE	LENGTH/FORMAT
ORGANIZATION	Text	30
CITY	Text	20
STATE	Text	2
DATE	Date	MMYYYY
VERSION	Text	10

1. INPUT DATA/RECORD TYPES
1.5.5 INPUT DATA/RECORD TYPES DETAILS

Instructions: Fill out a detail page for each entry made in the record type summary. Please be sure to copy the "RECORD TYPE" number used in the summary to this page. Then fill out the rest of the page. Your field names do not have to follow any particular conventions, and should succinctly say what the data item is. When specifying the field types for each field, try to use the following categories: Alpha Code, Numeric Code, Numeric, Text, Date, and Logical. If the field does not fall into one of these categories, you may call it what you like. In the LENGTH/FORMAT column, enter a field length for Code and Text fields. For Numeric fields, enter a format (i.e., decimal with 3 places) and the envisioned range of the numbers to be stored in the field (i.e., <100). For Date fields, please enter the format that you prefer. Logical fields need no entries in the LENGTH/FORMAT column.

RECORD TYPE (from Summary): 5.5

CONTENTS/PURPOSE: Non-PC software type.

What other record types might this record be linked with?

-----FIELDS-----		
NAME	TYPE	LENGTH/FORMAT
ORGANIZATION	Text	30
CITY	Text	20
STATE	Text	2
DATE	Date	MMYYYY
VERSION	Text	10

1. INPUT DATA/RECORD TYPES
1.5.6 INPUT DATA/RECORD TYPES DETAILS

Instructions: Fill out a detail page for each entry made in the record type summary. Please be sure to copy the "RECORD TYPE" number used in the summary to this page. Then fill out the rest of the page. Your field names do not have to follow any particular conventions, and should succinctly say what the data item is. When specifying the field types for each field, try to use the following categories: Alpha Code, Numeric Code, Numeric, Text, Date, and Logical. If the field does not fall into one of these categories, you may call it what you like. In the LENGTH/FORMAT column, enter a field length for Code and Text fields. For Numeric fields, enter a format (i.e., decimal with 3 places) and the envisioned range of the numbers to be stored in the field (i.e., <100). For Date fields, please enter the format that you prefer. Logical fields need no entries in the LENGTH/FORMAT column.

RECORD TYPE (from Summary): 5.6

CONTENTS/PURPOSE: Patent type.

What other record types might this record be linked with?

-----FIELDS-----		
NAME	TYPE	LENGTH/FORMAT
ASSIGNEE	Text	25
FILEDATE	Date	MMDDYYYY
ISSUE DATE	Date	MMDDYYYY
CITY	Text	20
STATE	Text	2

1. INPUT DATA/RECORD TYPES
1.5.7 INPUT DATA/RECORD TYPES DETAILS

Instructions: Fill out a detail page for each entry made in the record type summary. Please be sure to copy the "RECORD TYPE" number used in the summary to this page. Then fill out the rest of the page. Your field names do not have to follow any particular conventions, and should succinctly say what the data item is. When specifying the field types for each field, try to use the following categories: Alpha Code, Numeric Code, Numeric, Text, Date, and Logical. If the field does not fall into one of these categories, you may call it what you like. In the LENGTH/FORMAT column, enter a field length for Code and Text fields. For Numeric fields, enter a format (i.e., decimal with 3 places) and the envisioned range of the numbers to be stored in the field (i.e., <100). For Date fields, please enter the format that you prefer. Logical fields need no entries in the LENGTH/FORMAT column.

RECORD TYPE (from Summary): 5.7

CONTENTS/PURPOSE: Book article/chapter type.

What other record types might this record be linked with?

-----FIELDS-----		
NAME	TYPE	LENGTH/FORMAT
PUBLISHER	Text	30
CITY	Text	20
STATE	Text	2
DATE	Date	MMYYYY (sometimes only YYYY)
EDITOR1...n	Text	30/last name, FI, MI
EDITION	Numeric	1
BOOKTITLE	Text	50

1. INPUT DATA/RECORD TYPES
1.5.8 INPUT DATA/RECORD TYPES DETAILS

Instructions: Fill out a detail page for each entry made in the record type summary. Please be sure to copy the "RECORD TYPE" number used in the summary to this page. Then fill out the rest of the page. Your field names do not have to follow any particular conventions, and should succinctly say what the data item is. When specifying the field types for each field, try to use the following categories: Alpha Code, Numeric Code, Numeric, Text, Date, and Logical. If the field does not fall into one of these categories, you may call it what you like. In the LENGTH/FORMAT column, enter a field length for Code and Text fields. For Numeric fields, enter a format (i.e., decimal with 3 places) and the envisioned range of the numbers to be stored in the field (i.e., <100). For Date fields, please enter the format that you prefer. Logical fields need no entries in the LENGTH/FORMAT column.

RECORD TYPE (from Summary): 5.8

CONTENTS/PURPOSE: Other type.

What other record types might this record be linked with?

-----FIELDS-----		
NAME	TYPE	LENGTH/FORMAT
COMMENT	Text	50/free text to accommodate miscellaneous information

1. INPUT DATA/RECORD TYPES
 1.5.9 INPUT DATA/RECORD TYPES DETAILS

Instructions: Fill out a detail page for each entry made in the record type summary. Please be sure to copy the "RECORD TYPE" number used in the summary to this page. Then fill out the rest of the page. Your field names do not have to follow any particular conventions, and should succinctly say what the data item is. When specifying the field types for each field, try to use the following categories: Alpha Code, Numeric Code, Numeric, Text, Date, and Logical. If the field does not fall into one of these categories, you may call it what you like. In the LENGTH/FORMAT column, enter a field length for Code and Text fields. For Numeric fields, enter a format (i.e., decimal with 3 places) and the envisioned range of the numbers to be stored in the field (i.e., <100). For Date fields, please enter the format that you prefer. Logical fields need no entries in the LENGTH/FORMAT column.

RECORD TYPE (from Summary): 5.9

CONTENTS/PURPOSE: ECUT sponsored workshop type.

What other record types might this record be linked with?

-----FIELDS-----		
NAME	TYPE	LENGTH/FORMAT
WORKSHOP	Text	30
CITY	Text	20
STATE	Text	2
BEGINDATE	Date	MMDDYYYY
ENDDATE	Date	MMDDYYYY
AREA	Numeric Code	1/1=Combustion, 2=Thermal Sciences, 3=Materials, 4=Catalysts/Biocatalysts, 5=Tribology, 6=Systems Analysis, 7=Other
WORKSHOPID	Integer	2
ATTENDEES	Integer	3

1. INPUT DATA/RECORD TYPES

1.6 INPUT DATA/RECORD TYPES DETAILS

Instructions: Fill out a detail page for each entry made in the record type summary. Please be sure to copy the "RECORD TYPE" number used in the summary to this page. Then fill out the rest of the page. Your field names do not have to follow any particular conventions, and should succinctly say what the data item is. When specifying the field types for each field, try to use the following categories: Alpha Code, Numeric Code, Numeric, Text, Date, and Logical. If the field does not fall into one of these categories, you may call it what you like. In the LENGTH/FORMAT column, enter a field length for Code and Text fields. For Numeric fields, enter a format (i.e., decimal with 3 places) and the envisioned range of the numbers to be stored in the field (i.e., <100). For Date fields, please enter the format that you prefer. Logical fields need no entries in the LENGTH/FORMAT column.

RECORD TYPE (from Summary): 6

CONTENTS/PURPOSE: Mailing list information on attendees of ECUT-sponsored workshops, to enable more efficient surveying.

What other record types might this record be linked with?

5, 2

-----FIELDS-----		
NAME	TYPE	LENGTH/FORMAT
WORKSHOPID	Numeric	2
NAME	Text	30/Last name, FI, MI
ORGANIZATION	Text	30
ADDRESS	Text	30
CITY	Text	20
STATE	Text	2
ZIP	Text	5
PHONE	Text	13/(____)____ - ____

2. INDICATORS
2.1 COUNT INDICATORS

Instructions: Use this page to list indicators falling into the "count" category. For each count indicator, enter the variable you wish to count in the "COUNT OF" column. If you will want this count broken down by additional variables, list them in the "SUBSETS" column. (For example, to count abstracts overall and by research area, enter 'abstracts' in the "COUNT OF" column, and 'research area' in the "SUBSETS" column.) Use an additional page if necessary.

COUNT OF	SUBSETS
Citations	Research Area, Output Type, DocumentID (and document)
Requests	Research Area, Output Type, Provider1, (Document ID)
Attendees	Research Area
Outputs	Research Area, Output Type
USED FOR	Type of Use
USES	Type of Use

2. INDICATORS

2.2 CROSSTABS INDICATORS

Instructions: Use this page to list indicators falling into the "crosstab" category. For each entry, enter the two main variables you wish to tabulate in the "CROSSTABS OF" column. If you will want a further breakdown by an additional variable, enter it in the "SUBSETS" column. (For example, to produce a separate table for each industry of a 'research area by output type' table, enter 'research area' and 'output type' in the "CROSSTABS OF" column, and 'industry' in the "SUBSETS" column.) Use an additional page if necessary.

<u>CROSSTABS OF</u>	<u>SUBSETS</u>
Citations: Research Area by Output Type	Industry
Requests: Research Area by Output Type	Industry
Outputs: Research Area by Output Type	
USED FOR: Type of use by Output Type	Industry
USES: Type of use by Output Type	Industry

2. INDICATORS

2.3 LAG AND OTHER INDICATORS

Instructions: Use this page to list indicators which do not fall into the count or crosstab categories of indicator. For each entry, use a few words to describe what the indicator is, and indicate the variables you would like to analyze in the "VARIABLES INVOLVED" column. Try to (simply) state the relationship of these variables. For instance, the indicator 'publication/request lag' might be described as 'difference between publication date and request date, in months.' Use an additional page to list indicators if necessary. Also feel free to further describe complex indicators on additional pages.

TYPE OF INDICATOR	VARIABLES INVOLVED
Publication/Request	Difference between publication date and request date, in months; histograms by type of output (subsets by research area).
Publication/Citation	Difference between publication date and citation date, in months; histograms by type of output (subsets by research area).

3. OUTPUT REPORTS
3.0 OUTPUT REPORTS SUMMARY

Instructions: I am assuming that each indicator will provide for its own printed output, so you do not need to list indicator outputs. What I need here is a list of 'text output' reports (examples might be "list of all articles," "abstracts by industry" and so on). Use sequential numbers in the "REPORT" column so that each summary entry can be keyed to a detail page. Use an additional summary page if you need to. Then fill out a detail page for each summary entry.

<u>REPORT</u>	<u>DESCRIPTION (in a sentence or phrase)</u>
---------------	--

1	List of all outputs
---	---------------------

2	Abstracts by industry
---	-----------------------

3. OUTPUT REPORTS
3.1 OUTPUT REPORT DETAILS

Instructions: Fill out a detail page for each entry made in the report summary. Please be sure to copy the "REPORT" number used in the summary to this page. Then fill out the blanks. You may attach a sheet of paper with a rough sketch of the report if you like; please label it with the "REPORT" number if you do.

REPORT (from Summary): 3.1

TITLE: List of all outputs

DESCRIPTION: A "Bibliographic" listing describing specific outputs. Should be sorted chronologically, i.e., earliest to most recent.

DESIRED SUBSETS: Research Area and type of output

DESIRED FORMAT: 8-1/2x11 X 11x8-1/2 14x11 Other

3. OUTPUT REPORTS
3.2 OUTPUT REPORT DETAILS

Instructions: Fill out a detail page for each entry made in the report summary. Please be sure to copy the "REPORT" number used in the summary to this page. Then fill out the blanks. You may attach a sheet of paper with a rough sketch of the report if you like; please label it with the "REPORT" number if you do.

REPORT (from Summary): 3.2

TITLE: List of abstracts

DESCRIPTION: A list of Abstracts from analysis of referencing document and survey forms (if any) sorted by specific output, i.e., publication date of output.

Citations/Requests greater than x - I'd like to have the search capability to specify a minimum number of citations and/or requests and then print the abstracts of those outputs with a number greater than specified.

DESIRED SUBSETS: Citations/Requests >X, Research Area, Flagged Outputs

DESIRED FORMAT: 8-1/2x11 X 11x8-1/2 14x11 Other

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