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AN ASSESSMENT OF THE BASIC ENERGY SCIENCES PROGRAM

VOLUME II — APPENDICES

March 1982

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U.S. DEPARTMENT OF ENERGY
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APPENDIX A

LIST OF PEER REVIEWERS AND THEIR ORGANIZATIONS

APPENDIX A

List of Peer Reviewers and Their Organizations

Professor Hubert I. Aaronson
Carnegie-Mellon University

Dr. Charles A. Anderson
Los Alamos National Laboratory

Professor Ali S. Argon
Massachusetts Institute of Technology

Professor Lloyd Armstrong, Jr.
National Science Foundation

Dr. Pierre Ausloos
National Bureau of Standards

Professor R. W. Balluffi
Massachusetts Institute of Technology

Dr. Charles A. Bankston, Jr.
Los Alamos National Laboratory

Professor H. H. Barschall
University of Wisconsin

Dr. Lynus Barnes
National Bureau of Standards

Dr. John B. Bates
Oak Ridge National Laboratory

Dr. Raymond Baughman
Allied Chemical Corporation

Professor Claire M. Berg
University of Connecticut

Dr. T. G. Berlincourt
Office of Naval Research

Dr. Aaron N. Bloch
Exxon Research and Engineering Company

Dr. John S. Bradley
Exxon Research and Engineering Company

Dr. A. Brailsford
Ford Motor Company

Dr. Walter Braun
National Bureau of Standards

Dr. M. J. Brodsky
International Business Machines
Corporation

Dr. W. L. Brown
Bell Telephone Laboratories

Dr. Louis Brus
Bell Telephone Laboratories

Dr. Otto Buck
Ames Laboratory

Dr. L. E. Burkhart
Ames Laboratory

Professor C. Wayne Burnham
Pennsylvania State University

Professor Robert H. Burris
University of Wisconsin

Dr. R. H. Busey
Oak Ridge National Laboratory

Dr. W. H. Butler
Oak Ridge National Laboratory

Professor R. W. Carpenter
Arizona State University

Professor Richard K. Chang
Yale University

Dr. R. J. Charles
General Electric Research
Laboratories

Dr. Helena Chum
Solar Energy Research Institute

Professor Stuart W. Churchill
University of Pennsylvania

Dr. Timothy Coffey
Naval Research Laboratory

Dr. Robert N. Compton
Oak Ridge National Laboratory

Dr. Peter Connell
Lawrence Livermore National Laboratory

Professor John Costain
Virginia Polytechnic Institute
and State University

Professor Lawrence F. Dahl
University of Wisconsin

Dr. Susan Dahlberg
Bell Telephone Laboratories

Professor John M. Dawson
University of California,
Los Angeles

Dr. Anthony M. Dean
Exxon Research and Engineering Company

Dr. Richard DesLattes, Jr.
National Bureau of Standards

Dr. Charles B. Duke
Xerox Corporation

Dr. Thomas Dunning, Jr.
Argonne National Laboratory

Professor Charles Elbaum
Brown University

Dr. Marvin D. Erickson
Pacific Northwest Laboratory

Professor Peder J. Estrup
Brown University

Professor James G. Ferry
Virginia Polytechnic Institute
and State University

Professor George Fix
Carnegie-Mellon University

Dr. S. N. Foner
Johns Hopkins University

Dr. Horace Furumoto
Candela Corporation

Dr. J. W. Gadzuk
National Bureau of Standards

Professor Aaron I. Galonsky
Michigan State University

Dr. Robert Giaquinta
E. I. du Pont de Nemours
and Company

Professor Martin Gibbs
Brandeis University

Professor Donald M. Ginsberg
University of Illinois

Dr. John L. Gland
General Motors Research
Laboratories

Professor Martin E. Glicksman
Rensselaer Polytechnic Institute

Dr. Terry Godlove
U.S. Department of Energy

Professor Michael Golde
University of Pittsburgh

Professor Gene H. Golub
Stanford University

Dr. Dieter Gruen
Argonne National Laboratory

Dr. Michael Guinan
Lawrence Livermore National
Laboratory

Professor Vladimir Haensel
University of Massachusetts

Dr. Richard Hall
Exxon Research and Engineering
Company

Dr. George Hammond
Allied Chemical Corporation

Professor Robert Haselkorn
University of Chicago

Dr. Barry Haymore
Monsanto Company

Professor J. W. Hightower
Rice University

Dr. John Hulm
Westinghouse Research and Development
Center

Professor F. P. Jona
State University of New York,
Stony Brook

Professor Russell L. Jones
University of California,
Berkeley

Professor George Keller
Colorado School of Mines

Professor Herbert B. Keller
California Institute of Technology

Dr. William W. Kellogg
National Center for Atmospheric
Research

Professor Joseph Kestin
Brown University

Dean George W. Keulks
University of Wisconsin

Professor O. J. Kleppa
University of Chicago

Dr. K. L. Kliewer
Argonne National Laboratory

Dr. U. F. Kocks
Argonne National Laboratory

Professor George Krauss
Colorado School of Mines

Dr. Frank Kreith
Solar Energy Research Institute

Professor David Krogmann
Purdue University

Dr. Edwin L. Kugler
Exxon Research and Engineering
Company

Dr. J. T. Kummer
Ford Motor Company

Professor John D. Lamb
Brigham Young University

Professor Helmut Landsberg
University of Maryland

Professor Daniel Larson
University of Virginia

Professor Charles Levings
North Carolina State University

Dr. M. C. Lin
Naval Research Laboratory

Professor Carl Lundin
University of Tennessee

Dr. Thomas Manuccia
Naval Research Laboratory

Professor John Margrave
Rice University

Dr. J. B. Marling
Lawrence Livermore National Laboratory

Professor Barry Marrs
St. Louis University

Dr. Donald M. Mattox
Sandia National Laboratories

Professor Paul Mazzocchi
University of Maryland

Dr. Richard McCorkle
International Business Machines
Corporation

Dr. James McDonald
Naval Research Laboratory

Professor Marcus McEllistrem
National Science Foundation

Professor Thomas J. McIlrath
University of Maryland

Dr. Dennis McWhan
Bell Telephone Laboratories

Professor Richard Miles
Princeton University

Dr. Terry A. Miller
Bell Telephone Laboratories

Dr. James Muckerman
Brookhaven National Laboratory

Dr. J. D. Navratil
Rockwell International Corporation

Professor Malcolm Nicol
University of California, Los Angeles

Dr. J. L. Opsal
Lawrence Livermore National Laboratory

Professor Steven A. Orszag
Massachusetts Institute of Technology

Professor Ray D. Owen
California Institute of Technology

Dr. Robert A. Page
U.S. Geological Survey

Professor Peter Paul
State University of New York,
Stony Brook

Dr. Robert A. Penneman
Los Alamos National Laboratory

Dr. Samuel Penner
National Bureau of Standards

Dr. J. M. Poate
Bell Telephone Laboratories

Dr. Carl Poppe
Lawrence Livermore National
Laboratory

Professor Ronald Pugmire
University of Utah

Dr. Kent Reed
National Bureau of Standards

Dr. C. W. Reich
Idaho National Engineering
Laboratory

Dr. John F. Reintjes, Jr.
Naval Research Laboratory

Professor Irwin Remson
Stanford University

Professor Werner C. Rheinboldt
University of Pittsburgh

Professor John R. Rice
Purdue University

Dr. J. M. Rowe
National Bureau of Standards

Dr. A. W. Ruff, Jr.
National Bureau of Standards

Dr. Fred Saalfeld
Naval Research Laboratory

Professor Hiroshi Sato
Purdue University

Professor Carl J. Scandella
State University of New York,
Stony Brook

Professor George Schatz
Northwestern University

Professor Roman A. Schmitt
Oregon State University

Dr. Wallace Schulz
Rockwell Hanford Operations

Dr. Harold A. Schwarz
Brookhaven National Laboratory

Dr. Tom E. Scott
Alcoa Technical Center

Professor Tom K. Scott
University of North Carolina

Professor Dale E. Seborg
University of California,
Santa Barbara

Dr. Daniel J. Seery
United Technology Research Center

Dr. Richard Semonin
Illinois State Water Survey

Professor Fred Shafizadeh
University of Montana

Professor John R. Shapley
University of Illinois

Dr. Herbert R. Shaw
U.S. Geological Survey

Professor F. S. Sherman
University of Rochester

Dr. Arie Shoshani
Lawrence Berkeley Laboratory

Professor Duward F. Shriver
Northwestern University

Professor Gene Simmons
Massachusetts Institute of
Technology

Professor John P. Simons
University of Utah

Dr. Steve Skedzielewski
Lawrence Livermore National
Laboratory

Dr. Arthur W. Sleight
E. I. du Pont de Nemours and
Company

Dr. Alan B. Smith
Argonne National Laboratory

Dr. William Spindel
National Academy of Sciences

Dr. Clifford L. Spiro
General Electric Research and
Development Center

Professor Jeffrey Steinfeld
Massachusetts Institute of
Technology

Dr. John Stephenson
National Bureau of Standards

Dr. William Steyert
Los Alamos National Laboratory

Dr. G. Brian Street
International Business Machines
Corporation

Dr. Myron Strongin
Brookhaven National Laboratory

Dr. James Sullivan
Argonne National Laboratory

Professor D. W. Tedder
Georgia Institute of Technology

Dr. V. J. Tennery
Oak Ridge National Laboratory

Dr. Robb M. Thomson
National Bureau of Standards

Dr. Thomas A. Tombrello, Jr.
California Institute of Technology

Professor Karl K. Turekian
Yale University

Professor Larry N. Vanderhoef
University of Maryland

Dr. Isaac Vanderhoven
National Oceanic and
Atmospheric Administration

Dr. Edward Von Halle
Oak Ridge Gaseous Diffusion Plant

Professor James B. Wagner, Jr.
Arizona State University

Professor Peter Wagner
Michigan State University

Professor Sigurd Wagner
Princeton University

Professor Victor Wallace
University of Kansas

Professor Johannes Weertman
Northwestern University

Professor Irving Wender
University of Pittsburgh

Professor D. H. Whitmore
Northwestern University

Professor David Whitten
University of North Carolina

Professor John E. Willard
University of Wisconsin

Professor Forman A. Williams
Princeton University

Professor Kenneth Wilson
Cornell University

Professor Ralph Wolfe
University of Illinois

Professor W. G. Wolfer
University of Wisconsin

Dr. Obert R. Wood, II
Bell Telephone Laboratories

Professor Mark Wrighton
Massachusetts Institute of
Technology

Dr. James T. Yardley, III
Allied Chemical Corporation

Dr. F. W. Young
Oak Ridge National Laboratory

Dr. Oskar Zaborsky
National Science Foundation

APPENDIX B

BASIC ENERGY SCIENCES ASSESSMENT PLAN

APPENDIX B

BASIC ENERGY SCIENCES ASSESSMENT PLAN

Purpose

To assess the Basic Energy Sciences (BES) program on the basis of the following questions:

- a. What is the quality of science being conducted in the program?
- b. What is the quality of performers supported by the BES program?
- c. What is the impact of the research on mission oriented needs?

Scope

The intent of this assessment is to provide an indication of general status relative to these questions for each of the BES divisions. The focus is not on individual projects even though a random sample of these will be used to generate data for the overall assessment.

Approach

1. Develop a plan for sampling projects from each of the six BES divisions: Engineering, Mathematics, and Geosciences; Materials Sciences; Chemical Sciences; Nuclear Sciences; Biological Energy Research and Advanced Energy Projects (Attachment 1). An evaluation of the samples should provide for an estimate of the number of projects (within 15 percent at 90 percent confidence) within each division that require BES management attention. The sampling method should also provide for meaningful statement concerning the laboratory versus non-laboratory projects, the "large-dollar" projects and projects with continuous funding for over eight years.
2. Develop procedures (Attachment 2) for conducting project reviews to address the questions concerning quality of science, quality of

performers, and mission impact. The procedures include the mechanics of the process, the instructions to the review groups, items to be considered in the evaluations, and mission impact. The procedures include the mechanics of the process, the instructions to the review groups, items to be considered in the evaluations, and a means of rating each project against the above questions.

3. Develop an information system for recording and analyzing assessment data.
4. Implement the review process:
 - a. Randomly select 129 research projects from the six BES divisions.
 - b. Group each of the projects according to discipline research area (this will be largely on the basis of our ability to find peer reviewers whose expertise spans all or most of the projects in each group).
 - c. Request principal investigators to provide supplementary information needed to assess their projects. This material will be compiled with other material extracted from project files and provided to the reviewers prior to the review meetings.
 - d. Select reviewers competent to review all or most of the projects in each group. Request names of candidate reviewers from organizations such as National Laboratories, National Academy of Sciences, and the Department of Energy (DOE). Ask principal investigator to suggest names of reviewers competent to review projects in his particular research area.
 - e. Schedule reviews at the earliest possible date beginning on August 24 at DOE/Germantown. If necessary, reviews could be conducted at DOE/Forrestal and in special circumstances outside Washington.
 - f. Conduct the peer reviews in accordance with the procedures given in Attachment 2.
5. Prepare an initial report to the Director, Office of Energy Research and the Director for Basic Energy Sciences which provides a statistical

summary of results based on the assessment questions and a listing of the major concerns identified in the assessment process. This report, in the form of a briefing, should be available immediately after completion of the final peer reviews.

6. Prepare a detailed analysis of the assessment results as requested and prepare report(s) as appropriate.

Sampling Plan

The BES sampling plan calls for the use of ten cells based on the six BES Divisions. Material and Chemical Sciences were each subdivided into laboratory and non-laboratory cells making a total of eight cells. Two additional cells were created to provide for an adequate sample of long-term non-laboratory projects and large-dollar projects. "Long-term" projects are those over eight years old. "Large-dollar" was defined as the set of projects with the highest funding whose cumulative funding represented approximately one-fourth of the total BES operating funds. The lower cutoff was \$500,000 or five full-time employees.

The population of each cell and number of projects selected in each stratum of the sample universe are given below. The equations for determining sample size and the means of calculating significance are discussed in Appendix C.

<u>Program Area</u>	<u>Total Number of Projects</u>	<u>Total Number of Projects in Sample</u>	<u>Non-Lab Long-Term</u>	<u>Large- Dollar</u>
Materials Sciences (Labs)	207	18	0	5
Materials Sciences (Non-Labs)	214	19	4	1
Chemical Sciences (Labs)	189	16	0	2
Chemical Sciences (Non-Labs)	254	18	5	0
Biological Energy Sciences	85	14	0	0
Nuclear Sciences	38	13	3	2
Engineering, Mathematics and Geosciences	192	20	5	1
Advanced Energy Projects	<u>35</u>	<u>11</u>	<u>0</u>	<u>0</u>
SUBTOTAL	1214	129	17	11

Project Review Process

Project reviews will be conducted on the basis of discipline-research groups. It is estimated that each review group will assess two to five projects and will function semi-independently. In order to achieve an acceptable level of uniformity among the groups, fairly detailed guidelines and evaluation formats are provided as tabs to this Attachment.

Each review group will consist of three to six scientists qualified to review all or most of the projects in the group. DOE will designate a chairman and ask him to assist in forming the group. DOE will provide an executive secretary who will be supported by other DOE staff, DOE program offices and by the Oak Ridge National Laboratory and other National Laboratory staff. The instructions to the review groups are at the end of this Attachment.

Where practical, no more than four projects will be reviewed in a single day by a review group. The review day will consist of a discussion of the process followed by an introduction by the BES project manager(s) giving the background of the projects and their context in the BES program. The project reviews will consist of a five-minute mission impact statement by the program manager, a twenty-minute presentation by the principal investigator (longer for projects over \$500K) and a thirty-minute question and answer period. Ten-minutes remain for the members of the review group to complete their preliminary evaluation. The twenty-minute presentation should cover the following: the scientific motivation for the project (i.e., the scientific problem or question being addressed); the scientific approach being pursued including the logic of the method; techniques, equipment and facilities; previous,

current and anticipated results; and the mission impact. Since the BES project manager will also cover the mission impact, this may be omitted.

During the review period, the scientific peer reviewers will assess the quality of the science, quality of the performers and mission impact. Based upon the information gathered prior to the review meeting and upon the presentation, the reviewers will rate those factors using the formats given in Tabs A and B.

At the conclusion of the review day, each project will be revisited by the committee. The chairman or executive secretary will indicate the distribution of ratings in each category. The reviewers and the BES program manager will have opportunity for discussion, and the ratings can be modified at that time. Finally, each review committee member will be asked to characterize the overall quality and pertinence of each project (Tab C).

The executive secretary will have responsibility for consolidating the summary ratings of the panel. In addition to an unweighted average, the panel will be asked to develop a set of consensus scores. The reviewers will complete a self-rating form (Tab D) to assist the executive secretary in this task. Where the executive secretary believes the consensus score does not adequately reflect the merit of the project, he will enter an independent rating with explanation. The chairman will be invited to comment in writing concerning the executive secretary's evaluation.

Instructions to Review Committee

The review committee is requested to evaluate each project presented with respect to the quality of the research team, quality of science, and

the potential impact or pertinence to the nation's energy needs. To assist the review committee members in their evaluations, DOE has provided a package for each project which contains a number of items relevant to the above factors, including project publications and other project outputs, personnel achievements, honors and awards and detailed project descriptions. Your evaluations should be based on that information and the presentations by the project personnel.

Evaluation sheets are provided for quality of project team and quality of science (Tab A) and mission impact (Tab B). These should be completed during or immediately after each project presentation and given to the executive secretary. At the end of the review day, there will be an opportunity for participants to discuss their evaluations in relation to all the ratings and to reconsider their choices. At that time, the reviewers will be asked to complete an overall project evaluation (Tab C).

Scientific Peer Review (Tab A)

During or at the conclusion of each project presentation, you will be asked to rate the project in each of four areas: quality of project team, scientific merit, approach, and productivity (Tab A). Ratings in these categories use a 0 to 10 scale with the ends of the scale representing extremely bad and outstanding, respectively. Indicators which provide a flavor for the intermediate ratings are provided in the Tab.

For Item 1, "Quality of the Project Team," the reviewers should consider the quantity and quality of publications by the principal team members, honors and awards, review articles, experience relevant to the project area, and other less tangible factors which combine to provide a reputable and

high quality team.

For Item 2A, "Scientific Merit," reviewers should assess the importance of the scientific question or problem addressed by the project including the potential importance or value for science should the project succeed. This judgment should be based primarily on the reviewer's knowledge of the scientific field, and secondarily on the results of review panels and workshops which might be available.

For Item 2B, "Scientific Approach, Techniques, Resources," the reviewers should consider the appropriateness of the experimental and analytical methods used and the level of insight and innovation demonstrated in relation to the requirements of the project. Reviewers should assess the likelihood that the project will lead to significant progress in answering the scientific question it is addressing.

For Item 2C, "Productivity," the reviewers should consider the volume and quality of work produced and relate this output to the resources available and costs incurred. Projects which have not been underway sufficiently long to have products should not be rated on productivity.

Mission Impact (Tab B)

The evaluation of mission impact for a basic science project is a difficult task. The purpose of Tab B is to provide an indication of the nature of the relationship of the project to the Nation's energy needs (Item A). Choice 1 refers to a project whose agenda is directly related to a specific energy problem or need. Time, however, is not a consideration. This choice is as applicable to a fusion problem as a liquifaction problem. Choice 2 differs slightly in that it refers to projects that could lead to a

significant departure in approach (e.g., RF heating of shale). Choice 3 refers to a project whose agenda is primarily to advance science related to energy activities. Choices 4 and 5 are self explanatory.

The remaining parts of Tab B are intended to stimulate an understanding of the nature of the relationship between the project and energy and the importance of that project to the particular energy area, problem or need identified.

Item D asks how clearly a reviewer can articulate the relationship of the scientific issues associated with the energy area and the agenda of the project. Item E asks for an assessment of the potential impact of the project to energy. This calls for a "product" function of the importance of the project to an area and the importance of the area to energy. Clarifying statements in the discussion section are essential to the proper use of this rating.

Overall Project Evaluation (Tab C)

At the conclusion of the review day, all committee members will fill out an overall project evaluation for each project. They will be asked to choose a rating from 0 to 10 which best characterizes their overall evaluation of the project. At the bottom of the form, they should indicate the factors which weighed most heavily in your evaluation.

Project _____
R: _____

Project Group: _____
Date of Review: _____
Preliminary _____ Final _____

Scientific Peer Review Questionnaire

1. Quality of Project Team:

0 2 4 6 8 10

Where an outstanding team would rate in the range 8-10, a strong balanced team of experienced investigators would rate 5-7, a team which would profit from some strengthening would rate 3-4, and a team with serious shortcomings would rate 0-2.

Comments: _____

2A. Scientific Merit (the importance of the scientific problem being addressed).

0 2 4 6 8 10

Where a problem of central importance to advancing the discipline-research area would rate 7-10, sound programmatic research providing information of general usefulness and interest would rate 5-6, a routine research problem would rate a 3-4, and a problem of doubtful or peripheral interest would rate 0-2.

Comments: _____

2B. Scientific Approach, Techniques, Resources

0 2 4 6 8 10

Where a skillful and innovative approach would rate 8-10, a creditable and logical use of state-of-the-art methods would receive a 5-7, an out-of-date approach would score 3-4 and an inappropriate or illogical approach would rank 0-2.

Comments: _____

2C. Productivity

0 2 4 6 8 10

Where 8-10 would mean extensive, high quality output, 5-7 would correspond to interesting results at a reasonable rate, 3-4 would indicate marginal output and 0-2 would denote little evidence of progress.

Comments: _____

Project _____
R: _____

Project Group: _____
Date of Review: _____
Preliminary _____ Final _____

Mission Impact

- A. The following statements describe ways in which a research project can contribute to the Nation's energy needs. Select the one which best describes this project.
1. Project addresses questions related to an identified energy problem or need.
 2. Project addresses questions which could lead to a novel approach to energy development, conservation or use.
 3. Project addresses fundamental questions of science related to the BES mission.
 4. Project is providing information in support of other energy related projects.
 5. None of the above.
- B. Indicate the specific energy area, problem or need(s) to which this research relates
- _____
- C. Indicate the specific scientific question(s) addressed in the research that are most important to the energy applications indicated part B above
- _____
- D. State your estimate of the importance of this research to the area indicated in part A above.

Weak Strong

0 2 4 6 8 10

- E. State your estimate of the probable impact of this project, if successful, to energy development, conservation or use.

Insignificant Significant

0 2 4 6 8 10

Project _____
R: _____

Project Group: _____
Date of Review: _____
Preliminary _____ Final _____

Overall Project Evaluation

0 2 4 6 8 10

An outstanding project would rate 9-10. A strong project deserving of continuing priority support would score 7-8, while a good project with negligible important shortcomings would receive a score of 5-6. A good project with some deficiencies or concerns that should be addressed by BES would warrant a rating of 3-4, and a project with serious shortcomings which warrants close reevaluation by BES would rank 0-2.

Comments: _____

Check factors used in reaching this judgment:

Quality of research staff _____
Quality of science _____
Mission Impact-Pertinence _____
Appropriateness for BES support _____

Project _____
 Reviewer: _____
 R: _____

Project Group: _____
 Date of Review: _____
 Preliminary _____ Final _____

Reviewer Self-Rating

1. Please rate your knowledge in the scientific research area/discipline covered in this project.

0 2 4 6 8 10
 Novice Competent Expert

Comments: _____

2. Please rate your knowledge of mission impact/applications of the science in this project.

0 2 4 6 8 10
 Novice Competent Expert

Comments: _____

3. Indicate personal involvement with the research project or with BES.

	<u>Yes</u>	<u>No</u>
Now or previously funded by BES	_____	_____
Proposed to BES but not funded	_____	_____
Reviewed this project previously for BES	_____	_____
Serve on BES committee in this area	_____	_____
Former professor or student of PI	_____	_____
Now or previously collaborated with PI	_____	_____

Comments: _____

APPENDIX C

SAMPLE DESIGN AND STATISTICAL ANALYSES

SECTION C.1: THE BES EVALUATION SAMPLING PLAN

This section discusses the sampling plan which was used as a guide in determining the sample size and selecting the sample to evaluate the research program* of the Office of Basic Energy Sciences (BES). BES research projects were classified into twenty-four subpopulations (or strata) as a result of a two-way stratification along two factors; one factor being program area and the second factor consisting of the three categories: long-term non-laboratory projects, large-dollar projects, and all other projects.

For the first factor, program areas, Materials Sciences and Chemical Sciences were subdivided into laboratory and non-laboratory strata resulting in eight categories of interest, namely: 1) Materials Sciences projects conducted by DOE laboratories; 2) Materials Sciences projects not conducted by DOE laboratories; 3) Chemical Sciences projects conducted by DOE laboratories; 4) Chemical Sciences projects not conducted by DOE laboratories; 5) Biological Energy Research projects; 6) Nuclear Sciences projects; 7) Engineering, Mathematics, and Geosciences projects; and 8) Advanced Energy Projects. The second factor consists of three subcategories; the first, long-term non-laboratory projects, consists of those non-laboratory projects which started in or before 1974; the second

*The Carbon Dioxide program area was not included in the present assessment, since it had undergone an evaluation within the past year.

subcategory, large-dollar projects, consists of those projects which are in the set of projects whose cumulative funding accounts for approximately one-fourth of the total BES annual operating funds. - the lower cutoff was \$500,000 annual funding. The third subcategory, "all other projects," consists of those projects in the complement of the long-term non-laboratory projects and the large-dollar projects. This stratification scheme is shown in Table C-1.

The proportion, P , of BES projects rated at or above a given threshold is given by

$$p = \frac{\text{number of BES projects at or above a given threshold}}{N} \quad (C-1)$$

where N equals the total number of BES projects. To estimate P , a stratified random sample was taken using the framework as defined in Table C-1 .

Let P_{i1} , P_{i2} , and P_{i3} denote the proportions of projects rated at or above a threshold within the i -th stratum ($i=1, \dots, 8$ program areas) for each of the three subcategories indicated in Table C-1 in which there are any projects ($N_{ij} > 0$).

Let the proportion of projects rated at or above a specified threshold in the i -th program area (row i in Table C-1) be given by $P_{i\cdot}$, where

Table C-1: Stratification of Projects for the BES Evaluation

	1. Long-Term Non-Laboratory	2. Large- Dollar	3. Other*	Total
1. Materials Sciences (Laboratories)	N_{11}^{**}	N_{12}	N_{13}	$N_{1.}$
2. Materials Sciences (Non-Laboratories)	N_{21}	N_{22}	N_{23}	$N_{2.}$
3. Chemical Sciences (Laboratories)	N_{31}	N_{32}	N_{33}	$N_{3.}$
4. Chemical Sciences (Non-Laboratories)	N_{41}	N_{42}	N_{43}	$N_{4.}$
5. Biological Energy Research	N_{51}	N_{52}	N_{53}	$N_{5.}$
6. Nuclear Sciences	N_{61}	N_{62}	N_{63}	$N_{6.}$
7. Engineering, Mathematics, and Geosciences	N_{71}	N_{72}	N_{73}	$N_{7.}$
8. Advanced Energy Projects	<u>N_{81}</u>	<u>N_{82}</u>	<u>N_{83}</u>	<u>$N_{8.}$</u>
Total	$N_{.1}$	$N_{.2}$	$N_{.3}$	N

*Includes all projects which are not Long-Term Non-Laboratory and not Large-Dollar.

** N_{ij} represents the number of projects in the cell defined by the i -th row and j -th column.

$$P_{i.} = \frac{\text{number of projects rated at or above a given threshold in the } i\text{-th program area}}{N_{i.}} \quad (C-2)$$

for $i = 1, \dots, 8$. $N_{i.}$ is the total number of projects in the i -th program area.

If we randomly select n_{i1} , n_{i2} , and n_{i3} projects within the respective three subcategories of the i -th program area, an unbiased estimator of $P_{i.}$ is given by

$$\hat{P}_{i.} = \frac{N_{i1}}{N_{i.}} \hat{P}_{i1} + \frac{N_{i2}}{N_{i.}} \hat{P}_{i2} + \frac{N_{i3}}{N_{i.}} \hat{P}_{i3} \quad (C-3)$$

for $i = 1, \dots, 8$, where

$$\hat{P}_{ij} = \frac{\text{number of projects rated at or above a threshold out of } n_{ij}}{n_{ij}}$$

for $j = 1, 2, 3$. If $N_{ij} = 0$, then the term with $\hat{P}_{ij}$ does not appear.

Note that the size of the sample for the i -th program area ($n_{i.}$) is the sum of n_{i1} , n_{i2} , and n_{i3} , and that $n = \sum_{i=1}^8 n_{i.}$ is the overall sample size.

Let the proportion of projects rated at or above a threshold in the long-term non-laboratory projects category ($j=1$), the large-dollar projects category ($j=2$), and "other" projects category ($j=3$) be given by $P_{.j}$, where

$$P_{.j} = \frac{\text{number of projects rated at or above a given threshold in the } j\text{-th category on the second factor}}{N_{.j}} \quad (C-4)$$

for $j = 1, 2, 3$.

An unbiased estimator of $P_{.j}$ is given by

$$\hat{P}_{.j} = \frac{N_{1j}}{N_{.j}} \hat{p}_{1j} + \frac{N_{2j}}{N_{.j}} \hat{p}_{2j} + \dots + \frac{N_{8j}}{N_{.j}} \hat{p}_{8j} \quad (C-5)$$

for $j = 1, 2, 3$. If $N_{ij} = 0$, then the term with $\hat{p}_{ij}$ does not appear.

Note that the size of the sample for the j -th category is given by

$$n_{.j} = n_{1j} + n_{2j} + \dots + n_{8j}.$$

An unbiased estimator of P , the overall proportion of BES projects rated at or above a given threshold, is given by

$$\hat{P} = \sum_{i=1}^8 \frac{N_i}{N} \hat{P}_i . \quad (C-6)$$

The sample estimate of a proportion and an estimate of its standard deviation permit us to construct approximate lower confidence bounds with prescribed confidence that the one-sided interval includes the average result of all possible samples. To illustrate what is meant by a 90 percent lower confidence bound, assume all possible samples were selected. If each of these were surveyed under essentially the same conditions and an estimated proportion of projects rated at or above a given threshold and its estimated standard deviation were calculated from each sample, then approximately 9/10 of the one-sided intervals from 1.28 standard deviations below the estimate would include the average value (in our case the true value of the proportion being estimated) of all possible samples. An approximate 90 percent lower confidence bound for P can be expressed by:

$$\hat{P} - 1.28(S.D.(\hat{P})) , \quad (C-7)$$

where $S.D.(\hat{P})$ is an estimate of the standard deviation of $\hat{P}$. Similar approximate lower confidence bounds can be given for P_i and $P_{.j}$. These lower confidence bounds assume that the sampling distribution of the estimator is approximately normal. Note that the average value of all

possible samples may or may not be contained in any particular computed one-sided interval. But for a particular sample, one can say with specified confidence that the average of all possible samples is included in the constructed one-sided confidence interval. (Formulas (C-2) through (C-7) are based on Cochran (1977), Chapters 3 and 5.)

The remainder of Section C.1 discusses the determination of appropriate sample sizes. The following criteria were established to determine target sample sizes: 1) 90 percent confidence that the estimate of P be within .1 of the true value of P , and 2) 90 percent confidence that $\hat{P}_{i.}$ and $\hat{P}_{.j}$ be within .15 of $P_{i.}$ and $P_{.j}$, respectively. These criteria are expressed by the following equations:

$$\Pr \left(\left| \hat{P} - P \right| < .1 \right) = 90\%, \quad (\text{C-8})$$

$$\Pr \left(\left| \hat{P}_{i.} - P_{i.} \right| < .15 \right) = 90\%, \text{ for each } i, \text{ and} \quad (\text{C-9})$$

$$\Pr \left(\left| \hat{P}_{.j} - P_{.j} \right| < .15 \right) = 90\%, \text{ for } j = 1 \text{ and } 2^*, \quad (\text{C-10})$$

where "Pr" is an abbreviation for probability. Before the sampling, there was no evidence which indicated that there was a difference among the three proportions within stratum i for $i = 1, 2, \dots, 8$. If there were no differences, the optimum allocation of the sample for any program area would be distributed proportionately over the categories. Then the criterion expressed in equation (C-9) leads to the following equation for

*A criterion on the "other" stratum, $j = 3$, was not required specifically.

determining independently each $n_{i.}$.

$$n_{i.} = \frac{\sum_{j=1}^3 \frac{N_{ij}}{N_{i.}} P_{ij}(1-P_{ij})}{\left(\frac{.15}{1.645}\right)^2 + \frac{1}{N_{i.}} \sum_{j=1}^3 \frac{N_{ij}}{N_{i.}} P_{ij}(1-P_{ij})} \quad \text{for each } i. \quad (C-11)$$

(The formula in (C-11) was derived assuming $N_{ij}/(N_{ij}-1)$ is approximately unity. For more details, see Cochran (1977), pp. 110-111.) The number $n_{i.}$ in (C-11) satisfies the requirement of (C-9). After $n_{i.}$ is determined, each $n_{i.}$ is allocated to its three substrata proportionally in the following manner:

$$n_{ij} = n_{i.} \left(\frac{N_{ij}}{N_{i.}} \right) \quad (C-12)$$

If n_{ij} is not a whole number, we round upward to the next integer.

In a similar manner, we can determine the appropriate $n_{.j}$, ($j=1, 2$) to satisfy the requirement expressed in equation (C-10).

In determining the target sample size in each stratum (i.e., each $n_{i.}$ and $n_{.j}$), it was assumed that the proportion of projects with ratings at or above 5.0 in each stratum, P_{ij} , was equal to .85. With the distribution of projects in the universe over the strata, the resulting $n_{i.}$ and $n_{.j}$ also satisfy the requirement in equation (C-8). The actual selection of the BES evaluation sample is discussed in Section C.2.

SECTION C.2: SELECTION OF THE EVALUATION SAMPLE

This section describes the sampling process by which the evaluation sample was ultimately selected. Initially, the universe of projects and target sample sizes (i.e., numbers of projects to be evaluated) were established for each of the eight program areas:

1. Materials Sciences - Laboratory
2. Materials Sciences - Non-Laboratory
3. Chemical Sciences - Laboratory
4. Chemical Sciences - Non-Laboratory
5. Biological Energy Research
6. Nuclear Sciences
7. Engineering, Mathematics and Geosciences
8. Advanced Energy Projects

and, within each program area, separately for "long-term non-laboratory" projects and for all other projects (i.e., "large-dollar" and "other") as described in Section C.1. The sampling frame and the distribution of BES projects among the categories were compiled from the annual summary publication for fiscal year 1980 issued by six program areas in the Office of Basic Energy Sciences. These were supplemented by a list of all projects funded as of June 22, 1981, provided by the budget office of the Office of Energy Research. The initial distribution of the projects and target sample sizes are summarized in Table C-2.

Table C-2: Initial Distribution of BES Projects in the Sampling Frame and Target Sample Sizes for Evaluation

<u>Program Area</u>	<u>Non-Laboratories, Long-Term</u>		<u>Large-Dollar and Other</u>		<u>Total Target Sample</u>
	<u>Projects in Sampling Frame</u>	<u>Target Sample Size</u>	<u>Projects in Sampling Frame</u>	<u>Target Sample Size</u>	
Materials Sciences-Laboratories	0	0	207	14	14
Materials Sciences-Non-Laboratories	16	2	198	13	15
Chemical Sciences-Laboratories	0	0	189	15	15
Chemical Sciences-Non-Laboratories	31	2	223	13	15
Biological Energy Research	0	0	85	14	14
Nuclear Sciences	5	2	34	10	12
Engineering, Mathematics and Geosciences	12	2	180	14	16
Advanced Energy Projects	0	0	35	11	11
	—	—	—	—	—
Total	64	8	1,151	104	112

An initial sample of projects in each program area was designated to be referred for screening to identify active projects. A larger sample of projects than required for the target sample size was designated partly in anticipation that some projects in the frame would be found to be inactive and partly to avoid disclosing the specific projects which would be evaluated ultimately. The projects reported by each program area as active were then subsampled to obtain the number in the target sample size.

The subsampled projects were then reviewed again prior to mailing out a letter to each principal investigator describing the study and his or her participation in the study. This review identified a few additional projects as inactive. The results of these operations are summarized in Tables C-3 and C-4. For example, referring to line 1 in Table C-3, the initial target sample size for Materials Sciences laboratory, "large-dollar" and "other" projects, was 14. A sample of 24 projects in that area was selected, and 22 were classified as active in the initial screening. A subsample of 14 of these 22 projects was then selected, and one of these projects was determined to be inactive in the detailed screening. Referring to line 1 in Table C-4, it can be seen that of the initial sample of 24 projects, 3 were "large-dollar" projects, all of which were classified as active, and 21 were "other" projects, 19 of which were classified as active. Of the subsample of 14 "large-dollar" and "other" projects initially classified as active, 13 were "other" projects, one of which was determined to be inactive, and one was a "large-dollar" project which continued to be classified as active.

Table C-3: Distribution of Initial Sample of BES Projects for Evaluation

Program Area	Non-Laboratory, Long-Term					Large-Dollar and Other				
	Initial Target Sample Size	Initial Sample Screened		Subsample of Initial Active Sample		Initial Target Sample Size	Initial Sample Screened		Subsample of Initial Active Sample	
		Total	Active	Total	Active		Total	Active	Total	Active
Materials Sciences-Laboratories	0	0	0	0	0	14	24	22	14	13
Materials Sciences-Non-Laboratories	2	4	3	2	2	13	24	22	13	10
Chemical Sciences-Laboratories	0	0	0	0	0	15	24	22	15	14
Chemical Sciences-Non-Laboratories	2	4	3	2	2	13	23	19	13	12
Biological Energy Research	0	0	0	0	0	14	21	20	14	14
Nuclear Sciences	2	3	3	2	2	10	13	13	10	10
Engineering, Mathematics and Geosciences	<u>2</u>	<u>5</u>	<u>5</u>	<u>2</u>	<u>2</u>	<u>14</u>	<u>33</u>	<u>28</u>	<u>14</u>	<u>14</u>
a. Engineering	0	0	0	0	0	4	8	5	4	4
b. Mathematics	1	3	3	1	1	4	10	9	4	4
c. Geosciences	1	2	2	1	1	6	15	14	6	6
Advanced Energy Projects	0	0	0	0	0	11	16	15	11	10
	—	—	—	—	—	—	—	—	—	—
Total	8	16	14	8	8	104	178	161	104	97

Table C-4: Distribution of Initial Sample of Large-Dollar and Other BES Projects for Evaluation

Program Area	Large-Dollar				Other			
	Initial Sample Screened		Subsample of Initial Active Sample		Initial Sample Screened		Subsample of Initial Active Sample	
	Total	Active	Total	Active	Total	Active	Total	Active
Materials Sciences-Laboratories	3	3	1	1	21	19	13	12
Materials Sciences-Non-Laboratories	0	0	0	0	24	22	13	10
Chemical Sciences-Laboratories	6	6	3	2	18	16	12	12
Chemical Sciences-Non-Laboratories	0	0	0	0	23	19	13	12
Biological Energy Research	0	0	0	0	21	20	14	14
Nuclear Sciences	2	2	2	2	11	11	8	8
Engineering, Mathematics and Geosciences	0	0	0	0	33	28	14	14
a. Engineering	0	0	0	0	8	5	4	4
b. Mathematics	0	0	0	0	10	9	4	4
c. Geosciences	0	0	0	0	15	14	6	6
Advanced Energy Projects	0	0	0	0	16	15	11	10
Total	11	11	6	5	167	150	98	92

The target sample size was 112 (8 non-laboratory long-term, and 104 large-dollar and other projects as shown in Table C-2 and in the Total column under Subsample of Initial Active Projects in Tables C-3 and C-4). Of the initial draw, only 105 were found to be active (8, 5, and 92, respectively, as shown in the same tables). In order to replace the inactive projects, seven additional projects were required in the appropriate program areas. To minimize the time required and administrative burden on the BES staff, the additional sample projects required to meet the target sample size were selected by an inverse sampling procedure* (Sukhatme and Sukhatme, Section 1.20; Cochran, Section 4.5), rather than by the double sampling procedure used for the initial sample. Of the 7 projects selected, 1 was ultimately found to be inactive leaving a net of 111 projects.

To achieve the study objectives for the reliability of estimates (p. C-7), it was necessary to increase the sample sizes for the non-laboratory long-term and the large-dollar projects. A supplemental sample of projects was selected to provide the additional projects. For the non-laboratory long-term category, an additional sample of six projects was selected randomly from a list of all non-laboratory long-term projects. One of these projects was classified incorrectly as inactive for a net increase of five. This was later reclassified as active. For the large-dollar category, an additional sample of seven

*Inverse sampling is utilized to minimize the total sample size required to obtain a specified number of cases of interest. With this method, sampling is performed continuously until the specified number of cases of interest (i.e., active projects) have been found.

Table C-5: Revised Distribution of BES Projects in the Sampling Frame, Target Sample Sizes for Evaluation
Which Combines the Initial and Supplemental Samples

<u>Program Area</u>	<u>Non-Laboratory, Long-Term</u>		<u>Large-Dollar</u>		<u>Other</u>	
	<u>Projects in Sampling Frame</u>	<u>Revised Sample</u>	<u>Projects in Sampling Frame</u>	<u>Revised Sample</u>	<u>Projects in Sampling Frame</u>	<u>Revised Sample</u>
Materials Sciences-Laboratories	0	0	33	5	174	13
Materials Sciences-Non-Laboratories	17 <u>a/</u>	4 <u>a/</u>	2 <u>b/</u>	1	195	11
Chemical Sciences-Laboratories	0	0	29	4	160	12
Chemical Sciences-Non-Laboratories	31	3	0	0	223	13
Biological Energy Research	0	0	0	0	85	14
Nuclear Sciences	4 <u>c/</u>	3	5	2	29	8
Engineering, Mathematics and Geosciences	<u>12</u>	<u>5 d/</u>	<u>3</u>	<u>1</u>	<u>177</u>	<u>14</u>
a. Engineering	0	0	0	0	47	4
b. Mathematics	7	2	3	1	47	4
c. Geosciences	5 <u>d/</u>	3 <u>d/</u>	0	0	83	6
Advanced Energy Projects	0	0	0	0	35	11
Total	<u>-64</u>	<u>15</u>	<u>72</u>	<u>13</u>	<u>1,078</u>	<u>96</u>

a/ Includes one non-laboratory, long-term project found to have been sampled as an other project.

b/ Includes one large-dollar project which is also a non-laboratory, long-term project.

c/ Excludes a project listing determined to be a duplicate of another project in this category.

d/ Includes one project linked as an adjunct to another project in this category.

projects was selected randomly from a list of large-dollar projects in each program area. The number of additional projects selected was proportional to the number of projects in each program area.

After the addition of the net of 12 projects from the supplemental sample (prior to the reclassification), the total was 123. In Geosciences, one additional project was identified which was required as an adjunct to another project in that program area. This raised the total to 124. In Table C-5, the revised sample is shown which incorporates these additions. It also incorporates the reclassification of another project as non-laboratory, long-term (this was one of the two projects selected by inverse sampling in the "other" category).

Five projects (three Materials Sciences non-laboratory and two Chemical Sciences non-laboratory) classified as inactive (four during the initial sample and one during the supplemental sample) were subsequently determined to have been active at the time of the draw and were thus added to the sample bringing the final number of sample projects to 129.

A summary of the sampling operations is provided in Table C-6, which shows the full sample with the five elements of the sampling process: the initial sample described in Table C-3, the projects selected by the inverse sampling technique, the supplemental sample including the addition of the adjunct project, and the reclassification of five projects previously classified as inactive.

Table C-6: Summary of Sampling of BES Projects for Evaluation

	Total Number of Projects	Sample of Projects			Subsample of Active Projects			Notes
		Total	Initial Classification		Total	Classification		
			Active	Not Active		Active	Not Active	
1. Materials Sciences-Laboratories								
A. Long-Term, Non-Laboratory	—							
B. Large-Dollar and Other:								
(i) Large-Dollar	33							
(a) Initial sample		3	3	—	1	1	—	
(b) Supplement		5	4	1	4	4	—	
Total	33	8	7	1	5	5	—	
(ii) Other	174							
(a) Initial sample		21	19	2	13	12	1	+1 Project from inverse sampling
(b) Supplement		—	—	—	—	—	—	
Total	174	21	19	2	13	12	1	+1 Project from inverse sampling
2. Materials Sciences-Non-Laboratories								
A. Long-Term, Non-Laboratory								
Self-representing	1	1	1	—	1	1	—	Self-representing ^a
Other	16							
(a) Initial sample		4	3	1	2	2	—	
(b) Supplement		1	1	—	1	1	—	
Total	16	5	4	1	3	3	—	
B. Large-Dollar and Other:								
(i) Large-Dollar	2							
(a) Initial sample		—	—	—	—	—	—	
(b) Supplement		1	1	—	1	1	—	
Total	2	1	1	—	1	1	—	

^a From inverse sampling of Materials Sciences-Non Laboratories Other (See note on next page.)

Table C-6: Summary of Sampling of BES Projects for Evaluation (continued)

	Total Number of Projects	Total	Sample of Projects Initial Classification		Total	Subsample of Active Projects Classification		Notes
			Active	Not Active		Active	Not Active	
(ii) Other	195							
(a) Initial sample		24	22 ^a	2	14	13 ^b	1	+2 Projects from ^c
(b) Supplement		-	-	-	-	-	-	inverse sampling
Total	195	24	22 ^a	2	14	13	1	+2 Projects from ^c
3. Chemical Sciences-Laboratories								inverse sampling
A. Long-Term, Non-Laboratory	-							
B. Large-Dollar and Other:								
(i) Large-Dollar	29							
(a) Initial sample		6	6	-	3	2	1	+1 Project from
(b) Supplement		1	1	-	1	1	-	inverse sampling
Total	29	7	7	-	4	3 ^d	1	+1 Project from
Total								inverse sampling
(ii) Other	160							
(a) Initial sample		18	16	2	12	12	-	
(b) Supplement		-	-	-	-	-	-	
Total	160	18	16	2	12	12	-	
4. Chemical Sciences-Non-Laboratories								
A. Long-Term, Non-Laboratory	31							
(a) Initial sample		4	4	-	3	3 ^e	-	
(b) Supplement		2	2	-	2	2 ^e	-	
Total	31	6	6	-	5	5	-	

^a One project principal investigator was hospitalized and the project was not reviewed or considered for subsampling.

^b Includes three projects initially classified as not active and reclassified as active.

^c One of the two projects from inverse sampling was reclassified as long-term non-laboratory (see note a on Table C-5).

^d Two of these three projects were originally classified as "large-dollar" based on the person years of effort involved. However, it was determined that these two projects were not funded at \$500,000 per year. Accordingly, 2/3 of this group was estimated to be "other" rather than "large-dollar." This is reflected in the estimated 15 "other" projects $\hat{N}_{3.2,3}$ in Table C-8, line 3.2.

^e Each of the initial sample and the supplement contains one project initially classified as not active and reclassified as active.

Table C-6: Summary of Sampling of BES Projects for Evaluation (continued)

	Total Number of Projects	Sample of Projects			Subsample of Active Projects			Notes
		Total	Initial Active	Classification Not Active	Total	Active	Not Active	
B. Large-Dollar and Other:								
(i) Large-Dollar	-	-	-	-	-	-	-	
(a) Initial sample								
(ii) Other	223							
(a) Initial sample		23	19	4	13	12	1	+1 Project from inverse sampling
(b) Supplement		-	-	-	-	-	-	
Total	223	23	19	4	13	12	1	+1 Project from inverse sampling
5. Biological Energy Research								
A. Long-Term, Non-Laboratory	-							
B. Large-Dollar and Other:								
(i) Large-Dollar	-							
(ii) Other	85							
(a) Initial sample		21	20	1	14	14	-	
Total	85	21	20	1	14	14	-	
6. Nuclear Sciences								
A. Long-Term, Non-Laboratory	4							
(a) Initial sample		3	3	-	2	2	-	
(b) Supplement		1	1	-	1	1	-	Duplicate listing of one project eliminated, treated as self-representing
Total	4	4	4	-	3	3	-	

Table C-6: Summary of Sampling of BES Projects for Evaluation (continued)

	Total Number of Projects	Sample of Projects			Subsample of Active Projects			Notes
		Total	Initial Active	Classification Not Active	Total	Active	Not Active	
B. Large-Dollar and Other:								
(i) Large-Dollar	5							
(a) Initial sample		2	2	-	2	2	-	
Total	5	2	2	-	2	2	-	
(ii) Other	29							
(a) Initial sample		11	11	-	8	8	-	
Total	29	11	11	-	8	8	-	
7a. Engineering								
A. Long-Term, Non-Laboratory	-							
B. Large-Dollar and Other:								
(i) Large-Dollar	-							
(ii) Other	47							
(a) Initial sample		8	5	3	4	4	-	
Total	47	8	5	3	4	4	-	
7b. Mathematics								
A. Long-Term, Non-Laboratory	7							
(a) Initial sample		3	3	-	1	1	-	
(b) Supplement		1	1	-	1	1	-	
Total	7	4	4	-	2	2	-	
B. Large-Dollar and Other:								
(i) Large-Dollar	3							
(a) Initial sample		1	1	-	1	1	-	
(b) Supplement								
Total	3	1	1	-	1	1	-	

Table C-6: Summary of Sampling of BES Projects for Evaluation (continued)

	Total Number of Projects	Sample of Projects Initial Classification			Subsample of Active Projects Classification			Notes
		Total	Active	Not Active	Total	Active	Not Active	
(ii) Other	47							
(a) Initial sample		10	9	1	4	4	-	
Total	47	10	9	1	4	4	-	
7c. Geosciences								
A. Long-Term, Non-Laboratory								
Self-representing	1	1	1	-	1	1	-	
Other	4							
(a) Initial sample		1	1	-	1	1	-	
(b) Supplement		1	1	-	1	1	-	
Total	4	2	2	-	2	2	-	
B. Large-Dollar and Other:								
(i) Large-Dollar	-							
(ii) Other	83							
(a) Initial sample		15	14	1	6	6	-	
Total	83	15	14	1	6	6	-	
8. Advanced Energy Projects								
A. Long-Term, Non-Laboratory	-							
B. Large-Dollar and Other:								
(i) Large-Dollar	-							
(ii) Other	35							
(a) Initial sample		16	15	1	11	10	1	+1 Project from inverse sampling
Total	35	16	15	1	11	10	1	+1 Project from inverse sampling

The following comments relate to the treatment of revisions in the sampling frame and the sampling of projects from the point-of-view of weighting the sample data to make estimates from the study for the universe of BES projects. In the Materials Sciences non-laboratory category, it was found that one long-term non-laboratory project had been sampled as an "other" project. Although it might have been treated as part of the sample selected from the long-term non-laboratory category, it was considered more appropriate, in view of the way in which it was sampled, to treat it as self-representing and to adjust the sampling-frame counts accordingly. Also, one large-dollar sample project is a long-term non-laboratory project as well. For making estimates from the study, this project is weighted according to the way in which it was sampled. However, it may be used in estimates from the study for either of the two categories. In the Geosciences program area, it was found that one sample project was considered an adjunct of another project not selected initially but which, it was decided, should be included in the evaluation. Accordingly, it was included in the sample and treated as self-representing.

The total distribution of projects for the BES evaluation is given in Table C-7. Note that rows 2, 3, and 7 have been partitioned for reasons discussed above.

An estimate of the number of active projects in each cell was calculated as follows. Each of the initial and supplemental samples was selected by a double sampling procedure as noted earlier (Cochran,

Table C-7: Sample Distribution of Projects for the BES Evaluation

	1. Long-Term Non-Laboratory	2. Large- Dollar	3. Other	Total
1. Materials Sciences (Laboratories)	$n_{11} = 0$	$n_{12} = 5$	$n_{13} = 13$	$n_{1.} = 18$
2. Materials Sciences (Non-Laboratories)				
2.1 Excluding the self- representing project	$n_{2.1,1} = 3$	$n_{2.1,2} = 1$	$n_{2.1,3} = 14$	$n_{2.1.} = 18$
2.2 The self-representing project	$n_{2.2,1} = 1$	$n_{2.2,2} = 0$	$n_{2.2,3} = 0$	$n_{2.2.} = 1$
3. Chemical Sciences (Laboratories)				
3.1 Excluding two "other" projects selected as "large-dollar"	$n_{3.1,1} = 0$	$n_{3.1,2} = 2$	$n_{3.1,3} = 12$	$n_{3.1.} = 14$
3.2 The two "other" projects selected as "large-dollar"	$n_{3.2,1} = 0$	$n_{3.2,2} = 0$	$n_{3.2,3} = 2$	$n_{3.2.} = 2$
4. Chemical Sciences (Non-Laboratories)	$n_{41} = 5$	$n_{42} = 0$	$n_{43} = 13$	$n_{4.} = 18$
5. Biological Energy Research	$n_{51} = 0$	$n_{52} = 0$	$n_{53} = 14$	$n_{5.} = 14$
6. Nuclear Sciences	$n_{61} = 3$	$n_{62} = 2$	$n_{63} = 8$	$n_{6.} = 13$
7. Engineering, Mathematics and Geosciences				
7.1 Engineering	$n_{7.1,1} = 0$	$n_{7.1,2} = 0$	$n_{7.1,3} = 4$	$n_{7.1.} = 4$
7.2 Mathematics	$n_{7.2,1} = 2$	$n_{7.2,2} = 1$	$n_{7.2,3} = 4$	$n_{7.2.} = 7$
7.3 Geosciences excluding the self-representing project	$n_{7.3,1} = 2$	$n_{7.3,2} = 0$	$n_{7.3,3} = 6$	$n_{7.3.} = 8$
7.4 The self-representing project	$n_{7.4,1} = 1$	$n_{7.4,2} = 0$	$n_{7.4,3} = 0$	$n_{7.4.} = 1$
8. Advanced Energy Projects	$n_{81} = 0$	$n_{82} = 0$	$n_{83} = 11$	$n_{8.} = 11$
Total	$n_{.1} = 17$	$n_{.2} = 11$	$n_{.3} = 101$	$n = 129$

Chapter 12; Hansen, Hurwitz and Madow, Volume I, Chapter 11, Section 3, and Volume II, Chapter 11, Sections 3-5). For these two components, a least squares approach leads to pooling the two samples at each stage on an unweighted basis and treating the result as a single double sample. For the inverse sampling component, this simple pooling for an estimated total does not apply, although it would apply to an estimate of the mean per project. To simplify the sample computations, therefore, the estimation approach ultimately used was as follows. Consider first an estimate of the total number of active projects in estimation cell ij based on the initial and supplemental samples. It would be

$$\hat{N}_{ij} = N_{ij} \frac{m_{ij}}{m_{ij}^0} \frac{m_{ij}''}{m_{ij}'} \quad (C-13)$$

where

N_{ij} = Total number of projects in estimation cell ij
(first column in Table C-6)

m_{ij}^0 = Number of projects in first sample from estimation cell ij
(initial and supplement combined) (second column in Table C-6)

m_{ij} = Number of projects, among the m_{ij}^0 , initially classified as active
(third column in Table C-6)

m_{ij}' = Number of projects in subsample of active projects
(fifth column in Table C-6)

m_{ij}'' = Number of projects out of m_{ij}' which were active
(sixth column in Table C-6)

For example, for large-dollar Materials Sciences laboratory projects
($i=1, j=2$)

$$N_{12} = 33$$

$$m_{12} = 7$$

$$m_{12}^0 = 8$$

$$m_{12}^I = 5$$

$$m_{12}^{II} = 5$$

Thus the estimated number of active large-dollar Materials Sciences laboratory projects would be

$$\hat{N}_{12} = 33(7/8)(5/5) = 231/8$$

as shown in Table C-8; that is, it is estimated that 29 (231/8 rounded) of the 33 large-dollar projects listed for this program area were active at the time the sample was selected. The estimation technique ultimately used took for $\hat{N}_{ij}$ the estimate based on the pooling of the initial and supplemental samples. Table C-8 gives the estimated number of active projects in the BES sampling frame. The table was produced using equation (C-13).

Table C-8: Estimated Number of Active Projects in Sampling Frame for the BES Evaluation*

	1. Long-Term Non-Laboratory	2. Large-Dollar	3. Other	Total
1. Materials Sciences (Laboratories)	$\hat{N}_{11} = 0$	$\hat{N}_{12} = \frac{231}{8} (=29)$	$\hat{N}_{13} = \frac{13224}{91} (=145)$	$\hat{N}_{1.} = 174$
2. Materials Sciences (Non-Laboratories)				
2.1 Materials Sciences (Non-Laboratories) excluding the self- representing project	$\hat{N}_{2.1,1} = \frac{64}{5} (=13)$	$\hat{N}_{2.1,2} = 2$	$\hat{N}_{2.1,3} = \frac{27885}{168} (=166)$	$\hat{N}_{2.1.} = 181$
2.2 The self-represent- ing project	$\hat{N}_{2.2,1} = 1$	$\hat{N}_{2.2,2} = 0$	$\hat{N}_{2.2,3} = 0$	$\hat{N}_{2.2.} = 1$
3. Chemical Sciences (Laboratories)				
3.1 Chemical Sciences (Laboratories) excluding "other" projects selected as "large dollar"	$\hat{N}_{3.1,1} = 0$	$\hat{N}_{3.1,2} = \frac{87}{12} (=7)$	$\hat{N}_{3.1,3} = \frac{1280}{9} (=142)$	$\hat{N}_{3.1.} = 149$
3.2 Chemical Sciences (Laboratories) "other" projects selected as "large dollar"	$\hat{N}_{3.2,1} = 0$	$\hat{N}_{3.2,2} = 0$	$\hat{N}_{3.2,3} = \frac{174}{12} (=15)$	$\hat{N}_{3.2.} = 15$
4. Chemical Sciences (Non-Laboratories)	$\hat{N}_{41} = 31$	$\hat{N}_{42} = 0$	$\hat{N}_{43} = \frac{50844}{299} (=170)$	$\hat{N}_{4.} = 201$
5. Biological Energy Research	$\hat{N}_{51} = 0$	$\hat{N}_{52} = 0$	$\hat{N}_{53} = \frac{1700}{21} (=81)$	$\hat{N}_{5.} = 81$
6. Nuclear Sciences	$\hat{N}_{61} = 4$	$\hat{N}_{62} = 5$	$\hat{N}_{63} = 29$	$\hat{N}_{6.} = 38$
7. Engineering, Mathematics and Geosciences				
7.1 Engineering	$\hat{N}_{7.1,1} = 0$	$\hat{N}_{7.1,2} = 0$	$\hat{N}_{7.1,3} = \frac{235}{8} (=29)$	$\hat{N}_{7.1.} = 29$
7.2 Mathematics	$\hat{N}_{7.2,1} = 7$	$\hat{N}_{7.2,2} = 3$	$\hat{N}_{7.2,3} = \frac{423}{10} (=42)$	$\hat{N}_{7.2.} = 52$
7.3 Geosciences exclud- ing the self-repre- senting project	$\hat{N}_{7.3,1} = 4$	$\hat{N}_{7.3,2} = 0$	$\hat{N}_{7.3,3} = \frac{1162}{15} (=77)$	$\hat{N}_{7.3.} = 81$
7.4 The self-represent- ing project	$\hat{N}_{7.4,1} = 1$	$\hat{N}_{7.4,2} = 0$	$\hat{N}_{7.4,3} = 0$	$\hat{N}_{7.4.} = 1$
8. Advanced Energy Projects	$\hat{N}_{81} = 0$	$\hat{N}_{82} = 0$	$\hat{N}_{83} = \frac{5250}{176} (=30)$	$\hat{N}_{8.} = 30$
Total	$\hat{N}_{.1} = 61$	$\hat{N}_{.2} = 46$	$\hat{N}_{.3} = 926$	$\hat{N} = 1033$

*Rounded numbers are given in parenthesis.

SECTION C.3: ESTIMATES OF PROPORTIONS AND ESTIMATES OF THEIR APPROXIMATE 90 PERCENT LOWER CONFIDENCE BOUNDS

While the final number and allocation of projects actually reviewed are as indicated in Table C-7, it was necessary to select randomly a total of over 150 projects before the 129 active projects were obtained because the BES frame used to draw the samples was found to contain inactive projects. This was discussed in detail in Section C-2. This has an effect on the estimates of proportions and their estimated standard deviations that were discussed in Section C.1. The adjustments used are discussed in this section.

Using the estimated number of active projects in Table C-8, the estimates of $P_{i.}$, $P_{.j}$, and P which were originally given in Section C.1 by equation (C-3), (C-5), and (C-6) respectively can be obtained by substituting $\hat{N}_{ij}$, $\hat{N}_{i.}$, $\hat{N}_{.j}$, and $\hat{N}$ for N_{ij} , $N_{i.}$, $N_{.j}$, and N respectively in these equations.

In Table C-9, the first column gives the sample estimates of the proportions of projects whose overall project quality rated greater than or equal to 5.0 in the various categories. In parenthesis is an approximate 9 percent lower confidence bound for the estimate. The derivation of these lower confidence bounds is given near the end of Section C.3. Columns two and three of Table C-9 give similar information using threshold ratings of greater than or equal to 7 and 9 respectively.

As an example, we compute $\hat{P}_{1.}$ (for Materials Sciences (Laboratories)) for a threshold rating of 7. Of the 5 large-dollar projects, 4 had panel

consensus overall project ratings greater than or equal to 7; of the 13 "other" projects, 11 had panel consensus overall project ratings greater than or equal to 7 (See Table C-10). Thus

$$\begin{aligned}\hat{p}_{1.} &= \frac{\hat{N}_{11}}{\hat{N}_{1.}} \hat{p}_{11} + \frac{\hat{N}_{12}}{\hat{N}_{1.}} \hat{p}_{12} + \frac{\hat{N}_{13}}{\hat{N}_{1.}} \hat{p}_{13} \\ &= 0 + \frac{(231/8)}{(231/8) + (13224/91)} \left(\frac{4}{5}\right) + \frac{(13224/91)}{(231/8) + (13224/91)} \left(\frac{11}{13}\right) \\ &= .84\end{aligned}$$

as given in row 1 and column 2 of Table C-9.

Table C-9: Estimates of Proportions of Projects At or Above Given Threshold Ratings with Their Respective Estimated 90% Lower Confidence Bounds Given in Parentheses.

	Panel Consensus Overall Project Quality Rating is		
	<u>≥5</u>	<u>≥7</u>	<u>≥9</u>
Materials Sciences (Laboratories)	.94(.86)	.84(.73)	.08(.00)
Materials Sciences (Non-Laboratories)	.87(.76)	.43(.28)	.02(.00)
Materials Sciences (Combined)	.90(.83)	.63(.52)	.04(.00)
Chemical Sciences (Laboratories)	1.00(*)	.64(.47)	.09(.00)
Chemical Sciences (Non-Laboratories)	.78(.65)	.52(.36)	.13(.02)
Chemical Sciences (Combined)	.88(.81)	.57(.46)	.11(.04)
Biological Energy Research	.93(.85)	.64(.49)	.07(.00)
Nuclear Sciences	.96(.94)	.64(.48)	.00(.00)
Engineering, Mathematics and Geosciences	.97(.93)	.49(.32)	.22(.08)
Advanced Energy Projects	.91(.82)	.73(.58)	.00(.00)
Long-Term Non-Laboratories	.58(.40)	.36(.19)	.10(.00)
Large-Dollar	1.00(*)	.88(.72)	.14(.00)
Overall BES	.91(.87)	.59(.53)	.10(.06)

*No estimate of lower bound is given because the estimate of the variance is equal to zero.

Before the sample was selected, it was desired to estimate proportions of projects at or above various rating thresholds for the 12 categories given in Table C-9. Stratification was used to ensure representation of the 12 categories in the sample. It was desired to give estimates for additional categories, and after the sample had been taken, it was determined that sufficient numbers of sampled projects were found in other categories to allow these estimates and their comparisons to be done. The paragraphs below discuss the method used to estimate the proportions for the following seven additional domains:

Domain (k)

1	All Laboratory
2	All Non-Laboratory
3	Long-Term Laboratory (Started during or before 1974
for Laboratory projects)
4	All Long-Term (Started during or before 1974)
5	Recent Laboratory (Started after 1974 for Laboratory
projects)
6	Recent Non-Laboratory (Started after 1974 for
Non-Laboratory projects)
7	All Recent (Started after 1974)

Treating these as domains of study in a stratified setup, the appropriate estimators for proportions are discussed by Cochran (1977) pp. 142-144. We have 23 strata,* and N_{ij} is the size of the ij -th stratum.

*The 23 strata result from rows 2, 3, and 7 being partitioned as indicated in Table C-8. This results in a total of 13 rows and 3 columns which define 39 strata. Sixteen of these have no projects in them leaving a net of 23 strata.

Table C-10: Numbers Used to Derive Estimates of 90 Percent Lower Confidence Bounds in Table C-9

Stratum	Row (i), Column (j) in Table C-8	N_{ij}	$\hat{N}_{ij}$	m_{ij}^0	m_{ij}	m_{ij}'	m_{ij}''	$\hat{m}_{ij}^*$	a_{ij}^{**} with Threshold		
									≥ 5	≥ 7	≥ 9
1	1,2	33	231/8	8	7	5	5	5	5	4	0
2	1,3	174	13224/91	21	19	13	12	13	12	11	1
3	2.1,1	16	64/5	5	4	3	3	3	3	1	1
4	2.1,2	2	2	1	1	1	1	1	1	1	0
5	2.1,3	195	27885/168	24	22	14	13	14	12	6	0
6	2.2,1	1	1	1	1	1	1	1	1	1	0
7	3.1,2	29	87/12	5	5	4	1	2	2	2	1
8	3.1,3	160	1280/9	18	16	12	12	12	12	7	1
9	3.2,3	29	174/12	2	2	4	2	2	2	2	0
10	4,1	31	31	6	6	5	5	5	2	2	0
11	4,3	223	50844/299	23	19	13	12	13	11	7	2
12	5,3	85	1700/21	21	20	14	14	14	13	9	1
13	6,1	4	4	4	4	3	3	3	2	1	0
14	6,2	5	5	2	2	2	2	2	2	2	0
15	6,3	29	29	11	11	8	8	8	8	5	0
16	7.1,3	47	235/8	8	5	4	4	4	4	2	1
17	7.2,1	7	7	4	4	2	2	2	1	0	0
18	7.2,2	3	3	1	1	1	1	1	1	1	1
19	7.2,3	47	423/10	10	9	4	4	4	4	2	1
20	7.3,1	4	4	2	2	2	2	2	1	1	1
21	7.3,3	83	1162/15	15	14	6	6	6	6	3	1
22	7.4,1	1	1	1	1	1	1	1	1	1	1
23	8,3	35	5250/176	16	15	11	10	11	10	8	0

* $\hat{m}_{ij}$ is the total number of active projects evaluated for cell (ij).

** a_{ij} is the number of projects out of $\hat{m}_{ij}$ which were rated at or above a given threshold.

For each stratum, there may be projects in any of the seven domains listed above. We use the following notation:

N^k is the number of projects in the k-th domain,

N_{ij}^k is the number of projects in the kth domain in the ij-th stratum,

P_{ij}^k is the proportion of projects with ratings at or above a given threshold in the k-th domain in the ij-th stratum.

For example, referring to Table C-8, row 1 ($i=1$), column 2 ($j=2$) the number of Materials Sciences projects in the first domain (all laboratory) equals $29(N_{12}^1 = 29)$. The number of long-term laboratory projects ($k=3$) in the stratum is designated as N_{12}^3 . This number is not shown in this report.*

For the k-th domain, we want to estimate, P^k , the proportion of projects with ratings at or above a given threshold in the k-th domain ($k=1,2, \dots, 7$). Note

$$P^k = \frac{\sum_i \sum_j N_{ij}^k P_{ij}^k}{N^k}$$

*It is determined by partitioning the data base appropriately (i.e., program area = Materials Sciences; institution = laboratory; and start date = 1974 or before).

where i is summed over all the rows and j over the columns. As in the case of estimating the proportion P , we obtain an estimate of p^k by substituting estimates of the N_{ij}^k and p_{ij}^k in the above equation for p^k . Thus

$$\hat{p}^k = \frac{\sum_i \sum_j \hat{N}_{ij}^k \hat{p}_{ij}^k}{\hat{N}^k}$$

where $\hat{N}^k = \sum_i \sum_j \hat{N}_{ij}^k$.

More specifically, let

m_{ij}'' be the number of projects in the subsample of active projects which were evaluated in the ij -th stratum (eighth column in Table C-10),

$(m_{ij}'')^k$ be the number of projects in the k -th domain among the m_{ij}'' which were evaluated,

$\hat{m}_{ij}^k$ be the total number of active projects in the k -th domain which were evaluated for cell ij ,

a_{ij}^k be the number of projects out of the $\hat{m}_{ij}^k$ which were rated at or above a given threshold,

and $\hat{p}_{ij}^k = a_{ij}^k / \hat{m}_{ij}^k$ $\hat{N}_{ij}^k = \hat{N}_{ij} (m_{ij}'')^k / m_{ij}''$.

Then

$$\hat{p}^k = \sum_i \sum_j \frac{\hat{N}_{ij} \frac{(m''_{ij})^k}{m_{ij}}}{\sum_i \sum_j \hat{N}_{ij} \frac{(m''_{ij})^k}{m_{ij}}} \hat{p}_{ij}^k \quad (C-14)^*$$

Note that the $\hat{N}_{ij}$ may be obtained by referring to Table C-8. The estimates of the proportion of projects rated at or above given thresholds for the seven domains were calculated using equation C-14 and are presented in Table C-11.

Table C-11: Estimates of Proportions of Projects At or Above Threshold Ratings for Various Domains of Study

	Panel Consensus Overall Project Quality Rating is		
	<u>>5</u>	<u>>7</u>	<u>>9</u>
All Laboratory	.96	.72	.09
All Non-Laboratory	.87	.49	.10
Long-Term Laboratory	.96	.73	.08
All Long-Term	.85	.62	.08
Recent Laboratory	.96	.72	.09
Recent Non-Laboratory	.90	.51	.10
All recent	.92	.58	.10

*This estimator corresponds to Cochran's estimator (p.144, eq. 5A.72).

In the remainder of this section, we discuss the derivation of the approximate 90 percent lower confidence bounds given in Table C-9.* If x_{hj} is the value of a variable X for the j -th project in estimation cell h , then the estimated total for estimation cell h , x'_h , may be written as

$$x'_h = \hat{N}_h \frac{1}{\hat{m}_h} \sum_{j=1}^{\hat{m}_h} x_{hj} \quad (C-15)$$

This equation may be rewritten as

$$x'_h = \sum_{j=1}^{\hat{m}_h} w_h x_{hj} \quad (C-16)$$

where $w_h = \hat{N}_h / \hat{m}_h$ is a weight associated with each of the projects evaluated in estimation cell h . Hence an estimated total from the sample for a given variable, say X for a particular category may be written as the sum of the estimates from each of the estimation cells involved, i.e.,

$$x' = \sum_{h=1}^L x'_h \quad (C-17)$$

*For the remainder of this section, we define a single subscript "h" to replace the double subscript "ij" used to designate a row "i" and a column "j". This is done for ease of notation only. Table C-10 shows the strata "h" ($h=1, \dots, L$ where $L=23$) with corresponding i's and j's.

The estimated proportions in equations (C-3), (C-5), and (C-6) can be viewed as special cases of combined ratio estimators of the form

$$\hat{P} = x'/y' \quad (C-18)$$

where x' and y' are the estimates of the totals of the variables X and Y respectively. For example, X might be the funding of acceptable projects in a particular category, and Y might be the total funding of all projects in that category. For proportions, the X and Y are 0 - 1 variables such that for an individual project $Y = 0$ or 1, and $X = 0$ whenever $Y = 0$.

Since the sampling in the estimation cells was independent, the sampling variance of an estimated total

$$x' = \sum_{h=1}^L x'_h = \sum_{h=1}^L \hat{N}_h \bar{x}'_h$$

is the sum of the variances of the individual cell estimates; i.e.,

$$V(x') = \sum_{h=1}^L V(x'_h) = \sum_{h=1}^L x_h^2 C^2(x'_h)$$

where $V(x'_h)$ is the sampling variance of x'_h and C^2 is defined below. Since x'_h as estimated is the product of two estimates, $\hat{N}_h$ and $\bar{x}'_h$, which are independently distributed,

$$C^2(x'_h) = C^2(\bar{x}'_h)[1 + C^2(\hat{N}_h)] + C^2(\hat{N}_h) \quad (C-19)$$

(Goodman (1960), Sukhatme and Sukhatme, Section 1.19; Hansen, Hurwitz and Madow, Volume II, Chapter 1, Sections 5 and 6), where C^2 denotes the relvariance or square of the coefficient of variation, e.g., for $\bar{x}'_h$,

$$C^2(\bar{x}'_h) = V(\bar{x}'_h)/\bar{x}_h^2. \quad (C-20)$$

The sampling variances of estimates of the number of projects have been computed conditional on the size of the combined sample and the subsampling fractions used; the sampling variances of the means, $\bar{x}'_h$, have been computed conditional on the number of projects evaluated.

Then

$$C^2(\bar{x}'_h) = (1-g_h) \frac{V_{hx}}{\hat{m}_h \bar{x}_h^2} \quad (C-21)$$

where

g_h = sampling rate of active projects in estimation cell $h = \hat{m}_h/M_h$.

V_{hx} = variance of X among active projects in estimation cell h .

$\bar{x}_h$ = mean of X per active project in estimation cell h .

M_h = number of active projects in universe in estimation cell h .

Since

$$\hat{N}_h = N_h p_{1h} p_{2h} \quad (C-22)$$

where

$$p_{1h} = m_h / m_h^0 \quad p_{2h} = m_h'' / m_h' \quad (C-23)$$

and p_{1h} and p_{2h} are uncorrelated,

$$C^2(\hat{N}_h) = C^2(p_{wh}) + C^2(p_{2h}). \quad (C-24)$$

In (C-24)

$$C^2(p_{wh}) = \frac{1 - f_{1h}}{m_h^0} C_{wh}^2 \quad (C-25)$$

with

$$C_{wh}^2 = \frac{Q_{wh}}{P_{wh}} \frac{N_h}{N_h - 1}, \quad P_{wh} = p_{1h} p_{2h}, \quad Q_{wh} = 1 - P_{wh}, \quad f_{1h} = m_h^0 / N_h \quad (C-26)$$

and

$$C^2(p_{2h}) = \frac{1 - f_{2h}}{m_h^0 p_{1h} f_{2h}} C_{2h}^2 \quad (C-27)$$

with

$$C_{2h}^2 = \frac{Q_{2h}}{P_{2h}} \frac{M_h}{M_h - 1}, \quad Q_{2h} = 1 - P_{2h} \quad \text{and} \quad (C-28)$$

f_{2h} = subsampling rate of projects initially classified as active.

The sampling variances are estimated by substituting in (C-21) and (C-24) the sample estimates of the quantities involved.

The relvariance of the combined ratio estimator $\hat{P}$ is, with the usual approximation

$$C_{\hat{P}}^2 = C_{x'}^2 + C_{y'}^2 - 2C_{x'y'} \quad (C-29)$$

where $C_{x'y'}$ is the relcovariance of x' and y' (Cochran, Section 6.11; Hansen, Hurwitz and Madow, Volume I, Chapter 5, Section 4). So the sampling variance of $\hat{P}$ is

$$V(\hat{P}) = P^2 [C_{x'}^2 + C_{y'}^2 - 2C_{x'y'}] \quad (C-30)$$

Since

$$C_{x'}^2 = \frac{1}{X^2} \sum_h X_h^2 C^2(x'_h) \quad (C-31)$$

and similarly for $C_{y'}^2$, while

$$C_{x'y'} = \frac{1}{XY} \sum_h X_h Y_h C(x'_h y'_h) \quad (C-32)$$

$V(\hat{P})$ can be written as

$$V(\hat{P}) = \frac{1}{Y^2} \sum_h [V(x'_h) - 2PV(x'_h y'_h) + P^2 V(y'_h)]. \quad (C-33)$$

Alternatively, using the relationships indicated in (C-19), (C-33) may be rewritten as

$$V(\hat{P}) = \frac{1}{Y^2} \sum_{h=1}^L [V(\bar{x}'_h) - 2PV(\bar{x}'_h \bar{y}'_h) + P^2 V(\bar{y}'_h)] + \frac{1}{Y^2} \sum_{h=1}^L Y_h^2 (P_h - P)^2 C^2(\hat{N}_h) \quad (C-34)$$

Equation (C-34) was derived using $C^2(x'_h) \approx C^2(\bar{x}'_h) + C^2(\hat{N}_h)$.

The first term on the right hand side of (C-34) is

$$\frac{1}{Y^2} \sum_{h=1}^L \frac{M_h^2}{\hat{m}_h} (1 - g_h) [V_{hx} - 2PV_{hxy} + P^2 V_{hy}] \quad (C-35)$$

where V_{hy} is the variance of Y and V_{hxy} is the covariance of X and Y in estimation cell h .

The quantity in brackets in (C-35) may be written as

$$\sum_{j=1}^{M_h} (x_{hj} - PY_{hj})^2 / (M_h - 1) \quad (C-36)$$

which may be estimated by

$$\sum_{j=1}^{\hat{m}_h} (x_{hj} - \hat{P}y_{hj})^2 / (\hat{m}_h - 1). \quad (C-37)$$

In the special case where X and Y are 0 - 1 variables as indicated earlier, using (C-34) and (C-37), one can show directly that an estimator of $\text{Var}(\hat{P})$ is given by

$$\begin{aligned} \hat{\text{Var}}(\hat{P}) = & \frac{1}{\left(\sum_{h=1}^L \hat{N}_h\right)^2} \left[\sum_{h=1}^L (\hat{N}_h)^2 \frac{\hat{N}_h - \hat{m}_h}{\hat{N}_h \hat{m}_h} \frac{(a_h - 2a_h \hat{P} + \hat{m}_h \hat{P}^2)}{\hat{m}_h - 1} \right. \\ & \left. + \sum_{h=1}^L (\hat{N}_h)^2 \left(\frac{a_h}{\hat{m}_h} - \hat{P}\right)^2 \left(\frac{(N_h - m_h^0)}{(N_h - 1)m_h^0} \frac{(m_h^0 m_h' - m_h m_h'')}{m_h m_h''} + \frac{(m_h - m_h')}{m_h m_h'} \frac{\hat{N}_h}{\hat{N}_h - 1} \frac{m_h' - m_h''}{m_h''} \right) \right] \quad (\text{C-38}) \end{aligned}$$

where a_h represents the number of projects out of $\hat{m}_h$ which were at or above a given threshold. Table C-10 gives the values which were used in computing the estimated variances for the various estimated proportions given in Table C-9. In Table C-10:

N_h is from the first column in Table C-6. If N_h was unavailable we used $\hat{N}_h$.

$\hat{N}_h$ is from Table C-8.

m_h^0 is from column two of Table C-6.

m_h is from column three of Table C-6.

m_h' is from column five of Table C-6.

m_h'' is from column six of Table C-6.

$\hat{m}_h$ is n_{ij} given in Table C-7.

As indicated earlier in equation (C-7), using equation (C-38), an approximate 90 percent lower confidence bound for P is given by

$$\hat{P} - 1.28\sqrt{\hat{\text{Var}}(\hat{P})}$$

Similar results exist for $P_{i.}$ and $P_{.j}$. In computing the estimated variance for a particular estimator, we included only the relevant cells. For example, to compute the estimated variance of the estimate of the proportion of Nuclear Sciences projects which have a panel consensus overall project rating greater than or equal to 7, we use columns 1, 2 and 3 of row 6 and the a 's given under the threshold greater than or equal to 7 in Table C-10.

SECTION C.4: CHI-SQUARE STATISTIC (χ^2) FOR TESTING EQUALITY OF PROPORTIONS

In this section, we discuss a technique for testing whether two proportions are equal. The usual test of equality of proportions in a 2 x 2 contingency table set up assumes that the contingency table is a classification of a simple random sample. The proportions of interest in this study have all been estimated assuming a stratified random sample. Thus, to test equality of certain proportions, the assumption of a simple random sample is violated. However, Nathan (1975) has concluded, through analytical and simulation results, there is very little loss in asymptotic power for the test if one uses proportional allocation with the stratified random sample, treats the stratified random sample as a simple random sample, and proceeds as usual.

Employing the results of Nathan (i.e. treating the $n_{i.}$ and $n_{.j}$ as if they were the sizes of simple random samples rather than stratified random samples), one can test a number of hypotheses on the equality of pairs of proportions. One case is discussed in detail. Other cases are handled similarly. (For more details, see Cochran (1977), Section 3.11; and Dixon and Massey (1969), p. 242.)

To test if the proportion of Materials Sciences laboratory projects rated greater than or equal to 5 is equal to the proportion of Materials Sciences non-laboratory projects rated greater than or equal to 5,

$$H_0: P_{1.} = P_{2.} \quad \text{vs.} \quad H_a: P_{1.} \neq P_{2.}$$

we proceed as follows using the following sample data for a threshold rating of 5.0.

	Materials Sciences (Laboratories)	Materials Sciences (Non-Laboratories)	
# of projects with rating ≥ 5.0	a	b	
# of projects with rating < 5.0	c	d	
	a + c = 18	b + d = 18	36

Compute the χ^2 statistic

$$\chi^2 = \frac{(ad-bc)^2 (a+b+c+d)}{(a+b)(a+c)(b+d)(c+d)} \quad (C-39)$$

If the value of χ^2 is greater than 2.71, then we reject the null hypothesis, H_0 , at significance level $\alpha = .10$. Otherwise we do not reject H_0 . (A significant difference between the proportions at $\alpha = .10$ represents the probability of committing the error of rejecting the hypothesis that the proportions are equal if they are in fact equal. If the χ^2 -calculated value exceeds 2.71, we reject the hypothesis that the proportions are equal at $\alpha = .10$. Note that 2.71 is the 90th percentile of a χ^2 distribution with 1 degree of freedom. For tables based on small samples, this probability may only be approximate.)

Table C-12 gives the results of some tests of equality of two proportions. The first column of the table gives the χ^2 value for testing equality of proportions of projects whose panel consensus rating on quality of project team (Q1) is greater than or equal to 5. The other columns give similar values where:

- Q2 - panel consensus rating on scientific merit,
- Q3 - panel consensus rating on scientific approach,
- Q4 - panel consensus rating on productivity,
- Q5 - panel consensus rating on strength of coupling,
- Q6 - panel consensus rating on probable impact, and
- Q7 - panel consensus rating on overall project quality.

Table C-12: Results of Tests of Equality of Proportions

Tests	χ^2 -calculated from sample where project has panel consensus rating ≥ 5 for						
	Q1	Q2	Q3	Q4	Q5	Q6	Q7
1. Materials Sciences (Laboratories) vs Materials Sciences (Non-Laboratories)	.31	.97	.00	.00	1.00	2.00	.31
2. Chemical Sciences (Laboratories) vs Chemical Sciences (Non-Laboratories)	4.03 ¹	2.93 ¹	1.89	2.93 ¹	1.88	3.82 ¹	5.21 ¹
3. Long-Term (Non-Laboratories) vs All Other Projects	.50	7.46 ²	3.27 ²	.58	9.14 ²	17.45 ²	13.74 ²
4. Long-Term (Laboratories) vs All Other Projects	1.05	1.09	.90	1.77	.46	1.46	.57
5. Long-Term (Laboratories) vs Long-Term (Non-Laboratories)	1.39	3.66 ¹	2.37	2.37	3.77 ¹	8.36 ¹	5.17 ¹
6. All Long-Term vs All Other Projects	.08	1.53	.38	.23	3.06 ²	4.84 ²	4.84 ²
7. Large-Dollar vs All Other Projects	1.70	.59	.49	.96	1.13	1.79	1.35
8. All Laboratory vs All Non-Laboratory	1.61	4.11 ¹	.83	3.69 ¹	1.15	10.05 ¹	1.64
9. Materials Sciences (Laboratories) vs All Other Projects	.90	1.02	.16	.10	.37	3.46 ¹	.47

Table C-12 (continued)

Tests	χ^2 -calculated from sample where project has panel consensus rating ≥ 5 for						
	<u>Q1</u>	<u>Q2</u>	<u>Q3</u>	<u>Q4</u>	<u>Q5</u>	<u>Q6</u>	<u>Q7</u>
10. Materials Sciences (Non-Laboratories) vs All Other Projects	.07	.02	.12	.06	1.05	.24	.00
11. Materials Sciences (Combined) vs All Other Projects	.88	.44	.33	.19	.11	3.30 ¹	.22
12. Chemical Sciences (Laboratories) vs All Other Projects	2.59	.89	.74	1.45	1.78	.79	2.05
13. Chemical Sciences (Non-Laboratories) vs All Other Projects	1.86	6.81 ²	2.94 ²	2.72 ²	.12	7.20 ²	7.23 ²
14. Chemical Sciences (Combined) vs All Other Projects	.02	1.81	.50	.16	.51	2.09	1.09
15. Biological Energy Research vs All Other Projects	.05	.77	.45	1.13	.10	2.60	.15
16. Nuclear Sciences vs All Other Projects	.12	3.76 ²	.58	.00	1.51	3.28 ²	.09
17. Engineering, Mathematics and Geosciences vs All Other Projects	.15	1.16	.95	1.56	.86	.66	.00
18. Advanced Energy Projects vs All Other Projects	.37	.59	.49	.12	1.07	.26	.01
19. Recent Laboratory vs All Other Projects	.36	2.08	.06	1.12	.43	6.77 ¹	.69
20. Recent Non-Laboratory vs All Other Projects	.70	.03	.09	2.04	.92	.11	1.44

¹The first category has the larger estimated proportion.²The second category has the larger estimated proportion.

Similar results are given in Table C-13 where the threshold score is greater than or equal to 7.

Table C-13: Results of Tests of Equality of Proportions

Tests	χ^2 -calculated from sample where project has panel consensus rating ≥ 7 for						
	Q1	Q2	Q3	Q4	Q5	Q6	Q7
1. Materials Sciences (Laboratories) vs Materials Sciences (Non-Laboratories)	1.67	.95	3.98 ¹	6.44 ¹	4.88 ¹	1.30	5.25 ¹
2. Chemical Sciences (Laboratories) vs Chemical Sciences (Non-Laboratories)	.01	3.03 ¹	2.56	3.27 ¹	1.95	.04	1.23
3. Long-Term (Non-Laboratories) vs All Other Projects	1.28	3.57 ²	3.09 ²	.43	4.29 ²	2.90 ²	3.32 ²
4. Long-Term (Laboratories) vs All Other Projects	.72	.52	.60	.64	.26	.30	1.45
5. Long-Term (Laboratories) vs Long-Term (Non-Laboratories)	1.67	2.73 ¹	2.68	.91	1.22	.74	3.90 ¹
6. All Long-Term vs All Other Projects	.03	.73	.51	.02	3.88 ²	2.94 ²	.18
7. Large-Dollar vs All Other Projects	1.48	.57	1.36	2.36	6.04 ¹	6.24 ¹	4.46 ¹
8. All Laboratory vs All Non-Laboratory	.46	1.68	4.20 ¹	7.48 ¹	2.83 ¹	.41	6.26 ¹
9. Materials Sciences (Laboratories) vs All Other Projects	1.48	.34	2.83 ¹	2.73 ¹	5.27 ¹	1.46	4.30 ¹
10. Materials Sciences (Non-Laboratories) vs All Other Projects	.51	.88	1.74	5.09 ²	1.02	.30	1.81

Table C-13 (Continued)

<u>Tests</u>	χ^2 -calculated from sample where project has panel consensus rating ≥ 7 for						
	<u>Q1</u>	<u>Q2</u>	<u>Q3</u>	<u>Q4</u>	<u>Q5</u>	<u>Q6</u>	<u>Q7</u>
11. Materials Sciences (Combined) vs All Other Projects	.14	.09	.07	.19	.94	.25	.29
12. Chemical Sciences (Laboratories) vs All Other Projects	.06	2.16	1.92	1.69	.36	1.75	.43
13. Chemical Sciences (Non-Laboratories) vs All Other Projects	.15	1.25	.99	2.17	2.40	2.90 ²	1.11
14. Chemical Sciences (Combined) vs All Other Projects	.23	.05	.06	.04	.60	5.37 ²	.11
15. Biological Energy Research vs All Other Projects	.28	3.37 ¹	.02	.68	.62	1.38	.06
16. Nuclear Sciences vs All Other Projects	.11	8.13 ¹	.07	.01	.45	.82	.00
17. Engineering, Mathematics and Geosciences vs All Other Projects	.27	.10	.37	.90	1.55	.06	1.26
18. Advanced Energy Projects vs All Other Projects	.01	.57	.03	.44	1.93	4.50 ¹	.67
19. Recent Laboratory vs All Other Projects	.01	.77	2.83 ¹	5.82 ¹	5.46 ¹	1.39	3.39 ¹
20. Recent Non-Laboratory vs All Other Projects	.00	.01	.89	4.15 ²	.16	.11	1.84

¹The first category has the larger estimated proportion.²The second category has the larger estimated proportion.

Use of Tables C-12 and C-13 can be facilitated by reference to the following χ^2 values for various α values.

<u>α-level</u>	<u>χ^2 Critical Number (for one degree of freedom)</u>
.001	10.83
.01	6.64
.02	5.41
.05	3.84
.10	2.71
.20	1.64

Thus, if the χ^2 statistic in equation (C-39) yields a value greater than a specific χ^2 critical number, then we say that there is a significant difference between the proportions being tested at the corresponding α -level. Hence from Table C-12, row 5, we would say that there is a difference between the proportion of long-term laboratory projects with a Q6 rating greater than or equal to 5 and the proportion of long-term non-laboratory projects with a Q6 rating greater than or equal to 5 at an α -level of .01 because the χ^2 -statistic equals 8.36. This value is greater than 6.64 which is the χ^2 critical number corresponding to $\alpha = .01$. (When a question was raised as to the applicability of the α -level for a given chi-square because the sample size was small, the finding was verified by using Fisher's Exact Test to compare the proportions. See Hays (1963) Section 17.9.)

SECTION C.5: CORRELATION AND MULTIPLE REGRESSION RESULTS

In this section, we discuss correlations among the seven ratings and determine which of the first six ratings best predicts the seventh. We begin with a discussion of estimates of correlation coefficients. Let the panel consensus ratings be denoted as indicated in Section C.4. Continuing to treat the stratified random samples as simple random samples and assuming that each pair of scores is bivariate normal, one can test to see if there is a correlation between the panel consensus overall project evaluation rating and the panel consensus quality of project team rating for the entire population of projects as follows (see Dixon and Massey, p. 204).

H_0 : There is no correlation between Q7 and Q1 . vs. H_a : There is a correlation between Q7 and Q1.

Data $n = 129$ pairs

X_1 = Q7 rating for 1st
sample project

•
•
•
•

X_{129} = Q7 rating for 129th
sample project

Y_1 = Q1 score for 1st
sample project

•
•
•
•

Y_{129} = Q1 score for 129th
sample project.

Compute sample correlation coefficient, r ,

$$r = \frac{\sum_{i=1}^{129} (X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum_{i=1}^{129} (X_i - \bar{X})^2 \sum_{i=1}^{129} (Y_i - \bar{Y})^2}} .$$

At $\alpha = .05$, we reject H_0 if r is greater than .175 or if r is less than -.175. Otherwise, we do not reject H_0 . (The critical value .175 is the approximate 97.5-th percentile of the distribution of r when the true correlation coefficient equals zero and was computed according to Table A-30a of Dixon and Massey (1969). There is some additional uncertainty in the test because we treated the stratified random sample as a simple random sample.)

Similar tests for correlation can be done for any pair of scores. Table C-14 gives the sample correlation coefficients among the seven variables (Q1 - Q7) for the overall sample. In all cases, the sample correlation coefficients suggest that there is some correlation between any two types of ratings.

Table C-14: Correlations Among the Q1 - Q7 Variables for Overall BES

	<u>Q1</u>	<u>Q2</u>	<u>Q3</u>	<u>Q4</u>	<u>Q5</u>	<u>Q6</u>	<u>Q7</u>
Q1	1.00000 0.0000 129	0.67061 0.0001 129	0.77614 0.0001 129	0.81832 0.0001 123	0.67412 0.0001 127	0.57929 0.0001 127	0.86416 0.0001 129
Q2	0.67061 0.0001 129	1.00000 0.0000 129	0.66289 0.0001 129	0.62279 0.0001 123	0.64509 0.0001 127	0.68424 0.0001 127	0.75239 0.0001 129
Q3	0.77614 0.0001 129	0.66289 0.0001 129	1.00000 0.0000 129	0.74209 0.0001 123	0.66323 0.0001 127	0.52812 0.0001 127	0.85827 0.0001 129
Q4	0.81832 0.0001 123	0.62279 0.0001 123	0.74209 0.0001 123	1.00000 0.0000 123	0.62532 0.0001 121	0.52537 0.0001 121	0.82560 0.0001 123
Q5	0.67412 0.0001 127	0.64509 0.0001 127	0.66323 0.0001 127	0.62532 0.0001 121	1.00000 0.0000 127	0.79697 0.0001 127	0.78127 0.0001 127
Q6	0.57929 0.0001 127	0.68424 0.0001 127	0.52812 0.0001 127	0.52537 0.0001 121	0.79697 0.0001 127	1.00000 0.0000 127	0.70227 0.0001 127
Q7	0.86416 0.0001 129	0.75239 0.0001 129	0.85827 0.0001 129	0.82560 0.0001 123	0.78127 0.0001 127	0.70227 0.0001 127	1.00000 0.0000 129

In each cell in Table C-14, the first number is the sample correlation coefficient; the second number is the smallest α -level at which the hypothesis of no correlation can be rejected; the third number is the number of sample projects used in the computations.

The sample correlation coefficient, r , is a measure of the linear relationship between two types of ratings. The panel consensus overall project rating (Q7) characterizes the panel's overall evaluation of a given project. To determine which of the other six ratings were strong predictors of Q7, multiple regression was used for the unweighted sample of 129 projects. All possible multiple regression models were fitted. Only 121 sample projects were included in the computations because of missing values for some ratings in eight of the projects.* Table C-15 gives all possible models and their R^2 values. R^2 represents the fraction reduction in the sample variation of the Q7 values that is explained by (or attributable to) the regression model. Thus, $R^2 = 0$ implies a complete lack of fit of the model to the data, and $R^2 = 1$ implies a perfect fit, with the model passing through every sample point. In general, the larger the value of R^2 , the better the model fits the data.

The table suggests that the strongest single predictor of Q7 is Q1 followed by Q3, Q6, Q4, Q5, and Q2. Note that Q1, Q3, and Q6 ($R^2 = .876$) appear to predict Q7 almost as well as all six of the variables ($R^2 = .894$).

*Productivity was not rated for eight projects recently started.

Table C-15: Regression Models for Dependent Variable Q7

<u>NUMBER IN MODEL</u>	<u>R-SQUARE</u>	<u>VARIABLES IN MODEL</u>
1	0.49313407	Q6
1	0.56351603	Q2
1	0.60032922	Q5
1	0.67528931	Q4
1	0.73556623	Q3
1	0.74820624	Q1
2	0.62059353	Q5 Q6
2	0.62943457	Q2 Q6
2	0.71032746	Q2 Q5
2	0.76866673	Q2 Q4
2	0.77635821	Q4 Q6
2	0.78707978	Q1 Q4
2	0.78710468	Q4 Q5
2	0.79388817	Q2 Q3
2	0.80686497	Q1 Q2
2	0.80933838	Q1 Q6
2	0.81221674	Q3 Q5
2	0.81339237	Q3 Q4
2	0.81689820	Q3 Q6
2	0.81910201	Q1 Q5
2	0.83736987	Q1 Q3
3	0.71061087	Q2 Q5 Q6
3	0.80072259	Q4 Q5 Q6
3	0.80163517	Q2 Q4 Q6
3	0.82118015	Q2 Q4 Q5
3	0.82756907	Q1 Q5 Q6
3	0.82814040	Q1 Q2 Q6
3	0.82866950	Q2 Q3 Q6
3	0.82891578	Q3 Q5 Q6
3	0.83021784	Q1 Q2 Q4
3	0.83551683	Q2 Q3 Q5
3	0.83862093	Q1 Q4 Q6
3	0.84168578	Q1 Q4 Q5
3	0.84370967	Q1 Q2 Q5
3	0.84397419	Q2 Q3 Q4
3	0.85059502	Q1 Q3 Q4
3	0.85716551	Q3 Q4 Q5
3	0.86056905	Q1 Q2 Q3
3	0.86557327	Q3 Q4 Q6
3	0.87075835	Q1 Q3 Q5
3	0.87637698	Q1 Q3 Q6
4	0.82356400	Q2 Q4 Q5 Q6
4	0.84089190	Q2 Q3 Q5 Q6
4	0.84502499	Q1 Q2 Q5 Q6
4	0.85076241	Q1 Q4 Q5 Q6
4	0.85086897	Q1 Q2 Q4 Q6
4	0.86050476	Q1 Q2 Q4 Q5
4	0.87034819	Q1 Q2 Q3 Q4
4	0.87061159	Q2 Q3 Q4 Q5
4	0.87068973	Q2 Q3 Q4 Q6
4	0.87113209	Q3 Q4 Q5 Q6
4	0.88004195	Q1 Q3 Q4 Q5
4	0.88081698	Q1 Q2 Q3 Q6
4	0.88122323	Q1 Q3 Q5 Q6
4	0.88161994	Q1 Q2 Q3 Q5
4	0.88699989	Q1 Q3 Q4 Q6
5	0.86269434	Q1 Q2 Q4 Q5 Q6
5	0.87666748	Q2 Q3 Q4 Q5 Q6
5	0.88604248	Q1 Q2 Q3 Q5 Q6
5	0.88935621	Q1 Q2 Q3 Q4 Q5
5	0.89029747	Q1 Q2 Q3 Q4 Q6
5	0.89071860	Q1 Q3 Q4 Q5 Q6
6	0.89436570	Q1 Q2 Q3 Q4 Q5 Q6

SECTION C.6: COMPUTATIONS FOR WEIGHTED DISTRIBUTIONS

In this section, we discuss the details behind the calculations of various weighted distributions. We discuss the following two cases:

Case I Weighted Relative Frequencies versus Rating Brackets.

Case II Weighted Relative Frequencies versus \$50,000 Funding Brackets.

These plots were done for all seven evaluation factors, Q1 - Q7 (when applicable) for each of the following categories and others of interest:

Materials Sciences (Laboratories)	Long-Term Non-Laboratory
Materials Sciences (Non-Laboratories)	Large-Dollar
Materials Sciences (Combined)	All Laboratory
Chemical Sciences (Laboratories)	All Non-Laboratory
Chemical Sciences (Non-Laboratories)	Long-Term Laboratory
Chemical Sciences (Combined)	All Long-Term
Biological Energy Research	Recent Laboratory
Nuclear Sciences	Recent Non-Laboratory
Engineering, Mathematics and Geosciences	All Recent
Advanced Energy Projects	Overall BES

CASE I: Weighted Relative Frequencies vs Rating Brackets (Horizontal Plots)

For any category of interest, we have the following setup:

		Rating Bracket (i)												
		1	2	3	4	5	6	7	8	9	10	11		
		$0 \leq x < 1$	$1 \leq x < 2$	$2 \leq x < 3$	$3 \leq x < 4$	$4 \leq x < 5$	$5 \leq x < 6$	$6 \leq x < 7$	$7 \leq x < 8$	$8 \leq x < 9$	$9 \leq x < 10$	$x = 10$		
Row-Column combina- tions which contribute to the category of interest	1	a_{11}	a_{12}	a_{13}								$a_{1\ 10}$	$a_{1\ 11}$	$\hat{N}_1 \hat{m}_1$
	2	a_{21}	a_{22}	a_{23}								$a_{2\ 10}$	$a_{2\ 11}$	$\hat{N}_2 \hat{m}_2$
	.													
	.													
	.													
	.													
J	a_{J1}	a_{J2}	a_{J3}								$a_{J,10}$	$a_{J,11}$	$\hat{N}_J \hat{m}_J$	
													$\hat{N}$	

The weighted relative frequency of the i-th column (rating bracket) is given by

$$\hat{p}_i = \frac{\hat{N}_1}{\hat{N}} \frac{a_{1i}}{\hat{m}_1} + \frac{\hat{N}_2}{\hat{N}} \frac{a_{2i}}{\hat{m}_2} + \dots + \frac{\hat{N}_J}{\hat{N}} \frac{a_{Ji}}{\hat{m}_J} \quad \text{for } i = 1, \dots, 11.$$

Case I (continued)

where $\hat{N}_j$ is the estimated number of active projects in the j-th row-column combination,

$\hat{m}_j$ is the number of sample elements evaluated in the j-th row-column combination in the category of interest,

a_{ji} is the number of elements out of $\hat{m}_j$ in the i-th rating bracket in the category of interest, and

$$\hat{N} = \sum_{j=1}^J \hat{N}_j.$$

In the categories, all laboratory, all non-laboratory, long-term laboratory, all long-term, recent laboratory, recent non-laboratory and all recent, we substitute for $\hat{N}_j$

$$\hat{N}_j = \frac{\hat{m}_j}{\text{number of sample elements in the j-th row-column combination}}$$

Example Nuclear Sciences (Q1)

	Rating Bracket							
	1	2	3	4	5	6		
	4<x<5	5<x<6	6<x<7	7<x<8	8<x<9	9<x<10		
Row 6, Column 1	1	0	0	1	1	0	$\hat{N}_1=4$	$\hat{m}_1=3$
Row 6, Column 2	0	0	1	1	0	0	$\hat{N}_2=5$	$\hat{m}_2=2$
Row 6, Column 3	1	1	0	1	4	1	$\hat{N}_3=29$	$\hat{m}_3=8$

$$\hat{p}_1 = \frac{4}{38} \cdot \frac{1}{3} + \frac{29}{38} \cdot \frac{1}{8} = 13.05\% \quad \hat{p}_3 = \frac{5}{38} \cdot \frac{1}{2} = 6.58\% \quad \hat{p}_5 = \frac{4}{38} \cdot \frac{1}{3} + \frac{29}{38} \cdot \frac{1}{2} = 41.67\%$$

$$\hat{p}_2 = \frac{29}{38} \cdot \frac{1}{8} = 9.54\% \quad \hat{p}_4 = \frac{4}{38} \cdot \frac{1}{3} + \frac{5}{38} \cdot \frac{1}{2} + \frac{29}{38} \cdot \frac{1}{8} = 19.63\% \quad \hat{p}_6 = 9.54\%$$

FIGURE C-1: HORIZONTAL BAR CHARTS BY CATEGORY

***** WEIGHTED *****

Q1

CATEGORY = NUCLEAR SCIENCES

PERCENTAGE BAR CHART

CASE II: Weighted Relative Frequencies vs \$50,000 Funding Brackets (Horizontal Plots)

The discussion here is identical to that given in Case I except that "Rating Bracket" is now replaced by "\$50,000 Funding Bracket."

Example Nuclear Sciences

		\$50,000 Funding Brackets (\$1,000)							
		$0 \leq x < 50$	$50 \leq x < 100$	$100 \leq x < 150$	$150 \leq x < 200$	$200 \leq x < 250$	$250 \leq x < 300$	$550 \leq x < 600$	$1400 \leq x < 1450$
		1	2	3	4	5	6	7	8
Row 6, Column 1	$\hat{N}_1=4$ $m_1=3$	1	1	1	0	0	0	0	0
Row 6, Column 2	$\hat{N}_2=5$ $m_2=2$	0	0	0	0	0	0	1	1
Row 6, Column 3	$\hat{N}_3=29$ $m_3=8$	2	3	0	0	1	2	0	0

$$\hat{p}_1 = \frac{4}{38} \cdot \frac{1}{3} + \frac{29}{38} \cdot \frac{2}{8} = 22.59\%$$

$$\hat{p}_5 = \frac{29}{38} \cdot \frac{1}{8} = 9.54\%$$

$$\hat{p}_8 = \frac{5}{38} \cdot \frac{1}{2} = 6.58\%$$

$$\hat{p}_2 = \frac{4}{38} \cdot \frac{1}{3} + \frac{29}{38} \cdot \frac{3}{8} = 32.13\%$$

$$\hat{p}_6 = \frac{29}{38} \cdot \frac{2}{8} = 19.08\%$$

$$\hat{p}_3 = \frac{4}{38} \cdot \frac{1}{3} = 3.51\%$$

$$\hat{p}_7 = \frac{5}{38} \cdot \frac{1}{2} = 6.58\%$$

REFERENCES

Cochran, W. G. (1977) Sampling Techniques (Third Edition). John Wiley and Sons, New York.

Dixon, W. J. and Massey, F. J. (1969) Introduction to Statistical Analysis (Third Edition). McGraw-Hill, Inc., New York.

Hansen, M. H., Hurwitz, W. N., and Madow, W. G. (1953) Sample Survey Methods and Theory, Volumes I and II. John Wiley and Sons, New York.

Hays, W. L., (1963) Statistics. Holt, Rinehart and Winston, New York.

Hollander, M. and Wolfe, D. A. (1972) Nonparametric Statistical Methods. John Wiley and Sons, New York.

Nathan, G. (1975) Tests of Independence in Contingency Tables from Stratified Proportional Samples, Sankhyā, Series C, Pt.1, pp. 77-87.

Sukhatme, P. V. and Sukhatme, B. V. (1970) Sampling Theory of Surveys with Applications, Iowa State University Press, Ames, Iowa.

APPENDIX D

SPECIAL ANALYSES AND DATA

APPENDIX D - SPECIAL ANALYSES AND DATA

Special analyses were conducted on the dispersion of reviewers' ratings, the ratings of the lower funded projects, and the amount of time the principal investigator devoted to the project. These are presented in this Appendix together with the histograms for individual rating variables for each program area.

The purpose of studying the dispersion in reviewers' ratings was to estimate what changes in results would occur if other similarly constituted panels had been utilized. The lower funded projects were examined to determine if there were any significant differences between projects funded below selected bounds and all other projects. The relationship of principal investigator time devoted to a project and overall project quality rating was examined to determine if a correlation exists between low involvement and low ratings.

Histograms for the individual rating variables (team quality, scientific merit, scientific approach, productivity, importance to mission, and energy impact) for each of the program areas (Materials Sciences; Chemical Sciences; Biological Energy Research; Nuclear Sciences; Engineering, Mathematics and Geosciences; and Advanced Energy Projects) are presented. These figures display detailed breakdowns and program area differences.

DISPERSION IN REVIEWERS' RATINGS

One important concern is whether the sample of projects selected for this study would have received significantly different ratings if an entirely different set of reviewers had been chosen. More specifically, it is important to determine whether the proportions of projects exceeding the quality

rating thresholds of 5, 7 and 9 would be significantly different from those quoted in the body of this report. Based on the observed dispersion in reviewers' ratings, a simulation study was performed to estimate how significantly the results shown in Table D-1 would be changed if a completely different set of reviewers had been selected. (Since this analysis used unweighted data rather than the weighted data used in estimating the proportions, the estimates of change should be viewed as approximate.)

TABLE D-1: Estimates of the Proportion of Active BES Projects Rated At or Above Selected Rating Thresholds

<u>Rating Threshold</u>	<u>Proportion of Projects At or Above Threshold</u>	<u>Proportion At or Above Threshold - 90 Percent Lower Confidence Bound</u>
5.0	.91	.87
7.0	.59	.53
9.0	.10	.06

The standard deviation of reviewer scores, σ_R , was calculated for each sample project according to the formula:

$$\sigma_r = \sqrt{\frac{\sum_{i=1}^N (Q7_i - \overline{Q7})^2}{(N - 1)}}$$

where $Q7_i$ is the overall project quality rating of the i -th reviewer, $\overline{Q7}$ is the panel average rating, and N is the number of reviewers.

It was found that the number of projects with standard deviations ranging from 0 to 1, 1 to 2, and 2 to 3, was 86, 35, and 8, respectively. The overall average standard deviation was 0.92.

The standard deviations were then averaged over all the projects in four rating ranges (Table D-2). It is noted in this table that the lower rated projects have higher average standard deviation.

Table D-2: Average Reviewer Standard Deviation Dispersion
Based On Overall Project Quality Rating

<u>Overall Project Quality Rating Ranges</u>	<u>Average Reviewer Standard Deviation</u>
0.0 - 4.9	1.32
5.0 - 6.9	1.14
7.0 - 8.9	0.80
9.0 - 10.0	0.50

Each of the 129 projects was examined to determine the probability that a different panel would have given it a rating in a different quality range; i.e., the probability that the project would cross one of the thresholds noted in Table D-1 and, thereby, alter the calculated proportions. The standard error of the average reviewer rating, σ_p , was determined from the average reviewer standard deviation in the relevant quality range and the number of reviewers:

$$\sigma_p = \frac{\sigma_R}{\sqrt{N}}$$

The probability, P_j of crossing below the j -th threshold (T_j) is the error function $F(X_j)$; the probability of crossing above the j -th threshold is one minus the error function. The variable X_j in the error function is defined by:

$$x_j = \frac{T_j - \bar{Q7}}{\sigma_p}$$

The calculated probabilities for all projects were summed, and the net change in the estimated proportion of projects above each threshold was obtained (Table D-3). In all cases the estimated proportions resulting from the changes were within the 90 percent lower confidence levels (Table D-1).

TABLE D-3: Calculated Changes in the Estimated Number and Proportion of Projects At or Above Selected Rating Thresholds Due to Selection of a Different Set of Expert Reviewers

<u>Rating Threshold</u>	<u>Number of Projects Moving Up</u>	<u>Number of Projects Moving Down</u>	<u>Net Change</u>	<u>Estimated Change in Measured Proportion Above Threshold</u>
5.0	1.05	4.23	-3.18	-0.025
7.0	1.72	5.26	-3.54	-0.027
9.0	3.04	2.23	+1.61	+0.012

RATING OF LOWER FUNDED PROJECTS

The lower funded projects were compared with all others. A sensitivity analysis was performed by varying the bound below which the projects are defined as lower funded (the lower bound). The magnitude of the difference between lower funded projects and all others and the degree of significance of the difference varied depending on the lower bound as given in Table D-4.

Table D-4: Estimates of the Proportion of Active BES Projects
Rated At or Above Selected Rating Threshold

<u>Lower Bound of Funding</u>	<u>Rating Threshold</u>	<u>Projects Funded At or Above Lower Bound</u>	<u>Projects Funded Below Lower Bound</u>	<u>Chi- Square</u>
\$ 60,000	5	.94	.91	.57
	7	.65	.44	6.21
\$ 75,000	5	.93	.86	4.14
	7	.65	.48	6.18
\$100,000	5	.92	.90	1.05
	7	.75	.45	13.00

In all of these lower bound cases (\$60, \$75 and \$100 thousand), the differences in the proportions of projects rated at or above 7.0 were significant at a confidence level above 90 percent (see Appendix C for discussion of confidence level and chi-square). In only one of the three cases, the \$75 thousand lower bound case, was the difference in proportions of projects rated at or above 5.0 significant.

PRINCIPAL INVESTIGATOR DEDICATION TO PROJECT

At the beginning of the peer review process, each principal investigator was asked to estimate the number of hours he devoted each year to his project. The distributions of responses for laboratory projects and non-laboratory projects are shown in Figure D-1. The non-laboratory principal investigators, most of whom are at universities, seldom devoted more than half their time to the project. By contrast, the laboratory principal investigators generally spent more than half of their time on the project, with the exception of a group of 19 researchers who spent less than 600 hours annually.

The overall project quality ratings for the group with principal investigator involvement of less than 600 hours were compared with ratings of all other projects for both DOE laboratory and non-laboratory samples (Figure D-2)

Figure D-1 — Distribution of Principal Investigator Involvement for DOE Laboratory and Non-Laboratory Sample Projects

Figure D-2 — Histograms of Overall Project Ratings for DOE Laboratory and Non-Laboratory Sample Projects in Which the Principal Investigator Invested Less Than 600 Hours Annually and Those in Which the Principal Investigator Invested 600 Hours or More.

to test the hypothesis that projects with heavy participation from the principal investigator would be of generally higher quality.

The quality rating of non-laboratory projects appears to be higher with greater principal investigator involvement for projects with a threshold rating of 5. There was no significant difference between the two groups of laboratory projects (high and low involvement), and the two groups of non-laboratory projects (high and low involvement) above a quality threshold rating of 7 (see Table D-5).

All of the analysis of principal investigator involvement has been performed on unweighted sample data, and the conclusions reached are applicable to the sample only.

Table D-5: Results of Chi-Square Tests of Proportion of Projects At or Above a Given Threshold for Low Principal Investigator (PI) Involvement (<600 Hours) Versus High Principal Investigator Involvement (>600 Hours)

<u>Institution</u>	<u>Threshold</u>	<u>Low PI Time</u>	<u>High PI Time</u>	<u>Chi-Square</u>
Laboratory	5.0	0.89	0.97	1.17
	7.0	0.79	0.72	0.32
Non-Laboratory	5.0	0.86	0.94	2.74
	7.0	0.48	0.54	0.34

HISTOGRAMS OF INDIVIDUAL RATING VARIABLES FOR EACH PROGRAM AREA

For each BES program area, ratings of the component variables (quality of project team, scientific merit, scientific approach, productivity, importance, and impact) were assembled for all of the sample projects within the area. Histograms for these six component variables for each of the six major program areas (Materials Sciences; Chemical Sciences; Biological Energy

Energy Research; Nuclear Sciences; Engineering, Mathematics, and Geosciences; and Advanced Energy Projects) are presented in Figures D-3 through D-8.

Figure D-3 — Histograms of Individual Rating Variables for Materials Sciences

Figure D-4 – Histograms of Individual Rating Variables for Chemical Sciences

Figure D-5 — Histograms of Individual Rating Variables for Biological Sciences

Figure D-6 – Histograms of Individual Rating Variables for Nuclear Sciences

Figure D-7 — Histograms of Individual Rating Variables for Engineering, Mathematics, and Geosciences

Figure D-8 — Histograms of Individual Rating Variables for Advanced Energy Projects

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