Program Plan for Reliability and Maintainability in Active Solar Heating and Cooling Systems

October 1980

Prepared for:
U.S. Department of Energy
Assistant Secretary Conservation
and Solar Energy
Office of Solar Applications for Buildings

Under Contract No. AC01-80CS36010

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Washington D.C. 20585

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Baltimore, Md.

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FOREWORD

This document is intended to provide direction to the administration of a program for reliability and maintainability in active solar energy systems. The program plan is meant to provide a framework for the R&M program which is applicable to FY81 activities as well as activities in the mid (1985-1990) and long term (1900-2000). Initial planning for this program has been accomplished through the following sequence of activities:

1.) Assessment of needs to be met by the program,
2.) Assessment of constraints under which the program will function,
3.) Development of a program goal and objectives,
4.) Development of an approach toward meeting the goal and objectives,
5.) Identification and evaluation of individual tasks,
6.) Prioritization of tasks.

A discussion of these initial planning activities constitutes the major part of this document.

Additionally, the following planning activities will be accomplished annually after the initial program framework has been established:

1.) Development of a program budget,
2.) Selection of tasks to be accomplished,
3.) Detailed definition of selected tasks, including:
    - o Subtask work statements
    - o Schedules and milestones
    - o Costs
4.) Identification of program participants.

Because constraints change over time, these annual planning activities are only addressed in this document in a general manner. Task selections for FY81 are recommended for several possible budgetary scenarios. Guidelines are provided for detailed planning of tasks and for selecting tasks to be accomplished in the near, mid, and long term. However, this document does not address directly the definition of subtask work statements, task scheduling, and identification of program participants.

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I. EXECUTIVE SUMMARY

This document presents a plan for the Department of Energy, Office of Solar Applications for Buildings program addressing reliability and maintainability (R&M) of active solar energy systems. The goal of the R&M program is to accelerate the removal of reliability and maintainability as major concerns impeding the widespread adoption of solar energy systems.

Specific objectives that support that goal are as follows:

- Provide all groups that have solar R&M concerns with the information that is available to the program and that can assist in alleviating those concerns.
- Assist the solar energy industry in improving levels of R&M performance in state-of-the-art solar energy systems, components, and materials.
- Assist in the early development of a viable infrastructure for the design, manufacture, installation, and maintenance of reliable, maintainable, and durable solar energy systems.
- Assist in the development of appropriate standards, code provisions, and certification programs relating to the R&M performance of solar energy systems, components, and materials.
- Develop the information required to support the other activities within the R&M program.

These objectives correspond to five areas of action; regulations, research and development, technology transfer, solar industry infrastructure development, and data collection and analysis.

Because several other existing Government programs are engaged in activities that relate to solar energy system R&M, much of the work to be performed under the R&M program involves supporting those activities. The selected approach is intended to prevent duplication of effort. Specific tasks to be performed under the R&M program for FY81 are listed below:

- Data Collection and Analysis
  - o Identify and assess existing data sources and bases
  - o Establish data sources for information on repair and maintenance costs and begin cost analysis.

- Identify systems that have good R&M performance records and evaluate that performance.
- Continue analysis of existing data to identify major generic R&M problems and solutions.
- Determine need for and feasibility of data base consolidation.

- Technology Transfer
  - Publish series of guidelines oriented toward residential and commercial hot water system owners.
  - Publish articles in professional and technical journals containing information on R&M status and problems and establish other mechanisms for exchanging R&M information with professional and technical organizations.
  - Provide R&M information and assistance for development of design manuals.
  - Present papers and otherwise assist in professional and technical conferences and workshops.
- Infrastructure Development
  - Identify existing training programs and assess programs to determine R&M informational material needs.
  - Develop R&M informational materials and make available to training programs.
  - Provide manufacturers with guidelines concerning what information should be included in installation, operation and maintenance manuals.
- Regulations
  - Assess activities of all organizations/programs involved in development of standards, codes, and certification and provide those groups with R&M status information. Recommend additional emphasis on R&M considerations where necessary.
- Research and Development
  - Identify existing R&D programs whose activities impact

the R&M performance of active solar energy systems, components and materials.

- o Review and collate existing results from R&D programs and assess impact on R&M performance
- o Recommend appropriate areas for additional R&M related R&D within each program.
- o Provide R&D programs with results of data collection and analysis

R&M program management activities will include continual review and evaluation of program activities and objectives, obtaining feedback from program user groups, and coordination of activities on a regional and local basis.

II. INTRODUCTION

A. Background

The reliability of solar energy systems is of great concern to the government, to industry, and to potential purchasers of these systems. The Domestic Policy Review completed in 1979 concluded that the reliability of solar energy systems was limiting the growth of the industry. The experience of the Department of Energy (DOE) in the Solar Heating and Cooling Demonstration Program (P.L. 93409) has confirmed the existence of serious reliability problems, since many of the projects within the Program have experienced failures. Table 1, taken from "Selling the Solar Home '80," which was prepared for the U.S. Department of Housing and Urban Development (HUD), indicates the questions most frequently asked of builders by prospective owners. From that table, it can be seen that R&M identified as a major buyer concern. Information from the private sector has indicated that R&M problems and concerns are not unique to the Federal program.

TABLE 1: Most Frequent Questions Asked by Purchasers of Solar Energy Systems. (Taken from "Selling the Solar Home '80, - Market Findings for the Housing Industry" prepared for HUD by RERC, January 1980, based on data taken from HUD Cycles 1, 2 and 3 residential solar energy projects.)

Issue	Percent Builders Reporting Question
Cost of Solar Energy System	55
Technical Questions on Solar System	35
Reliability of Solar	30
Utility Cost Savings	30
Operating Data on Solar	28
Recapture of Investment	25
Maintenance and Repair Costs	20
House Price	15
Amenity Package	4
House Style	3
General Location	3
Availability of Financing for Solar System	3
House Size	3
Convenience to Schools	1

To consider a solar energy system successful, the system must efficiently transfer energy to the load at reasonable cost, and the system must be normally available to perform its function. The availability of these systems, which is a function of their reliability and maintainability, has been inadequate in many cases.

B. Purpose

The purpose of this document is to provide a new overall plan for DOE's program for the improvement of reliability and maintainability of solar energy systems for buildings.

The requirements of the plan are that it:

- Incorporate the philosophy and recommendations of the "Active Solar Strategy" developed by the DOE Office of Solar Applications for Buildings.
- Identify an overall strategy and rationale for the DOE R&M program.
- Provide reference points including specific goals and objectives against which future program success can be measured and potential related tasks can be evaluated.
- Identify and prioritize specific activities designed to meet the stated goals and objectives.
- Provide a basis for the development of schedules and funding levels.
- Provide a partial basis for identification of appropriate program participants.

C. Scope

1. Technologies

The technologies considered in this plan include active solar heating, cooling, and hot water systems for building applications. Both new and retrofit construction and commercial and residential applications are included. Thermosyphon domestic hot water systems, while not classified as active systems, will benefit from almost all the information generated in an R&M program for active systems.

2. Definitions

Reliability is defined for the purposes of this plan as:

- The probability that a component or system will satisfactorily perform its intended function under given circumstances over a given time.

Under this definition the following types of system problems are among those that would be considered as reliability problems:

- Systems that have never functioned properly
- Systems that have not provided as much energy as expected while appearing to operate properly
- Components that have experienced severe corrosion in a short time
- Systems that provide as much energy as expected early in their life but degrade quickly
- Systems that have catastrophic failures such as collector system freeze up after the first exposure to severe cold.

Thus, it can be seen that reliability and system performance are very strongly related and are not completely separate aspects of the system. This fact has important implications for the structuring of the R&M program.

Maintainability is another system characteristic strongly related to system reliability. Maintainability is defined for the purposes of this plan as:

- The probability, when a maintenance or repair action is initiated, that a system will be restored to its specified operational condition within a specified period of down time.

This definition would account for ease of access to components and cost of repair. Thus, a component or subsystem that can be expected to fail frequently or need regular maintenance should be easy to assess, and the building owner or maintenance personnel should be able to perform the necessary adjustment.

The relative importance of system characteristics such as reliability, maintainability, durability, safety, cost and performance cannot be specified universally. The goal of a designer or manufacturer should be to minimize the life cycle costs of the system and maximize system effectiveness. The relationship of the components of system effectiveness are illustrated simplistically in Figure 1. Maximizing effectiveness requires tradeoffs. For example, life cycle cost tradeoffs can be made between improving the reliability or improving the maintainability of the system or technology. Similarly, these tradeoffs must consider the users' ability and inclination to provide maintenance.

The definitions provided are of necessity relatively broad and the boundaries between performance, cost, reliability and maintainability are not clear-cut. For instance, one should not make recommendations regarding performance improvements without considering the impact of the recommendations on cost, reliability and maintainability. Similarly, recommendations or guidelines regarding improving reliability must recognize the impact on cost and performance. Separate, poorly linked programs in R&M, cost and performance will not likely be as successful as a coordinated approach.

3. Requirements of the "Active Solar Strategy":

The Active Heating and Cooling Division, Office of Solar Applications for Buildings completed an "Active Solar Strategy" in May, 1980. That document places a number of direct and indirect requirements on the R&M program. The following points are paraphrased from that strategy:

- The Federal role is to create the climate in which the private sector can achieve the program objectives formulated in the public interest.
- The strategies employed must help maintain stability in the market place.

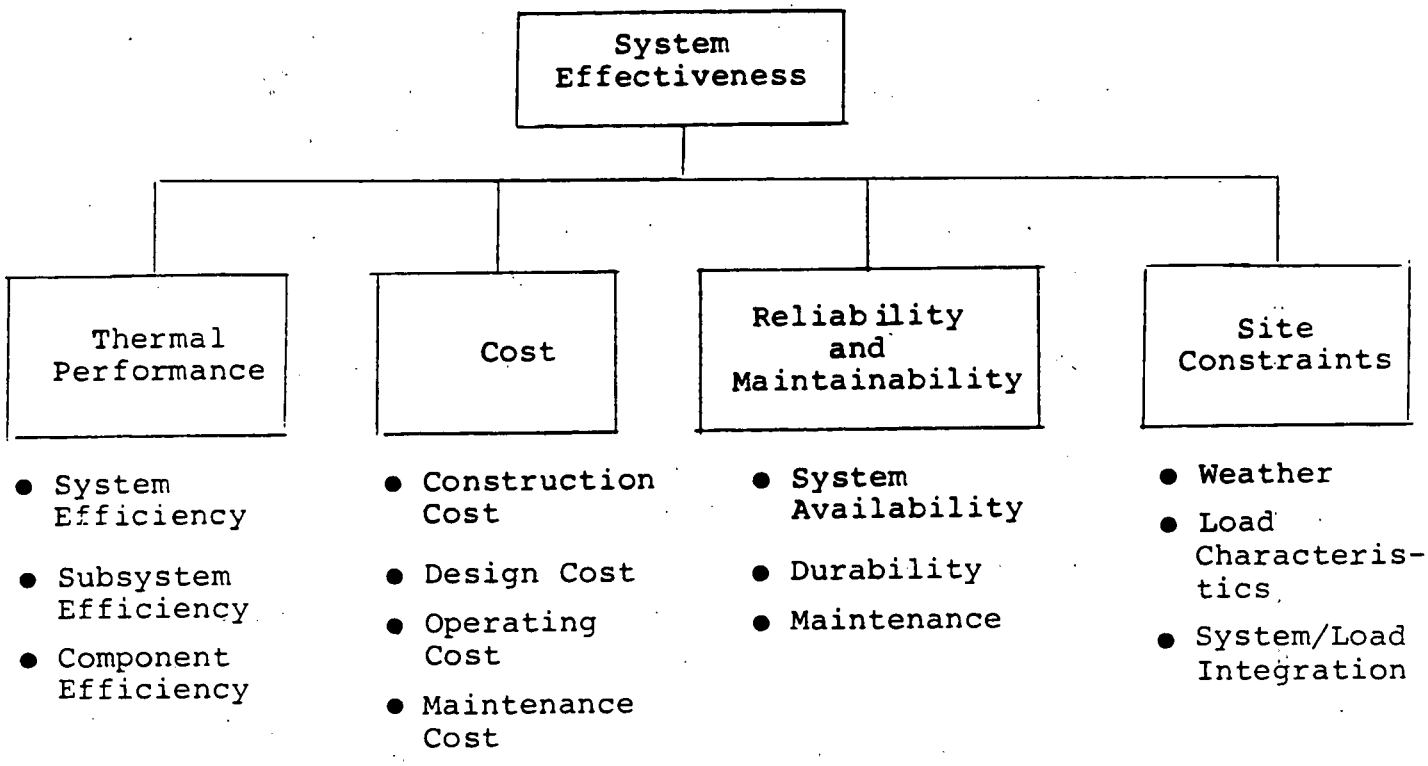


Figure 1: Components of System Effectiveness

- The overall goal must be converted into regional, state, and local program goals.
- The entire distribution system, from manufacturer to consumer, needs simultaneous support to assure market stability.
- Somewhat different strategies must be employed to bring the different technologies (water heating, space heating, and space cooling) to market.
- The solar program must concentrate available resources on activities with the greatest leverage in the private sector.
- The program will move away from supporting the development of components which leaves the assembly (and often system design) to field installers; towards well-integrated and packaged, easily installed systems; delivered with clear and well-written assembly, maintenance and servicing instructions.
- Simplicity and clear information will ensure system reliability and increase consumer confidence.
- Solar water heaters require improvements in the following areas: better prepackaging of systems, with improved installation/maintenance/service/operating instructions; pre-insulated piping, prefabricated roof-mounts and roof penetrations and other improvements to speed up and simplify installation; complete kit delivery, improved technical services by manufacturers and installers; provisions for pretesting before installation; monitoring/diagnostic capability, and similar product improvements.
- Manufacturers of components, such as controllers and storage tanks, should be encouraged to develop components specifically designed and warranted for solar applications.
- The strategy lists a number of specific activities and defines the time frame in which they should occur. The following activities have a bearing on the R&M program:

- 1980-1985
  - develop technical service capabilities for water heating systems,
  - develop and disseminate useful technical and general consumer information about water heating systems.
  - provide intensive installer training for water heating systems.
  - develop prepackaged water heating systems.
  - expand random testing of production models of water heating systems.
  - simplify data systems.
  - develop simple operational monitoring devices for installed water heating systems.
- 1980-1990
  - develop improved and simplified controls.
  - provide installer training for direct solar space heating and solar/heat pump systems.
  - develop prepackaged direct space heating and solar/heat pump systems.
  - conduct random testing of direct solar space heating and heat pump systems.
  - develop simple monitoring devices for direct space heating and heat pump systems.
- 1980-2000
  - develop new materials.
  - develop low cost UV resistant components and materials.
  - develop technical service capabilities for solar cooling systems.
  - develop and disseminate technical information for space cooling systems.
  - provide installer training for solar cooling systems.
  - develop prepackaged solar cooling systems.
  - conduct random testing of space cooling systems.
  - Develop simple monitoring devices for solar cooling systems.

- The strategy provides important points for program planning and operation as follows:

- One of the key needs of the solar program is accountability, i.e., a way of effectively evaluating program achievement against objectives, and mechanisms to redirect program activities as changing needs or ineffectiveness dictate.
- All participants in the program will have a voice in the planning document.
- A critical path flow chart should be established.
- Program implementation will be decentralized and centered on regional management.

III. R&M IN THE SOLAR INDUSTRY

A. The Building Industry

The building industry, of which the solar industry is a part, has rarely used traditional reliability analysis. Generally, R&M improvements are the result of an intuitive, experience-based process rather than a well defined scientific process in this industry.

Designers do not have the time or funds during a typical project to perform detailed reliability/maintainability analyses. In addition, they do not have adequate data on which reliability analyses could be based. Engineers and designers utilize configurations and techniques that their experience and education have taught them will work. For new products, they rely strongly on the manufacturer to provide design information on which to base decisions.

Manufacturers probably have the time to implement traditional R&M analysis, but they generally do not do it. Some of the larger manufacturers do apply basic R&M techniques. However, most manufacturers do not collect reliability information on their products in a form useful for traditional reliability analysis. If they get too many "call backs" on a particular product, they make changes based on their experience and judgement.

If the solar industry is to be part of building/HVAC industry, traditional reliability/maintainability analysis, as practiced in the defense and nuclear industry, is not appropriate and should not be forced on the fledgling industry.

B. Sequence for Development of Reliable Systems in a New Technology

Valuable insights can be gained by reviewing the normal process of development of reliable systems in a new technology in the building industry. A simplified version of the sequence of development and adoption is offered below:

Stage 1. Innovators demonstrate the feasibility of the technology. At this point very little reliability information is developed. General impressions of the reliability and maintainability as being major or minor problems are obtained.

Stage 2. Early adopters (owners, engineers, installers, manufacturers) gain experience in the technology. They learn what works and what does not. At this point, reliability and maintainability are still concerns, and a more accurate understanding of the reliability of the technology is developing.

Stage 3. Standard developers use the industry collective experience to provide standards on components and systems. This process can be long and is usually continuous, i.e., revisions to standards are made regularly. Concern over reliability and maintainability is reduced.

Stage 4. Codes developers utilize voluntary standards to develop enforceable regulations and building codes.

Stage 5. A mature industry exists. At this point, there are many groups with solar experience and knowledge, and reliability and maintainability are no longer major concerns. Also, in a mature technology, the manufacturers generally have the lead role in assuring and improving reliability/maintainability. They provide engineers with the necessary design information for their product. They provide the installer the necessary installation and servicing information and they provide the system owner adequate warranties, and operating and maintenance information.

It is generally agreed that the solar industry is in the first or second stage described above. However, there is activity now in the standards area, most of the activity involving specific system components. The government has played a part in accelerating standards development. Nonetheless, the availability of all the appropriate standards is still years away.

Figure 2 illustrates the cyclic nature of the development and implementation of the technology. Beginning at the upper left corner of that figure, "Technology" represents the "state-of-the-art" at any given time. This can be thought of as the sum of the collective wisdom that exists regarding the specific technology. The "Infrastructure" (designers, manufacturers, installers)

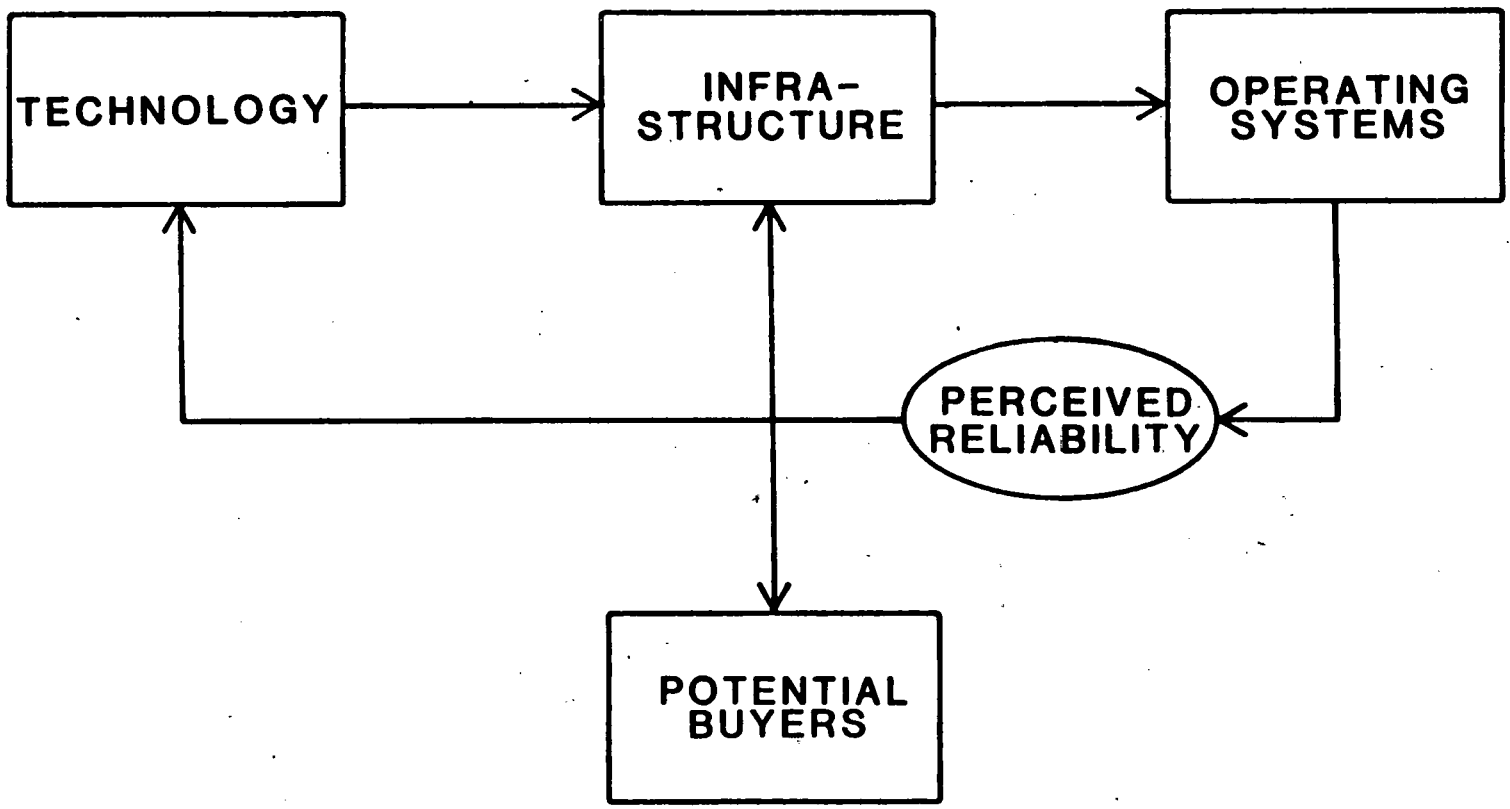


FIGURE 2. SOLAR RELIABILITY CYCLE

translates imperfect knowledge of the technology into operating systems. Over time these operating systems develop a track record and the information is fed back into the development of the technology and the infrastructure. Also, potential buyers perceive the reliability of the operating systems of which they have knowledge and make the decision as to the acceptability of that perceived reliability. One basic reason for the need for a DOE solar R&M program is the assessment that the perceived reliability of the existing, operating system is unacceptable to potential buyers and will limit the number of systems installed. Related concerns of maintainability and durability are also believed very important, strongly related aspects of this program.

C. The Status of Reliability in Existing Systems

The development of the reliability of a new technology could theoretically be tracked over time. Figure 3 below shows a hypothetical plot of reliability versus time for the average installed system and the "state-of-the-art" technology. The curves are strictly qualitative to indicate general relationships and are not intended to be used quantitatively. Figure 3 indicates that a time lag exists between state-of-the-art improvements and their implementation due to the time required for diffusion of information throughout the industry.

Many reliability problems are caused by persons unaware of the knowledge that exists elsewhere that could have prevented the failure. Thus, the reliability of the basic solar technology is generally better than the reliability of the typical systems that are installed at any point in time. The reliability of the average installed system is most important to the commercialization of solar energy.

In the early years of an emerging technology, like solar energy, the difference in reliability between state-of-the-art and existing systems can be great because many aspects are new to many members of the infrastructure. Figure 4 indicates the general trend that is hoped to occur in the reliability of installed systems. A distribution of reliabilities exist at any point in time. The hypothetical curve that indicates the current status of the reliability of installed systems indicates a relatively

broad distribution. Some systems have good reliability, however, the majority of systems may have a low reliability. These curves are not intended to be used quantitatively, but only to show general relationships. It is hoped that the very low reliability systems can be eliminated in the future by simply conveying the "lessons learned" from the early systems. Further technology transfer and identification of major problem areas can push the distribution of systems toward greater reliability. There are systems that are installed now that have very good reliability. The task is to have the individuals responsible for the good systems to spread the knowledge they have and raise the general reliability of installed systems.

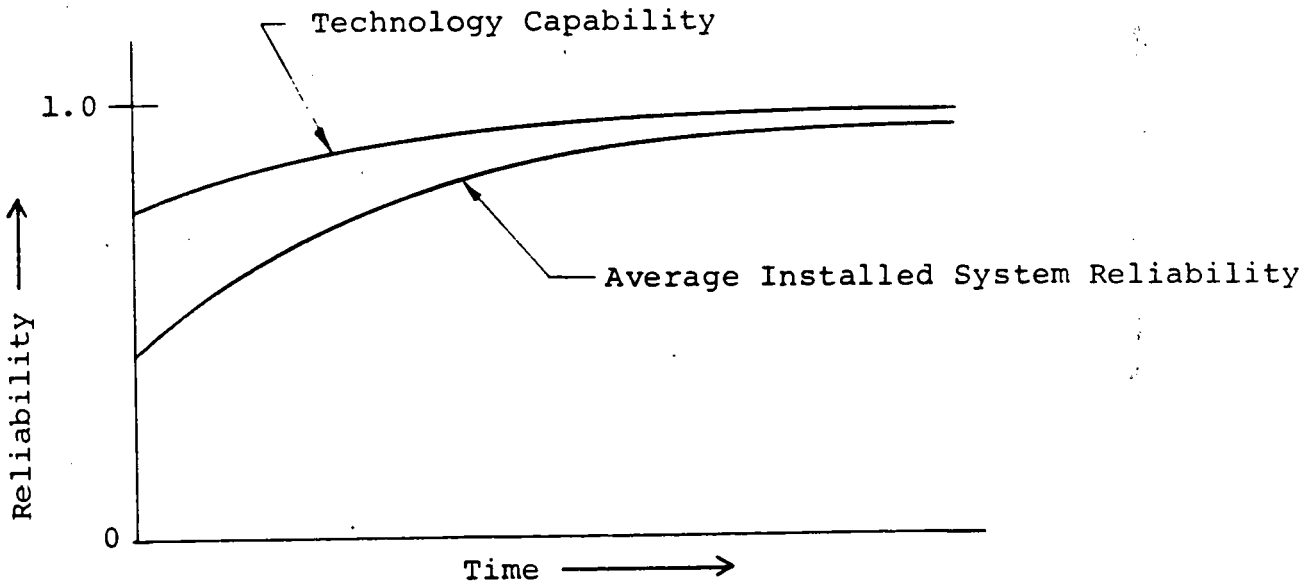


FIGURE 3: RELIABILITY VERSUS TIME

D. Areas of Possible Government Action

A number of government actions could be applied to the R&M problem. Figure 5 identifies the leverage points to which the following general categories of government action apply.

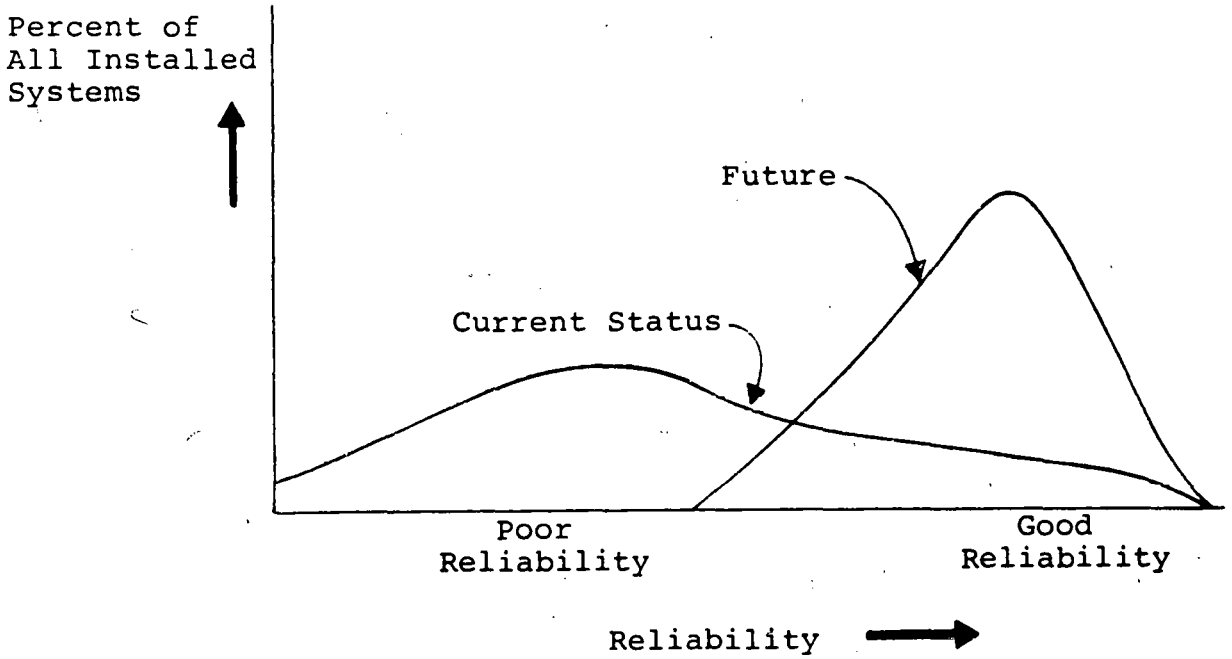


Figure 4: Hypothetical Reliability Distribution For Existing and Future Solar Energy Systems

1. Research and Development (R&D):

R&D as referred to here applies to the improvement of the basic state-of-the-art and not directly to the improvement in installed systems. The types of activities that could be included in this category are studies on the impacts of redundant components or subsystems, modularization or systemization of components, standardization, and development of improved materials. In the building industry these activities are traditionally performed by manufacturers.

2. Technology Transfer/Data Dissemination:

This area of government action is aimed at diffusing the state-of-the-art knowledge throughout the infrastructure. Activities within this area could include workshops, conferences, articles, manuals, guidelines, and hot lines. In the building industry these activities are typically carried out by professional societies or associations.

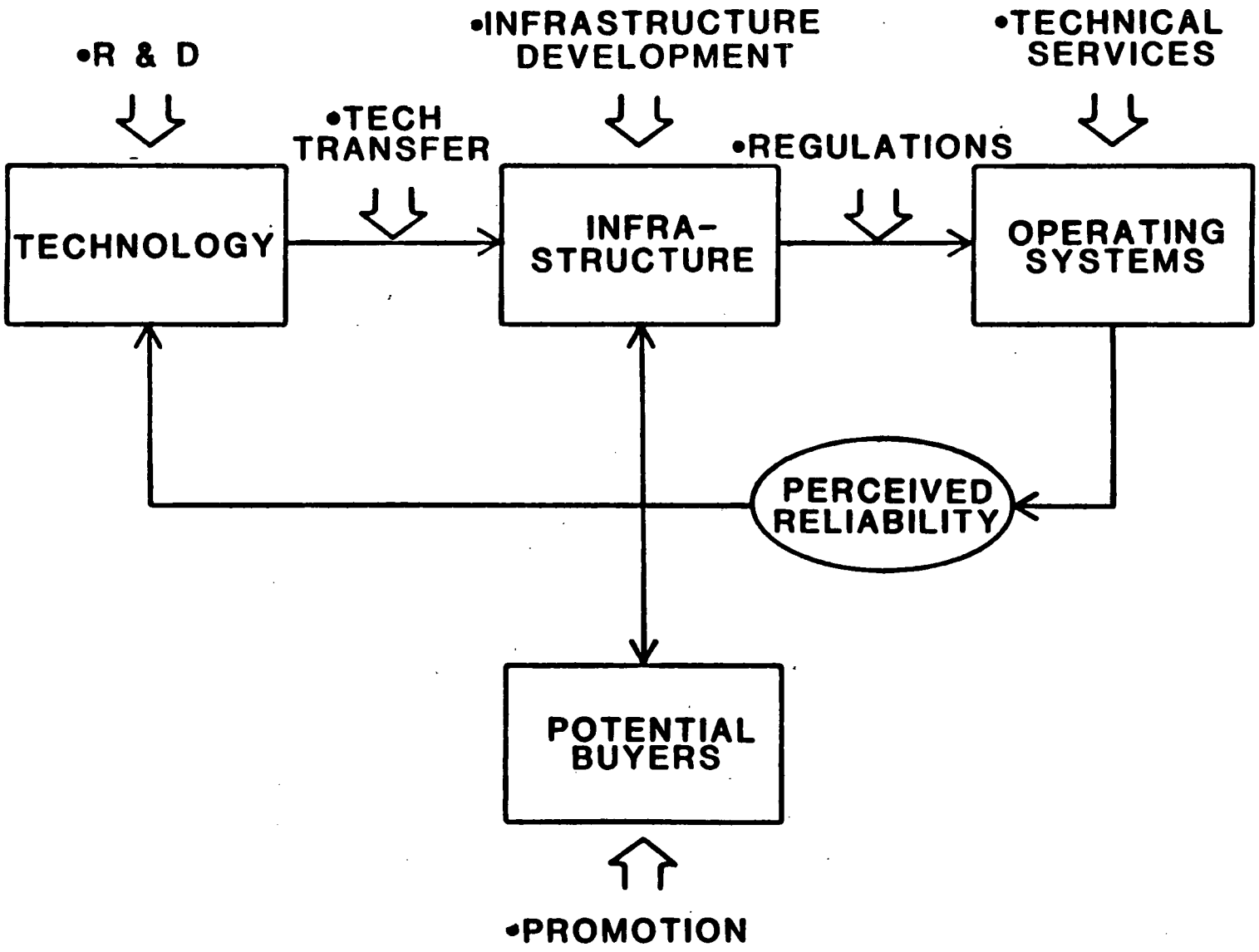


FIGURE 5: POINTS OF LEVERAGE FOR POSSIBLE GOVERNMENTAL ACTIONS

3. Infrastructure Development:

Activities that increase the availability of well-qualified designers, installers, and manufacturers and/or support their R&M related activities fall in this area. These activities might include training programs, underwriting guarantees, funding manual development, funding system testing or certification programs.

4. Regulations:

This area comprises external constraints that are placed on the infrastructure and includes standards, codes, certification or other legal requirements such as required guarantees for Federal programs. In this area the government could and does support development of concensus standards, codes and certification programs for private groups.

5. Technical Services:

Technical services are some of the activities normally performed by designers, installers, maintainers, and manufacturers and include inspecting systems and repairing/troubleshooting systems. These are aimed at improving the existing installed systems.

6. Promotional Activities:

These activities are normally performed by organizations within the infrastructure and are aimed at overcoming concerns of potential buyers by providing them information on the reliability of systems. Promotion can be quite effective at overcoming concerns if the concerns are unfounded. Of course, if the information provided indicates that the systems have poor reliability, this activity could be self-defeating. It is the perception of DOE that reliability and maintainability are serious concerns at the present time; thus, extensive promotional activities will be more appropriate later.

E. Reliability Problem Analysis

The types of reliability problems that are being encountered should be an important consideration in determining which government actions are adopted. For instance, many of

the current problems that are perceived to be reliability problems are due to design errors, installation errors, inadequate quality control, utilization of inappropriate materials, misuse or inappropriate operation, or inadequate maintenance.

In an environment in which most of the reliability problems are due to the above types of errors, a reliability model of generic systems based on mean-time-to-failure of components is relatively meaningless. Also, the added system reliability of utilizing redundant pumps will probably not be detectable if the pump materials are grossly incompatible with the heat transfer fluid or piping materials.

The early phases of the R&M program must recognize the types of errors that are being made and disseminate that information so that those errors are not repeated unnecessarily. Eventually, when a purchaser has more confidence that the system will be designed and installed correctly, the application of the more exacting R&M analysis techniques will help improve reliability even further.

IV. PROGRAM GOAL, OBJECTIVES, AND STRATEGY FOR PLAN DEVELOPMENT

A. Goal of the Federal Solar R&M Program

The goal of the DOE Solar R&M Program is to accelerate the removal of reliability and maintainability as major concerns impeding the widespread adoption of solar energy systems.

This goal is necessarily broad. It recognizes that there exists a normal process by which R&M concerns are alleviated. DOE's program must work within the normal process, applying leverage where possible to remove barriers to the commercialization of solar energy systems.

The goal implies actions that remove concerns, not only identify them. Thus, a program restricted to collection of data to identify reliability problems would not meet the goal. The need to go beyond identifying problems has been reflected in the criticisms received over the last few years regarding many reports published on solar energy systems.

A program limited to problem identification without an equal effort directed toward overcoming the problems could have a negative impact on the adoption of solar energy systems by emphasizing concerns and not solutions. The method selected for overcoming the problems, however, must be realistic and must reflect the limited resources available to the program.

Fortunately, from the standpoint of program costs, many of the activities that are required to overcome R&M concerns are underway in some form in the overall Federal solar program. All that may be lacking is the proper emphasis on the R&M aspects. In many cases, an R&M program needs only to interface with other programs so that reliability and maintainability considerations are given adequate attention and are balanced against performance, cost and other concerns. Specific examples of this type of interface activity are discussed in Section VI.

B. Objectives

The objectives of the program for R&M in solar heating and cooling systems are presented below:

1. Provide all groups that have solar R&M concerns with the information that is available to the program and that is necessary to alleviate those concerns.

2. Assist the solar energy industry in improving levels of R&M performance in state-of-the-art solar energy systems, components, and materials.
3. Assist in the early development of a viable infrastructure for the design, manufacture, installation, and maintenance of reliable, maintainable, and durable solar energy systems.
4. Assist in the development of appropriate standards, code provisions, and certification programs relating to the R&M performance of solar energy systems, components, and materials.
5. Develop the information required to support the other activities within the R&M program.

The first four of the five objectives listed above relate directly to four of the areas of possible government action identified in Section III:

1. Technology Transfer/Data Dissemination
2. Research & Development (R&D)
3. Infrastructure Development
4. Regulations

The fifth objective relates to a Data Collection and Analysis activity that will be required to support the above activities.

Note that two of the areas of possible government action identified in Section III, Promotional Activities and Technical Services, are not represented by respective objectives above. The evaluation presented in Section V will indicate why these activities have not been carried through with specific objectives for the program.

C. Strategy for Developing R&M Program Plan

Specific Government funded activities within this program will be evaluated in terms of the degree to which they act to reduce the R&M concerns within the solar market place. Development of the plan is based on the following procedure:

1. Identify the appropriate target groups within the solar infrastructure and market. The general groupings are:
   - Owners/Buyers
   - Lending Institutions

- Insurers
- Designers
- Manufacturers
- Installers/Contractors/Builders
- Labor Organizations
- Maintenance Personnel
- Codes Officials
- Standards Development Groups
- Government Agencies

2. Identify the major R&M concerns and requirements of each target group.
3. Identify and evaluate possible Government actions for reducing the user concerns. Evaluate actions based on:
   - Estimated effectiveness in reducing concerns
   - Estimated cost
   - Agreement with "Active Solar Strategy"
   - Estimated time requirements
   - Ongoing activities within other programs
4. Develop tasks, schedules and final costs for each action.
5. Prioritize actions and identify those to be accomplished within several budget constraint scenarios.

V. IDENTIFICATION OF APPROPRIATE GOVERNMENT ACTIONS

A. Effectiveness of Government Actions in Alleviating User Concerns

Table 2 is taken from a series of tables provided in Appendix A. Those tables were used to judge the effectiveness of a series of Government actions. Note that the table matches a list of user concerns with a list of possible Government actions. The estimated effectiveness of each of those Government actions in alleviating a particular concern is indicated by black circles, white circles, and blanks. Black circles show a direct effectiveness, white circles show indirect effectiveness, and blanks show that little or no effectiveness can be attributed to a particular action in meeting a particular concern. The tables can be read to assess the effectiveness of specific postulated actions or to identify the kinds of actions that would be most effective in alleviating a specific concern.

Table 2 lists the concerns of owners. The Appendix contains tables which list several possible concerns over the reliability and maintainability of solar heating and cooling systems for each of the following groups:

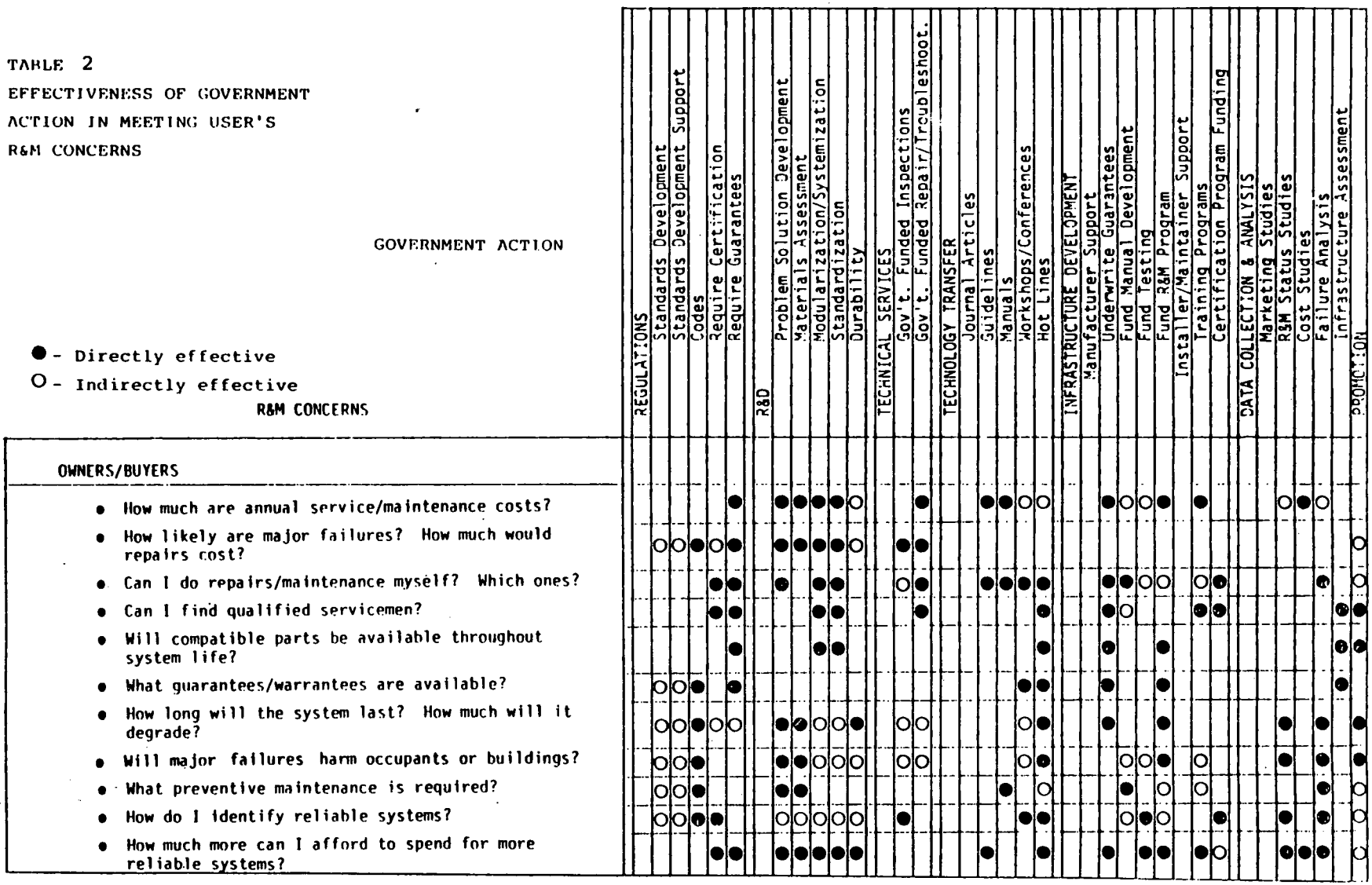
- Owners and potential buyers of solar energy systems
- Lending institutions
- Insurance organizations
- Engineers and designers of solar energy systems
- Manufacturers of solar energy systems, components, and materials
- Building contractors and installers of solar energy systems
- Labor organizations and groups involving the skills required for the installation of solar energy systems
- Personnel involved with the maintenance and repair of solar energy systems
- Building code officials
- Standards development groups

TABLE 2

EFFECTIVENESS OF GOVERNMENT ACTION IN MEETING USER'S R&M CONCERNS

● - Directly effective

○ - Indirectly effective



The concerns in these tables are expressed as lists of major questions that a member of each group asks regarding the reliability of solar energy systems. These tables are not intended to list all user concerns. It is believed that the major concerns are identified and that the tables represent a reasonable starting point for formulation of a program. As the program progresses, activities should be undertaken to provide greater confidence in our understanding of major R&M concerns. Also, the analysis of the effectiveness of actions in alleviating specific concerns is somewhat subjective. However, the most important point is that specific actions will alleviate different specific concerns to varying degrees. The actions finally selected for implementation must recognize the concerns they can address and the actions must be tailored to those concerns as much as possible.

On the tables in Appendix A are listed several possible actions that the Government could undertake in order to alleviate solar R&M concerns. (Some of these actions have already been initiated.) These possible Government actions are described briefly below. It must be stressed that this list discusses possible Government actions, not necessarily those actions to be undertaken that relate to the solar R&M program:

- Regulations
  - o Standards Development*- The Government could develop mandatory standards, criteria, and specifications for the R&M performance of solar energy systems that are constructed under Government programs.
  - o Standards Development Support*- Technical and financial assistance could be provided by the Government to groups involved with the development of voluntary standards relating to the R&M performance of solar energy systems.
  - o Codes Support*- Technical support could be provided to developers and enforcers of code provisions relating to solar energy systems.
  - o Require Certification - The Government could simply require that solar energy systems be constructed from R&M certified components and installed by certified installers on all projects.

*Indicates activities that are later recommended for implementation.

- Require Guarantees - Manufacturers and installers of solar energy systems, components, and materials could be required to provide guarantees or warranties against reliability problems on non-federally funded projects.

- Technology Transfer/Information Dissemination
  - Journal Articles*- Information on R&M problems and solutions could be disseminated through articles in professional and technical journals and magazines.
  - Guidelines*- The Government could publish a series of guidelines targeted for identification, design, installation, manufacture, maintenance, and repair of solar energy systems.
  - Manuals*- Design, installation, and operating and maintenance manuals could be developed.
  - Workshops/Conferences*- The Government could support workshops and conferences for groups with R&M concerns.
  - Hot Lines - Information about R&M could be made available through a toll free telephone exchange.
- Infrastructure Development
  - Manufacturer Support - The Government could support manufacturers' efforts to reduce R&M concerns by the following actions:
    - Underwriting manufacturers guarantees and warrantees,
    - Assisting the development of installation and maintenance manuals and instructions*
    - Assisting testing and quality control programs*
    - Assisting manufacturers' R&M improvement programs*
  - Installer/Maintainer Support - The Government could fund or otherwise support* training programs and certification programs for installers and maintainers of solar energy systems.
  - Infrastructure Assessment* -The Government could institute studies to determine the availability and effectiveness of specific components of the solar industry infrastructure.

*Indicates activities that are later recommended for implementation.

- o Data Collection and Analysis
  - o Marketing Studies*- Studies could be undertaken to determine the extent and effect of potential buyers' R&M concerns.
  - o R&M Status Studies*- The Government could collect and analyze data concerning the number and type of R&M problems in existing systems.
  - o Cost Studies*- Information about the cost of maintenance and repair of solar energy systems could be developed.
  - o Failure Analysis*- The causes and effects of failures of solar energy systems could be examined.
- o Research and Development
  - o Problem Solution Development*- The Government could fund R&D to determine solutions to specific R&M problems that have been identified in existing projects.
  - o Materials Assessment*- R&D could be undertaken concerning the effect of R&M performance of various materials and combinations of materials within solar energy components and systems.
  - o Modularization/Systemization*- The Government could seek to reduce R&M problem incidence by funding development of marketable solar energy systems and multi-component modules.
  - o Standardization*- R&D could be undertaken to determine effective standard sizes, shapes, and materials compatibility of solar energy components.
  - o Durability*- The Government could also seek though R&D to both determine and improve the durability of solar energy systems and components.
- ● Technical Service
  - o Government Funded Inspections - The Government could fund the direct inspection of installed solar energy systems to determine proper installation and design.
  - o Government Funded Repair and Troubleshooting - Systems with reliability problems could be repaired through Government funded programs.

*Indicates activities that are later recommended for implementation.

- Promotion - The Government could simply use the mass media to affect potential buyers attitudes toward R&M in solar.

B. Evaluation of Government Actions

Table 2 shows the evaluation process by which the postulated government actions were judged. Each action was evaluated according to the following criteria:

- Agreement of the action with the tenets expressed in the "Active Solar Strategy" (Yes-no)
- Estimated cost of implementing the action. (high-medium-low)
- Estimated general effectiveness of the action in meeting user concerns as measured in the tables in Appendix A (high-medium-low).
- Existence of ongoing activity related to the action in other Government programs. (yes-no)
- Estimated time until the action has made an impact on user concerns-by 1985, in two years, in one year. (yes-no)

C. Selection of Government Actions

The Government actions recommended for implementation were selected on the basis of the evaluations represented in Table 3. Recommendations are presented in Table 4, along with reasons for selection or rejection. In addition to entries that indicate selection or rejection for each possible action, a third entry, "Support Activity in Other Existing Programs," is used. This recommendation indicates activities that are pursued within ongoing Government programs, but could be effectively augmented through support from the R&M program in the form of information transfer and coordination.

ACTION	AGREEMENT WITH STRATEGY	ESTIMATED COST	GENERAL ESTIMATED EFFECTIVENESS	ACTIVITY IN OTHER EXISTING PROGRAMS	IMPACT BY 1985	IMPACT IN 2 YRS	IMPACT IN 1 YR
REGULATIONS							
Standards Development	✓	M	M	✓	✓	0	0
Standards Development Support	✓	L	M	✓	✓	0	0
Codes Support	✓	L	H	✓	✓	0	0
Require Certification	0	L	M	0	✓	✓	✓
Require Guarantees	0	L	L	0	✓	✓	✓
R&D							
Problem Solution Development	✓	M	H	✓	✓	✓	✓
Materials Assessment	✓	M	H	✓	✓	✓	0
Modularization/Systemization	✓	L	M	✓	✓	✓	0
Standardization	✓	L	M	✓	✓	0	0
Durability	✓	M	H	✓	✓	0	0
TECHNICAL SERVICES							
Gov't. Funded Inspections	✓	H	L	0	✓	✓	0
Gov't. Funded Repair/Troubleshoot	0	H	M	0	✓	✓	0
TECHNOLOGY TRANSFER							
Journal Articles	✓	L	M	✓	✓	✓	✓
Guidelines	✓	M	H	✓	✓	✓	✓
Manuals	✓	M	H	✓	✓	✓	✓
Assist Workshops/Conferences	✓	M	H	✓	✓	✓	✓
Hot Lines	✓	M	L	✓	✓	✓	✓
INFRASTRUCTURE DEVELOPMENT							
Manufacturer Support							
Underwrite Guarantees	0	H	M	0	✓	✓	✓
Assist Manual Development	✓	M	H	0	✓	✓	✓
Assist Testing	✓	H	M	0	✓	0	0
Assist R&M Program	✓	H	H	0	✓	0	0
Installer/Maintainer Support							
Training Programs	✓	M	H	✓	✓	0	0
Certification Program Funding	✓	H	L	0	✓	0	0
DATA COLLECTION & ANALYSIS							
Marketing Studies	✓	L	L	✓	✓	✓	0
R&M Status Studies	✓	M	H	0	✓	0	0
Cost Studies	✓	M	H	0	✓	0	0
Failure Analysis	✓	M	H	0	✓	0	0
Infrastructure Assessment	✓	L	L	✓	✓	✓	0
PROMOTION	✓	M	L	✓	✓	0	0

✓ - Yes 0 - No H - High M - Medium L - Low

TABLE 3. ACTION EVALUATION

TABLE 4. ACTION IMPLEMENTATION RECOMMENDATIONS

ACTION	RECOMMENDATION FOR FEDERAL ACTION
REGULATIONS	
Standards Development	Support activity in other existing programs
Standards Development Support	Support activity in other existing programs
Codes Support	Support activity in other existing programs
Require Certification	Not recommended - disagreement with "Strategy"
Require Guarantees	Not recommended - disagreement with "Strategy"
R&D	
Problem Solution Development	Support activity in other existing programs
Materials Assessment	Support activity in other existing programs
Modularization/Systemization	Support activity in other existing programs
Standardization	Support activity in other existing programs
Durability	Support activity in other existing programs
TECHNICAL SERVICES	
Gov't. Funded Inspections	Not recommended - High Cost/Low Effectiveness
Gov't. Funded Repair/Troubleshoot	Not recommended - disagreement with "Strategy"
TECHNOLOGY TRANSFER	
Journal Articles	Recommended - low cost
Guidelines	Recommended - high effectiveness
Manuals	Support activities in other programs
Assist Workshops/Conferences	Recommended - high effectiveness
Hot Lines	Not recommended - low effectiveness
INFRASTRUCTURE DEVELOPMENT	
Manufacturer Support	
Underwrite Guarantees	Not recommended - high cost/disagreement with "Strategy"
Assist Manual Development	Recommended - high effectiveness
Assist Testing	Recommended - high effectiveness
Assist R&M Program	Recommended - high effectiveness
Installer/Maintainer Support	
Training Programs	Support activity in other existing programs
Certification Program Funding	Not recommended - low effectiveness, high cost
DATA COLLECTION & ANALYSIS	
Market Studies	Recommended - provides feedback
R&M Status Studies	Recommended - needed to support other activities
Cost Studies	Recommended - needed to support other activities
Failure Analysis	Recommended - needed to support other activities
Infrastructure Assessment	Recommended - provides feedback
PROMOTION	Not recommended - inappropriate at this time

VI. ACTION IMPLEMENTATION

The R&M program will focus its approach to helping remove the R&M concerns of the solar community in five major action areas:

- Data collection and analysis
- Technology transfer
- Infrastructure development
- Regulations
- Research and development

Work in each of these areas is ongoing within other government and industry programs. The solar R&M program will, for the most part, act by interfacing with these existing programs. By acting through existing structures and mechanisms within the government and industry, the R&M program will ensure more cost effective use of its funding by avoiding duplication of effort.

This section discusses in turn each of the five areas of action. The objective for activity is stated for each area, followed by a description of the specific tasks and levels of effort required to achieve that objective. The tasks and levels of effort are explicitly stated for FY81 and are more generally stated for the near-term/mid-term and long-term. In formulating the FY81 activities, consideration has been given to activities that are ongoing within other programs. The activities under each area are discussed in general terms in a commentary which addresses the strategy behind selecting the specific tasks.

A. Data Collection and Analysis

The objective of data collection and analysis in the solar R&M program is to assemble the information required to support the other activities within the R&M program.

During fiscal year 1981, the following tasks should be accomplished. Minimum effective effort levels are indicated in parentheses:

- Identify and assess existing data sources and date bases including the National Solar Data Network, National Bureau of Standards, Argonne National Laboratory, Solar Energy Research Institute, International Energy Agency, etc. Emphasis must be on representative marketable systems. (5 man-months)

- Establish data sources for information on repair and maintenance costs and consequences of system failure. Begin cost analysis. (12 man-months)
- Identify and evaluate R&M performance and durability of systems that have good R&M performance records. Emphasis should be placed on packaged systems. (12 man-months)
- Failure analysis to identify major generic R&M problems and solutions. Emphasis to be placed on the following areas:

  (24 man-months)
  - o Freeze-ups
  - o Connections
  - o Controls
  - o Corrosion
  - o Storage
  - o Collectors
- Determine need for and feasibility of data base consolidation (5 man-months)

Near Term - Focus will be placed on hot water and space heating systems. Primary emphasis will be placed on establishing useful sources (both existing and new) of data and a central data base. Major R&M problems will be identified. Information on the specific costs associated with repair and maintenance of specific system components will be collected and analyzed. Systems with good R&M performance records will be tracked. The availability of parts and services will be assessed on a regional basis.

Mid-Term - Focus will include cooling systems. Data collection and analysis activities will be reformulated as the program informational needs are re-evaluated. It is expected that emphasis will shift more from data collection to dissemination of data in the mid term.

Long-Term - Major R&M problems and costs associated with R&M will continue to be tracked. Durability information will be collected and analyzed.

Although data collection and analysis data will constitute a major part of the work performed under the R&M program, it must be stressed that this activity is not an end in itself. Rather, this activity merely supplies information to be used elsewhere. Data collection and analysis must therefore be responsive to informational needs defined by the end users of that information.

A large base of data concerning R&M performance of solar energy systems has already been collected. These existing bases and sources of data are discussed in Appendix B. However, some informational needs may not be available from these existing sources. For example, data on the costs associated with the repair and maintenance of solar energy systems has not been widely or systematically collected. Another informational need not adequately addressed in the existing data bases is the R&M performance of state-of-the-art systems. Although data is continually updated, most of the data in the sources listed in Appendix B are concerned with the R&M performance of systems that were designed and installed several years ago. Significant changes have continued to occur in the technology, and any improvements in the reliability of solar energy systems that may have taken place since those early 'First Generation' systems is not reflected in these data. Collection of R&M performance data for these newer systems must be undertaken on a regional basis.

In order to serve the informational needs that cannot be addressed adequately by existing data and data sources, old data sources need to be updated and new sources must be identified and integrated into the overall R&M data base. The emphasis, however, will be placed on using data and data sources that are already available, rather than on generating new data and data sources.

B. Technology Transfer

The objective of technology transfer as an activity of the solar R&M program is to provide all groups that have solar R&M concerns with the information that is available to the program and necessary to alleviate those concerns. It is recognized

that there are limitations in the quality and quantity of data concerning R&M. There are many unknowns and problems to be solved. Nonetheless, there are many mistakes that are made in solar energy systems that could be prevented by providing information that is available.

During fiscal year 1981, the following tasks will be accomplished. Minimum effective effort levels are shown in parenthesis:

- Publish series of guidelines oriented toward residential and commercial hot water system owners (12 man-months)
- Support regional workshop/conferences on reliability and maintainability for designers/manufacturers/installers of solar energy systems. (13 man-months)
- Publish articles in professional and technical journals containing information on R&M status and problems (6 man-months)
- Provide R&M information and guidance to development of design manuals. (6 man-months)

The effective dissemination of information must be based on a strategy that incorporates the following features:

- Tailoring the format, content and availability of specific dissemination vehicles for specific user groups
- Using 'feedback' activities to identify user needs and to measure the suitability and effectiveness of dissemination activities.

The process of transferring information to those groups who need information is as vital as producing that information. Technology transfer therefore deserves careful attention. This dissemination of technical information must be accomplished through vehicles that are appropriately matched to the needs and levels of technical understanding of specific audiences. For example, technical reports are not effective vehicles for transferring information to residential solar energy system owners.

Several vehicles that are to be used by the solar R&M program for disseminating information are discussed below. The discussion identifies the appropriate target and type of information associated with each vehicle.

- Journal articles. Technical articles in professional and technical journals and magazines can be an effective means of transferring highly technical information to designers, engineers, and manufacturers.
- Manuals. Design manuals are useful to solar energy system designers. However, while R&M considerations should be taken into account within design manuals, separate design manuals devoted exclusively to R&M considerations are probably not appropriate. The designer must constantly make trade-offs between reliability, safety, maintainability, thermal performance, and costs, and a design manual should treat each of these important design factors with due emphasis.
- Guidelines. Published government recommendations and guidelines can effectively be tailored to several audiences, especially those without technical backgrounds. Published as short pamphlets, guidelines can address a variety of specific subjects targeted at specific user groups. For example, a pamphlet on maintenance actions that can prevent DHW system freeze-ups made widely available to system owners could be extremely effective in reducing the importance of freeze-ups as a concern.
- Workshops/Conferences. Designers, installers, manufacturers, and maintainers learn as much from experience as from more formal educational mechanisms. Workshops and conferences would give these groups a chance to share experience on R&M problems and solutions. To reach larger audiences, workshops and conferences should be held regionally.

Near Term - Focus will be placed on hot water and space heating systems.

Mid Term - Emphasis shifts to space heating and cooling applications from hot water systems. Transfer of information takes added emphasis over data collection.

Long Term - Increased emphasis is placed on space cooling systems.

C. Infrastructure Development

The objective of infrastructure development activities within the solar R&M program is to assist in the early development of a viable industry for design, manufacture, installation, and maintenance of reliable, maintainable, and durable solar energy systems.

Specific tasks to be pursued under this action area are described below only with estimated level of effort requirements.

For fiscal year 1981, the following tasks are to be accomplished. Minimum effective funding levels are shown in parenthesis:

- Identify existing training programs and assess programs to determine R&M informational material needs (4 man-months).
- Develop R&M informational materials and make available to training program and trade schools (12 man-months).
- Provide manufacturers with guidelines concerning what information should be included in installation, operation and maintenance instructions (8 man-months). Publishing generic installation and maintenance manuals is probably not appropriate because techniques and practices do not apply universally to equipment supplied by different manufacturers. Providing manufacturers with recommended checklists for formulating installation, operating and maintenance instruction and manuals will probably be more effective.
- Institute studies to evaluate methods to determine availability and effectiveness of infrastructure members (6 man-months).

Near Term - Focus will be placed on hot water and space heating systems. Existing training programs will be assessed, and R&M informational materials will be provided to these programs.

Mid Term - Focus will include space cooling systems. Effectiveness of information transfer will be assessed and informational material will be updated. Begin investigating and implementing methods for introducing R&M techniques to manufacturers and designers.

Long Term - Less emphasis will be placed on this activity as training programs become more widespread.

The role of the solar R&M program in assisting in the development of an effective solar infrastructure is to provide technical advice and to respond to informational needs in ongoing educational programs. These programs - installer, designer, and maintainer training - will be assessed to identify what informational materials and technical advice the R&M program can contribute. The program will then provide necessary training materials, information, and advice in order to improve the level of knowledge about reliability, maintainability, and durability considerations.

D. Regulations:

The objective of this activity within the R&M program is to assist in the development of appropriate standards, code provisions, and certification programs relating to the R&M performance of solar energy systems, components, and materials.

For fiscal year 1981, the following tasks are planned. Minimum effective effort levels for each task are shown in parenthesis:

- Assess activities of all organizations/programs involved in development of standards, codes, and certification and provide these groups with R&M status information and recommend additional emphasis on R&M considerations where necessary (8 man-months).

Near Term - Focus will be placed on hot water and space heating systems. Interface will be established with solar standards, codes, and certification development organizations and programs. Needed areas for development will be recommended.

Mid Term - Standards, codes, and certification organizations will be provided with information about R&M status of solar energy systems. Needed areas for development will be recommended.

Long Term - More focus will be placed on cooling systems. These organizations will continue to be provided with R&M status information and recommendations.

The main role of the solar R&M program for this activity will be to provide information to and to offer advice to those organizations that are involved in developing voluntary standards, criteria, codes, and certification programs that relate to active

solar energy systems. The organizations and programs with which the program will maintain contact include the following:

- Voluntary Standards
  - o American National Standards Institute (ANSI)
  - o American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE)
  - o American Society of Mechanical Engineers (ASME)
  - o American Society of Testing and Materials (ASTM)
  - o National Bureau of Standards (NBS)
  - o International Organization for Standardization (ISO)
- Federal Specifications/Standards/Performance Criteria
  - o FHA Minimum Property Standards (Solar/MPS)
  - o Performance Criteria for Solar Heating and Cooling Systems in Residential/Commercial Buildings
  - o Federal Guide Specifications
  - o Solar in Federal Buildings Program
  - o Solar Heating and Cooling Demonstration Programs
  - o Department of Defense Guideline Specifications
- Codes
  - o Council of American Building Officials (CABO)
  - o National Electrical Manufacturers Association (NEMA)
- Certification
  - o Solar Energy Industries Association (SEIA)
  - o American Refrigeration Institute (ARI)
  - o Underwriters Laboratory (UL)
  - o Interstate Solar Coordination Council
- International Energy Agency (IEA)

E. Research and Development

The objective of the solar R&M program in this activity is to assist industry in improving levels of R&M performance in state-of-the-art solar energy systems, components, and materials.

Below are listed specific tasks and estimated levels of effort required for the solar R&M program activity in research and development.

For fiscal year 1981, the following tasks are planned. Minimum effective effort levels for each task are indicated in parenthesis:

- Identify existing R&D programs whose activities impact the R&M performance of active solar energy systems, components and materials. Review and collate existing results and assess impact on R&M performance (7 man-months).
- Recommend appropriate areas for additional R&M related R&D within each program with emphasis on (6 man-months):
  - o Freeze-ups
  - o Connections
  - o Controls
  - o Corrosion
  - o Storage
  - o Collectors
- Provide R&D programs with results of data collection and analysis (4 man-months).

Since the Department of Energy has several solar R&D programs ongoing, additional research and development work within the R&M program should not be given primary emphasis. Instead, the role of the R&M program will be to provide information about the nature of reliability, maintainability, and durability problems in solar energy systems and identify areas for R&M research and development for these ongoing R&D programs.

Near Term - Focus on hot water and space heating systems, working on the major problem areas and making maximum use of the extensive R&D activities underway in other programs.

Mid Term - It is expected that some problem solution development activities specifically within the R&M program will be necessary in the mid term to satisfy weaknesses identified in the overall solar program.

Long Term - In the long term, as the infrastructure catches up to the state of the art, added emphasis will be placed on R&M as an area offering the best potential for improving the reliability of solar energy systems.

VII. PROGRAM MANAGEMENT ACTIVITIES

A number of activities are required to support the R&M program. These activities include:

- Periodic program review and evaluation

  Regularly assess the achievements of the program and evaluate against program objectives and milestones. This assessment should be achieved in part through detailed surveys of the levels of R&M concerns. Refine the program plan objectives and activities as required to reflect the improved understanding of industry requirements. Detailed procedures for evaluating program effectiveness should be identified and implemented early in the program.

- DOE-SERI-Industry Coordinating Committee

  Develop and implement a coordinating committee to assure close interface with industry and responsiveness to its constraints.

- Coordination of regional and local activities

  Some of the activities in the R&M program will be implemented at the regional level. It is expected that access to some private data can be made through the Regional Solar Energy Centers. These activities will require careful monitoring and coordination since DOE will retain responsibility for program success.

Table 5 shows the relative priorities to be assigned the tasks for FY81 outlined in Section VI by showing funding levels for each task for three program funding level priorities. The base case, program funding at $1,000K for FY81, is represented as the minimum effective effort level for each of the tasks. The values in Table 5 are based on an estimated $70K per man-year. Note that the low level funded program, $800K, is achieved by dropping those tasks that are deemed least important. Similarly, in the case where the program is funded at $1,200K, funding levels of particular tasks are raised from their base case levels. Two

TABLE 5: TASK FUNDING LEVELS

PROGRAM FUNDING LEVEL SCENARIO	$800K	$1000K	$1200K	1985* $1000K	1990* $1000K
DATA COLLECTION & ANALYSIS					
o ID & Assess Existing Sources	30	30	30		
o Cost Data Collection & Analysis	70	70	70		
o Evaluate 'Good' Systems	70	70	150		
o Failure Analysis	70	140	200		
o Evaluate Central Data Base	30	30	30		
	$270K	$340K	$480K	$200K	$200K
TECHNOLOGY TRANSFER					
o Guidelines	---	70	70		
o Support Workshop/Conferences	75	75	75		
o Journal Articles	35	35	35		
o Design Manual Support	35	35	35		
	$145K	$215K	$215K	$315K	$315K
INFRASTRUCTURE DEVELOPMENT					
o Assess Training Programs	25	25	25		
o Develop & Disseminate Material	70	70	70		
o Manufacturers' Manual Guidelines	50	50	50		
o Infrastructure Assessment	---	35	35		
	$145K	$180K	$180K	$180K	$ 70K
REGULATIONS					
o Assess Activities of Standards Organizations & Programs and Provide Recommendations & Information	$ 45K	$ 45K	$ 75K	$ 45K	$ 45K
RESEARCH AND DEVELOPMENT					
o ID Existing Programs and Collate Results	40	40	40		
o Provide Recommendations	35	35	35		
o Provide Information	25	25	25		
	$100K	$100K	$100K	$140K	$250K
MANAGEMENT ACTIVITIES	$ 95K	$120K	$150K	$120K	$120K
TOTAL R&M PROGRAM	$800K	$1000K	$1200K	$1000K	$1000K

*In 1980 Dollars

additional columns indicate the trends in funding for the general activities area for 1985 and 1990 at the $1,000K total program funding level (constant 1980 dollars).

The expected budget range listed is not enough to address all areas and R&M problems. As a result, the breakdown of the total budget into specific tasks shown in an attempt to prioritize the activities, recognizing the compromises that must be made. It is important that the program not be spread too thin and that the most important activities be taken to completion. It must also be remembered that many of the listed activities simply support activities in other programs and the listed costs are not the total government funding for these areas.

APPENDIX A

EFFECTIVENESS OF POSSIBLE GOVERNMENT ACTIONS IN ALLEVIATING USER CONCERNS

The following tables, in addition to Table 2 on page V-2, provide partial lists of the R&M concerns of each target group and matches their concerns with a number of possible governmental actions. The degree to which these actions will address each specific concern is also indicated.

It can be seen that for each concern, a number of possible actions can be applied.

TABLE 2

EFFECTIVENESS OF GOVERNMENT ACTION IN MEETING USER'S R&M CONCERNS

●- Directly effective

O- Indirectly effective

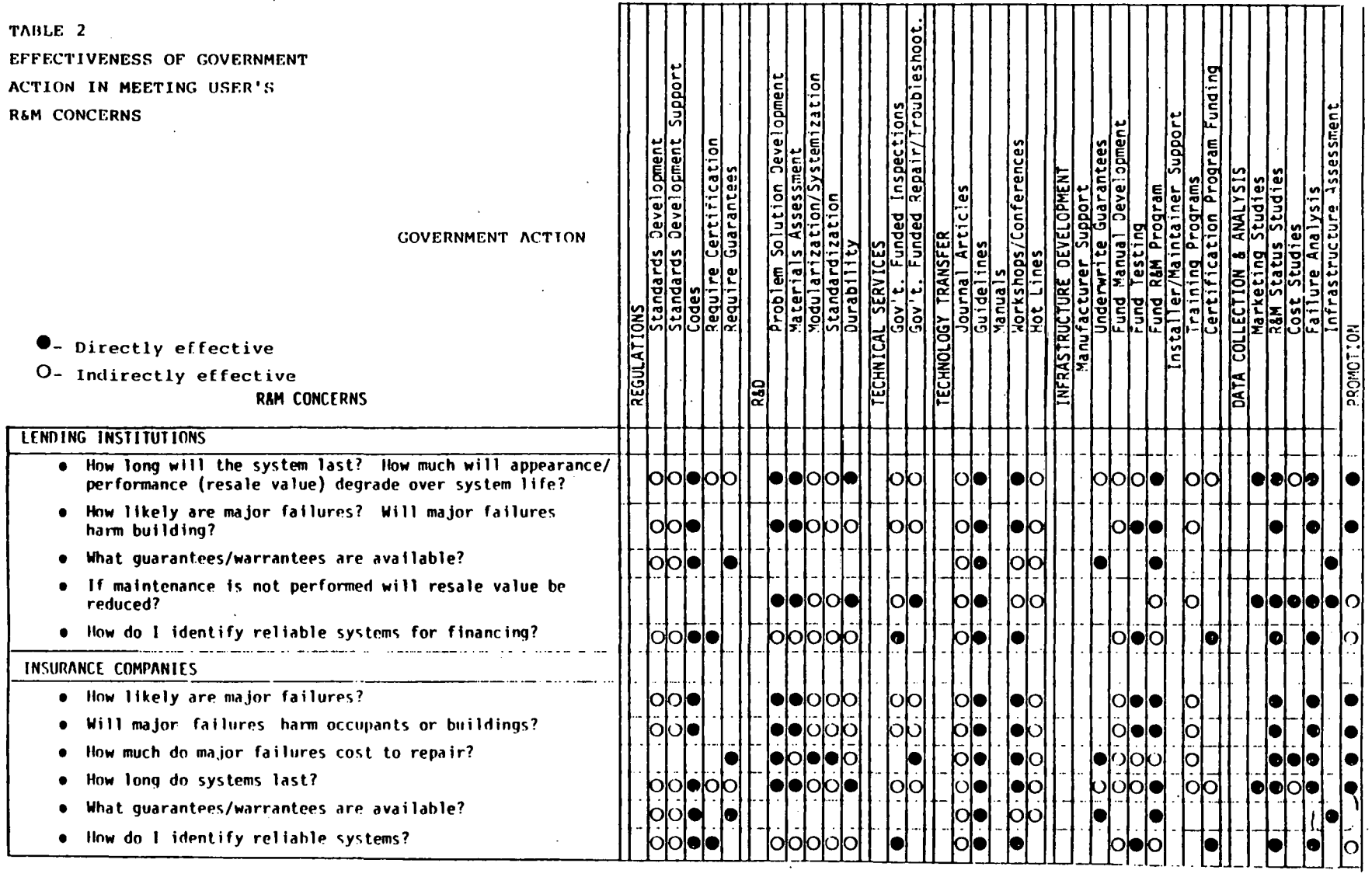


TABLE 3

EFFECTIVENESS OF GOVERNMENT ACTION IN MEETING USER'S R&M CONCERNS

GOVERNMENT ACTION

● - Directly effective

○ - Indirectly effective

R&M CONCERNS

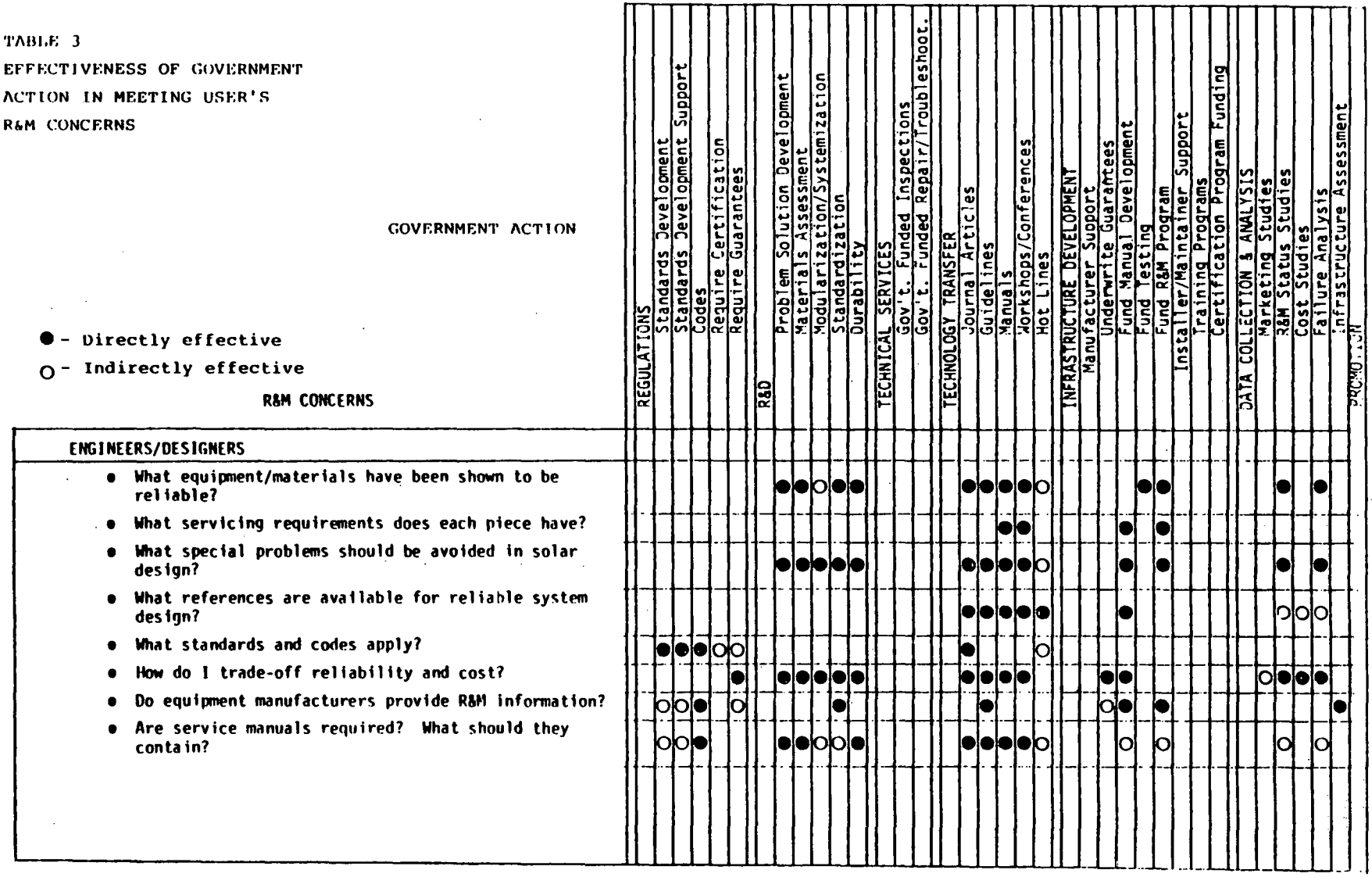


TABLE 4

EFFECTIVENESS OF GOVERNMENT ACTION IN MEETING USER's R&M CONCERNS

GOVERNMENT ACTION

● - Directly effective

○ - Indirectly effective

R&M CONCERNS

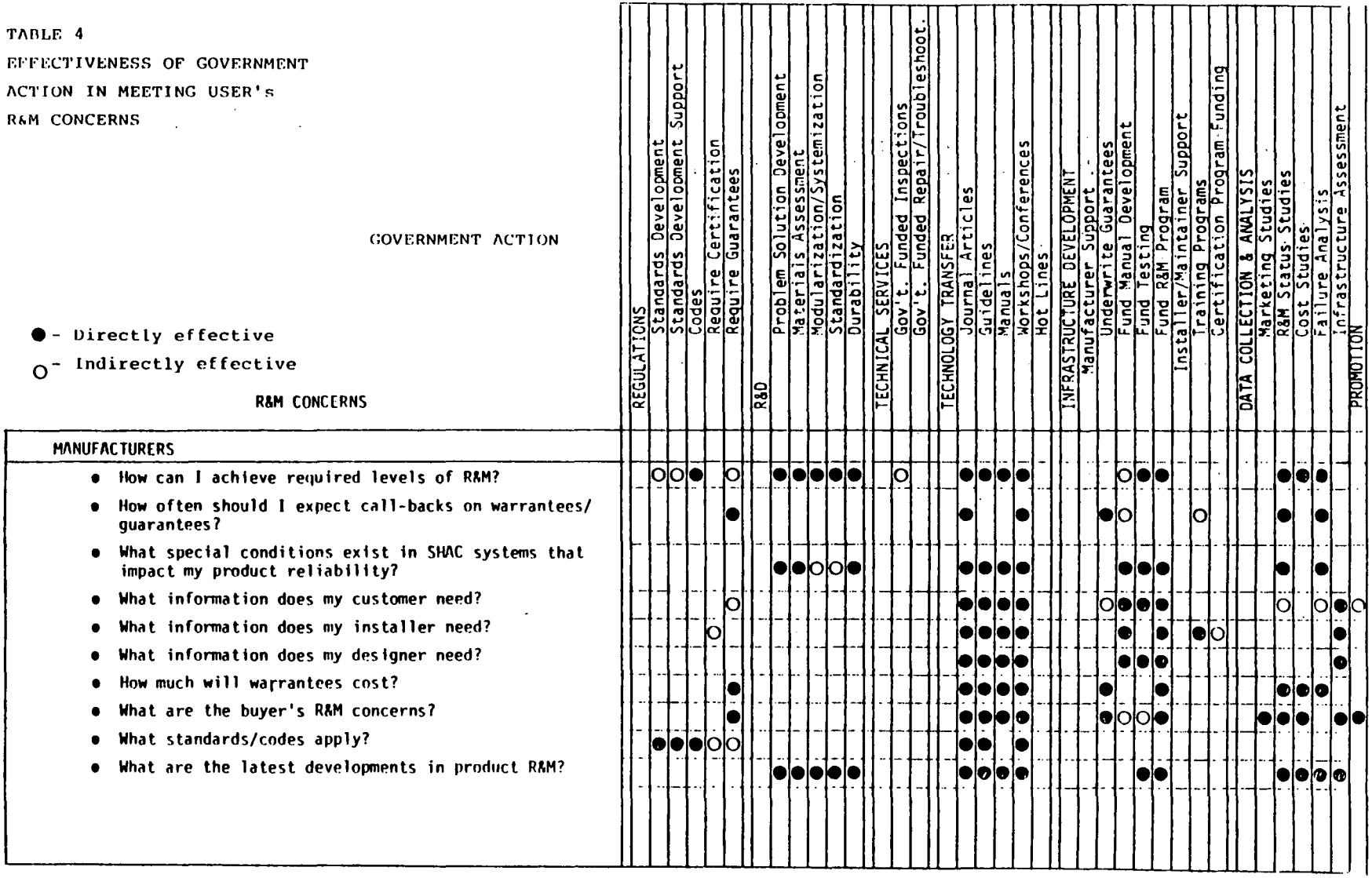


TABLE 5

EFFECTIVENESS OF GOVERNMENT ACTION IN MEETING USER'S R&M CONCERNS

GOVERNMENT ACTION

● - Directly effective

○ - Indirectly effective

R&M CONCERNS

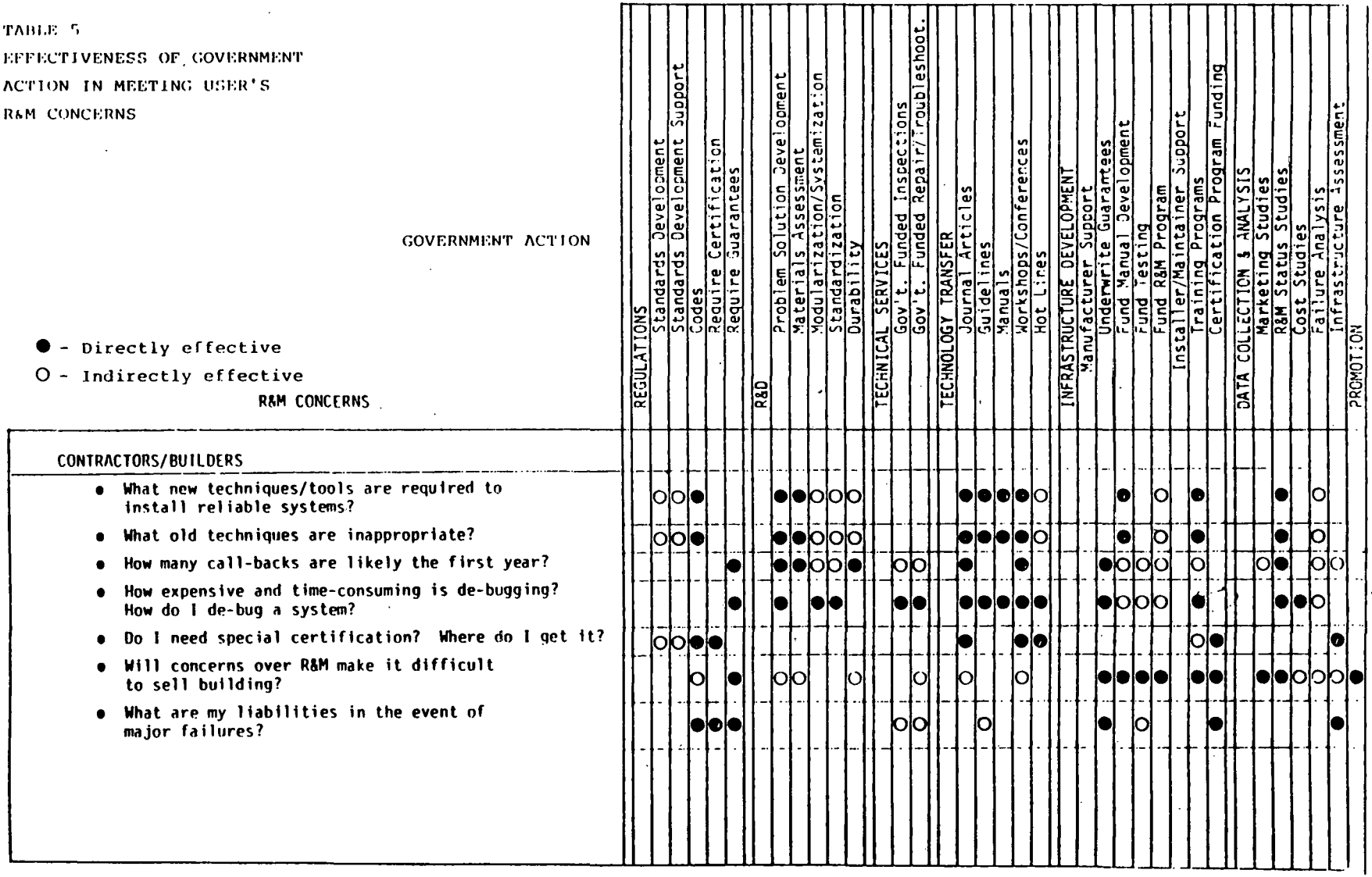


TABLE 6

EFFECTIVENESS OF GOVERNMENT ACTION IN MEETING USER'S R&M CONCERNS

● - Directly effective

○ - Indirectly effective

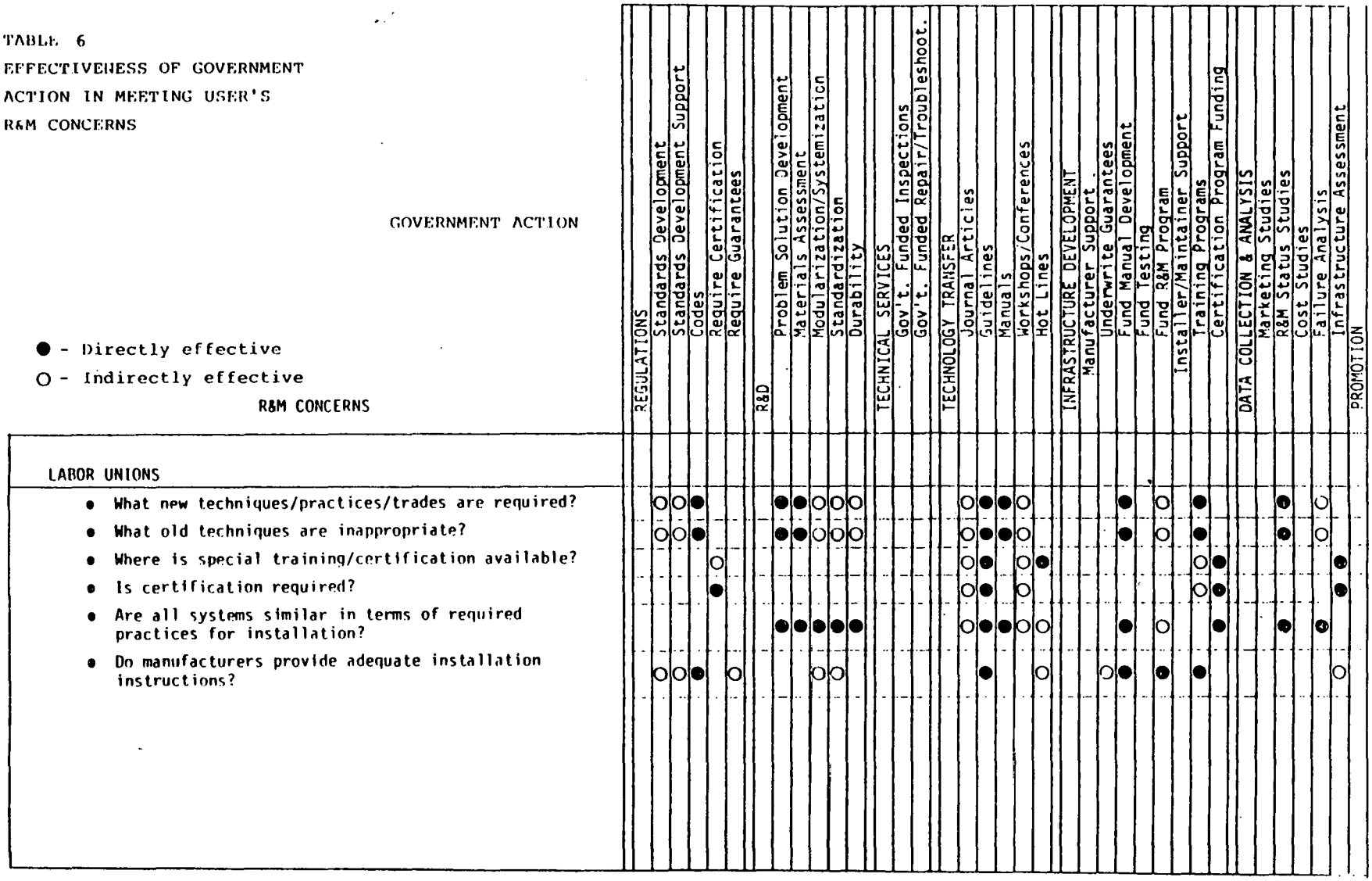


TABLE 7

EFFECTIVENESS OF GOVERNMENT ACTION IN MEETING USER'S R&M CONCERNS

● - Directly effective

○ - Indirectly effective

GOVERNMENT ACTION

R&M CONCERNS	REGULATIONS						R&D						TECHNICAL SERVICES			TECHNOLOGY TRANSFER						INFRASTRUCTURE DEVELOPMENT							DATA COLLECTION & ANALYSIS					PROMOTION
	Standards Development	Standards Development Support	Codes	Require Certification	Require Guarantees		Problem Solution Development	Materials Assessment	Modularization/Systemization	Standardization	Durability		Gov't. Funded Inspections	Gov't. Funded Repair/Troubleshoot.		Journal Articles	Guidelines	Manuals	Workshops/Conferences	Hot Lines		Manufacturer Support -	Underwrite Guarantees	Fund Manual Development	Fund Testing	Fund R&M Program	Installer/Maintainer Support	Training Programs	Certification Program Funding		Marketing Studies	R&M Status Studies	Cost Studies	Failure Analysis	Infrastructure Assessment	
MAINTENANCE PERSONNEL																																	
• What servicing is required? How often?		○	○	●		○		●	●		○	●			○		○	●	●	●	○	○		○	●		○	●				○	○	○	
• What are the symptoms of various system problems?								●	●			●	●	●			○	●	●	●	○	●			●	○	○	●				●			
• What are recommended trouble-shooting repair techniques?														●			○	●	●	●	○	●			●		○	●					○		
• What special tools are required?																	○	●	●	●	○	○			●		●	●				○			
• Will parts be available throughout system life?					●				●	●										○														
• Where is special training/certification available?				○													○	●		○	○	●						○	●						
• Is certification required?				●													○	●		○								○	●						
• Are all systems similar in terms of maintenance requirements?								●	●	●	●	●					○	●	●	○	○				●		○	●							
• Are there standards that apply?		●	●	●													○	●	●	○	●							●							
• Do manufacturers provide maintenance instructions?		○	○	●		○				○	○							●					○	●		●								
• What level of sophistication is required for maintenance personnel?					●	○		○	○	●	●	○					○	●	●	○			○	●		○		●	●		○		○		
• What is required regarding maintenance provisions in warrantees?		○	○	●	○	●		●	●	●	●	●						●					●	●		○		●	○				○		

TABLE 8

EFFECTIVENESS OF GOVERNMENT ACTION IN MEETING USER'S R&M CONCERNS

● - Directly effective

○ - Indirectly effective

GOVERNMENT ACTION

R&M CONCERNS

R&M CONCERNS	REGULATIONS: Standards Development	Standards Development Support	Codes	Require Certification	Require Guarantees	R&D: Problem Solution Development	Materials Assessment	Modularization/Systemization	Standardization	Durability	TECHNICAL SERVICES: Gov't. Funded Inspections	Gov't. Funded Repair/Troubleshoot.	TECHNOLOGY TRANSFER: Journal Articles	Guidelines	Manuals	Workshops/Conferences	Hot Lines	INFRASTRUCTURE DEVELOPMENT: Manufacturer Support	Underwrite Guarantees	Fund Manual Development	Fund Testing	Fund R&M Program	Installer/Maintainer Support	Training Programs	Certification Program Funding	DATA COLLECTION & ANALYSIS: Marketing Studies	R&M Status Studies	Cost Studies	Failure Analysis	Infrastructure Assessment	PROMOTION
CODE OFFICIALS																															
• Will failures harm occupants of buildings?	●	●	●	○		●	●	○	○	○	●		●			●			○	●	●		○				●			
• What reliability/safety certification programs exist?	●	●	●								●		●			●				●	●									
• What standards apply?	●	●	●										●			●														
• Will system degradation cause safety hazards?	●	●	●	○		●	●	○	○	●	●		●			●			○	●	●		○				●			
STANDARDS DEVELOPMENT GROUPS																															
• What new reliability standards for systems, components, materials need to be developed?	●	●	●										●			●											●			
• Are existing evaluation procedures and standards adequate?	●	●	●										●			●											●		●	

APPENDIX B

EXISTING DATA BASES AND RELATED ACTIVITIES

This appendix presents an overview of the existing Reliability and Maintainability and Materials Assessment data bases which were sponsored by previous Federal programs and which are currently funded by Federal programs. Because the largest effort (in funding levels) has been the Argonne National Laboratory R&M and MA program, there is a brief description of the various ANL publications. Where ANL deliverables are required for FY80 they have been included in this appendix.

Comparison among various programs are included as well as short discussions as to the state of the processing of the data base. Some data bases exist primarily as raw data stored on magnetic tapes. Other data bases have been reduced with respect to specific R&M reporting formats. Other data bases have been presented in various technical reports.

It should be noted that there are data bases which have large areas of common overlap of information, however, to date no effort has been made to combine these common areas into a large comprehensive data base. Such an effort might be desirable because a statistically more accurate picture of the state of the R&M of solar systems would emerge from the combination of similar data bases.

I. Argonne National Laboratory Program

There are three phases of technical effort and one phase of planning and publication involved in the ANL Reliability, Maintainability and Materials Assessment Program. The program scope is organized into the following categories: A. Reliability and Maintainability; B. Materials Assessment; C. Systems Engineering; and D. Planning and Publication.

A. Reliability and Maintainability

Work was accomplished in four out of five planned activities in FY79. Data was collected from 66 field installations, component manufacturers and other sources. It was then analyzed and published in several generic problem reports:

1. Preliminary Evaluation of Selected Reliability, Maintainability, and Materials Problems in Solar Heating and Cooling Systems. ANL/ADP-TM-78-2 September 1978.
2. Reliability and Maintainability Evaluation of Freezing Solar Systems. ANL/SDP-TM-78-3
3. Reliability and Maintainability Evaluation of Solar Collector and Manifold Interconnections. ANL/ADP-TM-79-4 March 1979
4. Reliability and Maintainability Evaluation of Solar Control Systems ANL/SDP-TM-79-5
5. ANL Program Deliverable for FY80 Reliability and Materials Design Guidelines for Solar Domestic Hot Water Systems 9/80.

In addition, a computerized data bank of R&M information was established. This library is being maintained by ANL on the instrumented systems in the NSDN program. It includes information such as reason for component malfunction, record of repairs, and later failure. All are located or stored in a magnetic tape and are accessible for print out.

B. Materials Assessment

This program area included: atmospheric corrosion; fluid corrosion; fluid properties and scaling studies.

1. Atmospheric Corrosion

   Nine data sites were established for the purpose of transmitting data on atmospheric corrosion of the metallic supporting structures of flat plate collectors. This was to be determined by monitoring atmospheric conditions and correlating them, to a weight loss by pitting of metallic coupons housed on site.

2. Fluid Corrosion

   As of November, 1979, two in-situ sites for transmitting data regarding solar fluid degradation were operational. The objectives are to detect the early breakdown of the solar fluid by means of electric resistivity sensors. The following report was published:

   - Influence of Solar Fluid Properties on Thermal Performance Based on Nominal and Measured Values NAL/SDP-TM-79-6 March 1979

3. Fluid Properties and Scaling

Heat transfer fluid samples were obtained from five solar systems for the purpose of predicting deposition of chemical scales on heat transfer surfaces. Previously developed prediction techniques were computed with a simplified ANL method. The following report was published:

- Prediction of Calcium Carbonate Scaling from Water in Solar Energy Systems
  ANL/SDP-TM-79-7 August 1979

C. Systems Engineering

Two special studies were done as a part of the systems engineering task: analysis of a collector failure and a specific corrosion study.

D. Planning and Publication

This included reports, conferences, and program planning.

II. National Bureau of Standards Program (NBS)

A. HUD Solar Demonstration Residential Projects References

1. Residential Solar Data Center Data Resources and Reports
   NBSIR 79-1762 June 1979.
2. Residential Solar Data Center Grant Reports
   NBSIR 79-1923 October 1979
3. Problem Identification of Solar Systems Used in HUD Residential Solar Heating & Cooling, Demonstration Program Report Letter Report No. 1 June 1978
4. Letter Report No. 2 December 1978
5. Letter Report No. 3 May 1979
6. Letter Report No. 4 April 1980
7. Proposed Technical Data Requirements for National Solar Heating and Cooling Demonstration Program
   NBSIR 77-1274 April 1977
8. Interim Performance Criteria for Solar Heating and Cooling Systems in Residential Buildings
   NBSIR 78-1562

B. Standards Development is an ongoing process at the National Bureau of Standards. It is anticipated that many "concensus" standards will be initiated and furthered by NBS efforts. The document, Solar

Technology for Buildings Publications November 79, offers a complete listing of NBS publications. Below are representative reports on standards development activities which are R&M related.

1. Solar Energy Systems - Standards for Rubber Hose NBSIR 79-1917 November 1979.
2. Solar Energy Systems - Survey of Materials Performance NBSIR 77-1314 October 1977.
3. Evaluation of a Proposed ASTM Standard Guide to Assess the Compatability of Metal-Heat Transfer Liquid Pairs in Solar Heating and Cooling Systems NBSIR 79-1919 November 1979.

In FY 77 NBS initiated a collector durability/reliability research program. Initial results from this program will be published in 1980.

III. National Solar Data Program (NSDP)

The NSDP was initiated to provide data to the solar community from projects within the National Solar Heating and Cooling Demonstration Program. The NSDP includes the National Solar Data Network (NSDN) which is a large scale instrumentation and monitoring system established for collection of performance data from the demonstration projects. The data that have been collected directly under the NSDP represents the largest source of instrumented data on solar system thermal performance. The continuous monitoring of the demonstration systems over long periods of time has yielded data which could be used for R&M purposes as well as thermal performance purposes. To date very little emphasis has been placed on reducing this data for R&M purposes, and yet it is a very large data base.

New instrumented sites are being selected for FY80, and it might be possible and desirable at the time of the site instrumentation to include specific R&M measurement capability.

Other activities within the NSDP include collection and dissemination of cost and descriptive data from the demonstration projects and preparation of summary evaluation and analysis reports.

The document entitled, Availability of Solar Energy Reports from the NSDP, Solar/0020-80-45, has a complete listing of all documents published under the instrumented data program as of May, 1979.

IV. National Aeronautical and Space Agency (NASA)

NASA has been involved since early in the Federal solar effort. The activities include several areas.

A. Commercial Demonstration Program
   1. Refurbishment Program (non-instrumented sites)
   2. Project Management

B. Research and Development
   1. Selective Coatings of Collector Surfaces
   2. Insulation for Solar Collectors

C. Operational Test Sites

V. Solar Energy Research Institute (SERI)
R&M and MA Program

A. The second annual steering committee report on the future direction of R&M and MA studies has been issued by SERI. The participants were: SERI, JPL, BNL, BCL, and ANL. There are basically two large areas of the Solar R&M Program discussed in this report. They are the ANL program covered in section I of Appendix B and the reliability engineering activities of the National Photovoltaic Program.

1. Reliability Engineering in Solar Energy: Workshop summary, SERI/TP-334-489 March 1980.

B. Active Heating and Cooling Reliability Residential Inspection Program. This is a newly organized program which initially will include sites in Albuquerque, Grand Fork and Atlanta.

C. Materials Handbook published by SERI in December 1979.

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