Title
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Publication Date
1976-08-01

To be presented at the Workshop Conference
on Management of Laboratory Instruments,
Cairo, Egypt, November 5 - 14, 1976

LBL-4836

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August 1976

Prepared for the U. S. Energy Research and
Development Administration under Contract W-7405-ENG-48

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November 11, 1976

OVERVIEW OF THE ELECTRONICS ENGINEERING DEPARTMENT AT THE LAWRENCE BERKELEY LABORATORY

ABSTRACT

The Lawrence Berkeley Laboratory is engaged in a broad range of research and development programs to develop the energy resources of the United States. The Electronics Engineering Department, in addition to other responsibilities, provides the necessary instrumentation and control systems for these R and D programs of the Laboratory. This overview examines the planning, organization and staffing that are needed to efficiently carry out department responsibilities.

When undertaking a new research program it is important that the instrumentation and control specialists study the overall system development rather than being constrained to consider the use of a number of individual devices. The use of the systems approach is discussed in the light of laboratory experience.

Effective management requires that a variety of both long-range and short-range programs be undertaken to develop data-acquisition and control systems applicable to laboratory problems. Long-range planning relates to programs that are expected to be operational in 3 to 5 years. Short-range planning makes use of present day technology that can be adapted to more immediate utilization. Equipment designed with a broad range of applications must be considered in contrast to instruments tailored to the needs of a specific user.

The training and experience necessary for the selection of the engineering and technical staff will be discussed. Management policies and operating procedure required for an effective operation will be considered in some detail.

This work performed under the auspices of the Energy Research and Development Administration with partial support from the U.S. National Science Foundation.

I. INTRODUCTION

The Lawrence Berkeley Laboratory is celebrating its 45th anniversary in 1976. Operated by the University of California under a contract with the U.S. Energy Research and Development Administration, it is one of the seven multi-disciplinary national laboratories in the United States. Currently research at the Laboratory includes fundamental studies in nuclear physics, biology and medicine; work is also under way on the development of new energy technologies such as geothermal, solar and fusion energy, and the use of fossil fuels. The Laboratory's goal is to understand the functions of our physical world and apply this knowledge to human problems and concerns.

The Electronics Engineering Department is one of six departments in the Engineering and Technical Services Division; it is responsible for the development and implementation of the control and instrumentation systems required by the Laboratory's research programs. These programs range all the way from high voltage and radio frequency power generation to semiconductor detector systems employed in x-ray fluorescence analysis. This report is an overview of the organization and staffing of our department.

II. MANAGEMENT RESPONSIBILITIES

Before discussing the specific responsibilities of the Electronics Engineering Department, it would be worthwhile to consider briefly some of the problems of laboratory management in general. Interpretations of early Egyptian papyri extending as far back as 1300 B.C., indicate the importance of organization and administration. In more recent years management has been regarded as including the following functions: planning, organization, staffing, training, directing and controlling.[1]

Let us consider planning as selecting the objectives of an activity, such as our department, in the light of the direction and purpose of the overall activity, such as our Laboratory. After primary objectives have been selected, planning should also include the implementation of policies, programs and procedures for achieving these objectives. Planning, thus is the decision-making aspect of a department's activities. Good planning requires continuity as well as flexibility; lack of planning is a sign of incompetence.

Organization involves deciding how the personnel should be distributed in order to accomplish the tasks which are required to achieve the objectives of the laboratory and department, the assignment for carrying out these tasks and then the delegation of authority to accomplish them.

Staffing may be defined as the activities that are essential to supplying the department with workers. Staffing includes selecting new personnel and maintaining the morale of all workers so as to achieve continuity and efficiency. It also includes training both new and existing personnel and evaluating the performance of both. Training is required at all levels to relate abstract scientific or mathematic concepts to their physical realizations. Also, inanimate equipment reacts differently to environmental conditions than do its human operators; instruments cannot protect themselves like living creatures.

Directing includes the responsibilities of both guiding and supervising subordinates. The staff should have a keen appreciation of the expectations, objectives and policies of the laboratory. Each member must be guided so that he can work with others while at the same time be responsible for his own assignment. Most laboratories are staffed by a number of dynamic individualists. Coordination is the process in which the differences of opinion of the various members of the staff are made to harmonize. The best coordination occurs when individuals see how their own contributions can be brought into accord with the primary goals of the laboratory.

An organization is effective when it successfully gains its objectives. It is not efficient, however, unless it meets these objectives without undue costs and disburbances. It is a supervisor's responsibility to guide the personal aims of the individual members of the staff so that the goals of the whole organization can be achieved.

In the simplest case one might envision a single laboratory director supervising the tasks of each individual worker. As soon as an organization of any size exists, the obvious limitation of human ability and time prohibit this. Departmentalization and delegation of authority must take over. How many subordinates can a supervisor effectively manage? In one survey of one hundred companies the median number was nine.[2] In more routine supervision, such as an instrument construction shop, up to twelve or more subordinates can be handled effectively.

Controlling implies the idea of making the final outcome of the program conform to the expected plans. In many cases this is difficult to achieve in a laboratory situation; however, if projects are to be finished within the contemplated framework of time and cost, judicious control must be exercised.

In an expanding laboratory one is immediately faced with the decision of how to grow effectively. Since adding additional levels of responsibility is costly and complicates management, there should be compelling reasons before any new levels of supervision are instituted. Basically, different levels exist only because one human being cannot effectively manage an infinite number of subordinates. In a typical case there may be three levels of management: department head, project leader and group leader. The department head and project engineers in most cases are engineers; group leaders divide themselves among engineers and technicians with a great deal of experience.

In a laboratory operating on a fixed or diminishing budget, great care must be exercised to maintain a viable operation with a high esprit de corps. Communication from the laboratory management through the administrative structure to those at the working level must be maintained. Each person on the staff needs to feel that he is a member of a team serving a vital function in society. Communication from the worker back to management is also important.

There is also a possibility of a low employee termination rate in a laboratory with a fixed number of staff. The present staff gets older each year and if no younger members are added, management is soon faced with an unusually large number of staff members near retirement. This is a particularly undesirable situation. Appendix A cites an interesting model of a declining budget and suggests a solution.

III. DEPARTMENT ORGANIZATION

In the light of the above discussion let us now examine the manner in which the LBL Electronics Engineering Department is constituted and makes its plans. The department is composed of ten program or projects each headed by a senior engineer. There are usually three levels of managemnt as recommended above. See Appendix B for an organization chart of the department.

Department programs in general correspond to the various research activities of the Laboratory. In some cases the the engineering groups conduct independent studies in the research and development of new technologies. One example is microwave spectroscopy applied to the identification of air pollutants. In many other cases our groups provide the engineering and technical support of the scientific research programs. To accomplish scientific and administrative direction, each of the project engineers may have two supervisors.

When the work of the Electronics Engineering Department is in support of a scientific research program, the research worker first makes contact with the department head who will assign the support program to the senior engineer of the group best qualified to do the work. After doing this the department head usually delegates the technical direction of the support program to the research worker, while retaining the administrative direction. Thus for the technical direction of his project the senior engineer reports to the research worker in charge of that program. This person may be a biophysicist, chemist, physicist or another engineer, usually associated with one of the seven research divisions of the Laboratory. In some cases, however, a committee may direct the work; in other cases the research may be located at some other laboratory quite remote from Berkeley. In yet other instances the work may be under contract with some other government agency.

For his administrative direction the project engineer reports to the department head. Administrative functions include 1) personnel matters, such as interviewing, evaluation and salary review, 2) budget matters, and 3) interpretation of Laboratory policy.

IV. PLANNING

Long-range scientific program planning is usually made by the research staff of the Laboratory with the engineers making their contribution through appropriate channels. Long-range administrative policy is usually proposed by the Laboratory management and sent to the engineering departments for their comment and recommendations.

The ten project engineers meeting with the department head comprise the Electronics Engineering Planning Committee. The group meets as often as necessary, usually about 10 times per year. At these meetings the Committee considers a variety of topics. Recent topics include a professional staff policy, the method of allocation of capital funds for the purchase of new equipment, the priority with which printed circuit boards should be constructed in the model shop, evaluation of the performance of engineering and technical staff members, review of engineers' salaries, the formation of a new computer systems group within the department, and long-range plans for microprocessor utilization at the Laboratory.

Long-range planning for new buildings and major procurements, such as a large computer system, are of laboratory-wide interest and ad hoc committees are formed to consider their specifications.

Short-range needs are usually met in a routine manner. For example, requests for additional personnel are provided by loaning or reassinging staff to the requesting group. If all our staff are busy on priority jobs, temporary staff are hired or borrowed from other departments, or for longer range projects, permanent staff are hired. Requests for equipment or components are met in the same manner by loan or acquisition.

Two considerations must be reviewed whenever a new experimental program is under consideration. In the first case one must consider whether a control or data gathering system should be designed for one specific experiment or customer or should a more general design be considered. While no rigid rules can be laid down, general considerations are obvious. For example, a real time computer may initially be used to acquire data from a radiobiology experiment. If a whole series of experiments are envisioned or if the same configuration can be used in a particular physics experiment or a fusion reactor experiment, then a general purpose system should be constructed. An alternative is to design a system in modular form so that future expansion is easily facilitated. if the experiment appears to be unique in its requirements, then a specific design may be more appropriate. An example of a specific design is one being considered in connection with an existing computer processor that is not likely to be duplicated or expanded.

While no clear-cut figures can be quoted, general designs are almost always more expensive than those for a single purpose system. However, the cost of design is such a large part of the expense that even when two similar systems are required, it is usually cost-effective to make one design that will include the features needed in both systems. When many experimenters can use a common design, the cost savings are obvious.

A corollary of the cost savings made by employing a common design may be found when considering the question of designing equipment in-house compared with purchasing instruments from commercial sources. If a manufacturer's present equipment will meet an experimental need, it is almost always more economical to buy it than to design and construct the apparatus in-house. We would only consider developing our own equipment when commercial designs do not meet our experimental needs. A manufacturer's design cost is spread over many units to make it economically competitive; the resulting savings are passed on to the customer.

The second consideration for a new experimental program is whether to use a systems approach or a unit approach. In a systems approach the design team considers the entire problem from the initial controller through the various electrical or mechanical devices that carry out that control; likewise in a data acquisition system one should consider each component from the initial transducers or detectors through the appropriate electronics circuits to the computer and readout peripherals. Once the entire system has been envisioned, the responsibility for designing or procuring the various components can be made. The unit approach, on the other hand, is an outdated system better left to antiquity. In this method the experiment is designed a piece at a time. Each component is considered as a separate unit with its own specifications and usually supplied by a different designer who is unaware of the problems and needs of the other unit designers. As might be expected the performance of a system assembled from a number of uncoordinated units is frequently chaotic.

V. TRAINING

Training may be one of the most important functions of management. The more effort that goes into training the less effort required in direction and control of the staff later. This results because a trained subordinate is better able to make decisions on his own. This tradeoff has its limitations; however, some staff members may be excellent engineers or technicians but poor supervisors no matter how much training they receive.

Our department engineers are selected on the basis of a combination of ability, education and experience. Ability implies natural talent that is enhanced with acquired proficiency. A measure of ability is the ease with which a person can relate abstract mathematical concepts to the solution of practical problems. Ability is a trait that is easy to observe in another individual but difficult to quantify.

The basic educational requirement for employement in the Electronics Engineering Department is a bachelor's degree (12 years of school plus 4 years of college or university) in engineering or one of the physical sciences. Of the 90 professionals in the department 48 have bachelor's degrees, 26 have graduate degrees at the master's level, 9 doctoral degrees, and 7 have no formal degrees but the equivalent in practical experience.

Each professional is encouraged to continue both his formal and informal educational training. Laboratory policy allows staff members six hours educational leave during the normal 40 hour work week to attend formal instruction. In addition, a variety of other educational benefits are offered. For example, extension classes are held in the evening, one or two week intensive training sessions are often available, and occasionally self taught correspondence courses are used.

"Experience is a great teacher". This adage is well recognized at our Laboratory. In fact, salary scales are related to one's experience and technical performance. An invaluable resource of any research organization is its experienced engineering staff. An important but difficult task, however, is for the experienced engineers to impart their knowledge and judgement to the younger engineers. Pressing management responsibilities always seem to rob older staff members from finding time to train their subordinates.

Technician training follows a similar pattern of ability, education and experience. Except that more manual dexterity and less formal education is expected of technicians (most technicians have 12 years of school plus 2 years of college). Related experience is equally important with technicians and engineers.

Retraining of the staff in the light of new laboratory emphases or changing national priorities poses a severe problem. Some persons have the ability and foresight to prepare themselves for an entirely different discipline at any stage of their employment; others cling to the status quo and find a new discipline particularly distasteful. Our own Laboratory in the last three years has embarked on a program of developing new energy technologies and placing less emphasis on basic nuclear research. In my own case at the age of 50 I learned a new discipline - instrumentation related to air and water pollution. The new assignment has been both exhilarating and exciting.

VI. OPERATING PROCEDURES

Government regulations require that accurate record be maintained of the time worked by each individual. Technicians must be paid a premium for work in excess of 40 hours per week. Engineers are expected to work a minimum of 40 hours each week.

In addition, a record is kept of the performance evaluations, educational achievements, salary history, awards and reprimands of our department staff. These provide a permanent record of an employee's performance, and are valuable in supplying recommendations to prospective employers for employees who have left the department for positions elsewhere.

VII. SUMMARY

The Electronics Engineering Department has been organized to provide the R and D in electronics systems for the generation, control and data handling necessary to carry out the research programs at the Lawrence Berkeley Laboratory. Its dedicated staff are an excellent model for other institutions contemplating similar R and D activities.

ACKNOWLEDGEMENT

I acknowledge the advice of Drs. George A. Morton and Nabil M. Amer in the preparation of this report; Worrell H. Deuser and Lee J. Wagner who read the manuscript, and Mrs. Lillian A. Wirth who assisted in preparing the final report.

REFERENCES

1. Harold Koontz and Cyril O'Donnell, Principles of Management, McGraw-Hill, 1959.

2. Ibid, Pg. 71.

APPENDIX A

Age Distribution of Employees

E. H. Cooke-Yarborough, Head of the Electronics Engineering Department at AERE, Harwell, England, in 1971 derived a model of the age profiles of employees in an era of declining budgets.

He assumed a uniform age distribution between 20 and 50 years old at time t = 0. Then budget conditions were such that the loss of funds was balanced by attrition. In his simple model 6% of the employees below 42½ years old voluntarily left each year. None of the employees above 42½ left except by retirement at 65 years. He selected 42½ years because it was the median year between 20 and 65. Below 42½ years employees may seek employment elsewhere; above the age, they have such an investment in the laboratory, their home and the retirement system that they remain with the lab until retirement.

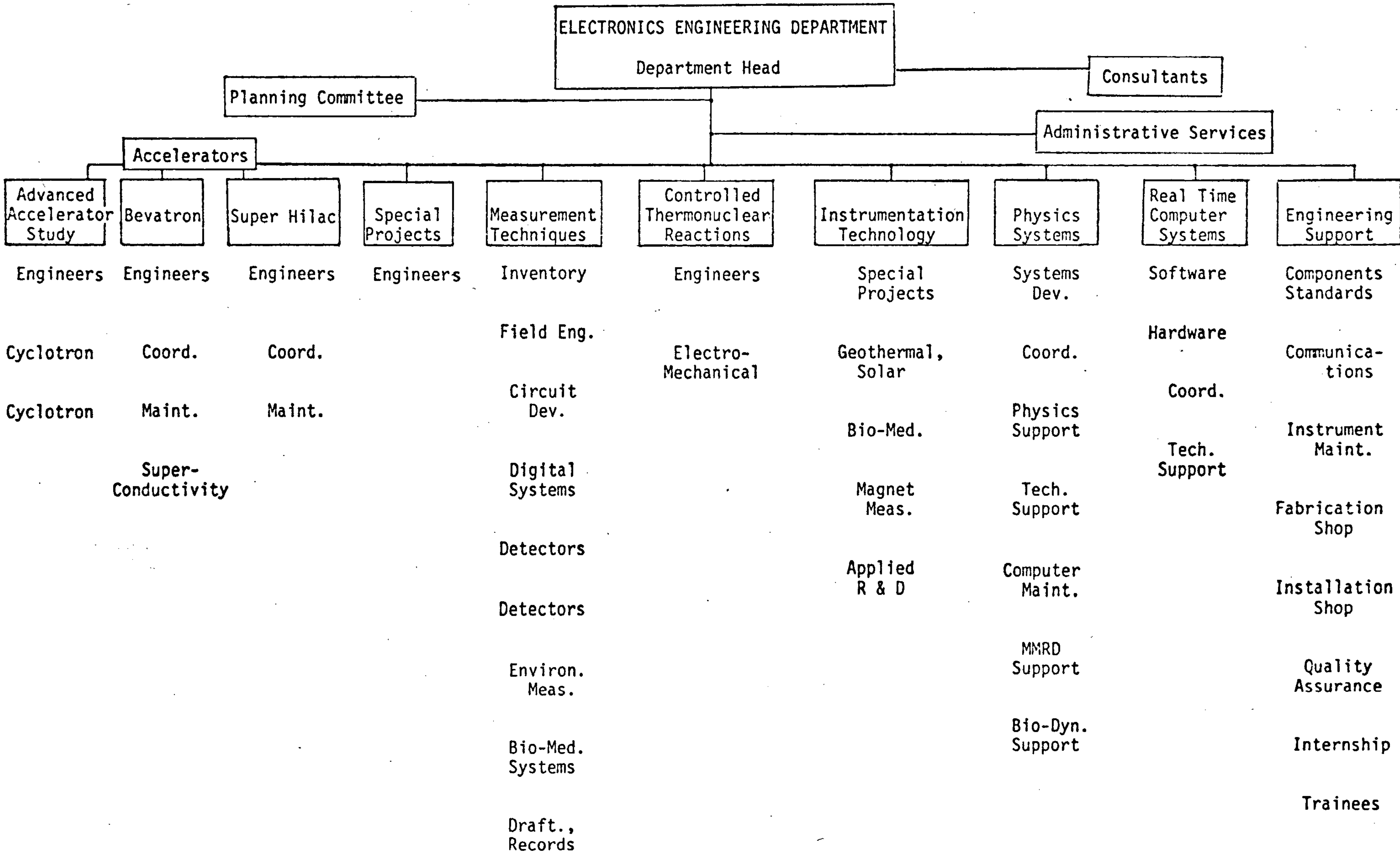
Under these conditions the following table may be constructed:

Period	Percent of Employees Under 42½ Years Old	Percent of Employees Over 42½ Years Old
1. Initially	50	50
2. After 5 years	47	53
3. After 10 years	31	69
4. After 15 years	15	85
5. After 20 years	5	95*

*One-third are between 60 and 65 years.

The solution recommended by Mr. Cooke-Yarborough was that older experienced employees should be transferred to new laboratories in allied disciplines and that he hire young engineers. In this manner the new labs could take advantage of the know-how of older workers.

His own laboratory ceased hiring new engineers about 5 years earlier; his department was then at step 2 of the table; he had no reason to believe he would not be at step 3, 5 years hence.



APPENDIX B ORGANIZATION OF ELECTRONICS ENGINEERING DEPARTMENT

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