THE CONDUCT OF BASIC RESEARCH IN THE AEROSPACE INDUSTRY

Thesis by

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ABSTRACT

An analysis of basic research activities in the Aerospace industry is presented. A detailed study of Boeing, Convair, Lockheed, and Douglas indicates extensive and widely varying approaches to basic research in these companies.

The establishment of a successful basic research organization in any environment is a sequential process subject to many problems and setbacks. The airframe companies, though making promising progress toward this goal, still have a long way to go. The inherent hazards associated with the aerospace business threaten the fledgling basic research organizations, and I believe it will be the exception and not the rule that sound basic research activity will result.

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INTRODUCTION

Basic research is defined by the National Science Foundation as:

> "...projects that represent original investigation for the advancement of scientific knowledge...which do not have specific commercial objectives, although they may be in fields of present or potential interest to the (sponsoring) company. Basic research is research in which the primary aim of the investigator is a fuller knowledge or understanding of the subject under study, rather than the practical application thereof."

The conduct of industrial basic research cannot be separated from the commercial objectives of the companies that sponsor it. The recent emphasis on basic research in the aerospace industry has generated new conditions and considerations. A rough cost ratio of 1000: 100: 10:1 exists between sales, engineering development and applied research, company funded research, and basic research. It is important to recognize that basic research is relatively much less expensive than applied research and development. The cost of supporting a basic research project is about half of the total cost, the other half being the scientist's salary.

This report is concerned specifically with the scope and nature of basic research activities in four aerospace companies (Boeing, Convair, Douglas, and Lockheed). The information presented is drawn primarily from discussions with more than 100 research managers and scientists from industry, universities, and the government.

My original objective was to determine how basic research results find their way into improved aerospace products. This study quickly mushroomed into the entire spectrum of aerospace research and development. I decided to limit the final report specifically to the problems and practice of basic research in the four aerospace companies.

In the first section, which contains my principal qualitative observations and conclusions, I have attempted to separate and discuss some of the elements of the matrix of complex factors that influence basic research in the aerospace industry.

In the second section I have briefly summarized the extent of basic research activities in the United States. The scope, nature and distribution of such activities are studied, and apparent trends are identified.

In the third section I have briefly summarized the business posture of the aerospace industry. An understanding of the characteristics of the industry is a prerequisite for studying its basic research activity.

The final section is a detailed description of the basic research activity in the four companies selected for study. I obtained this information from conferences with company research managers and scientists. I generally started with the highest research manager in the company with authority over basic research, and then followed his recommendations in interviewing as many research managers and scientists as possible. I encouraged discussion along developing lines of interest rather than to follow a predetermined agenda (although this procedure makes valid comparisons difficult). I also talked with many executives who were not directly responsible for basic research. My main attempt was to get a feeling for the research attitude, activity, and environment in the companies.

OBSERVATIONS AND CONCLUSIONS

1. Basic Research is New to the Aerospace Industry

Practically all research managers in the industry agree that almost no basic research activity was conducted in the aircraft companies until about 1955. NACA and the universities had been the traditional performers of basic research for the industry, and there was little incentive for individual companies to duplicate or supplement the excellent scientific results being provided without direct expense to the company. The aircraft industry grew and expanded by consuming government and university research results.

2. What Factors Caused the New Emphasis on Basic Research

A complex combination of factors, inter-related and acting concurrently, caused the aircraft companies to invest increasingly in basic research activities. In this matrix of factors it is difficult to isolate and judge individual elements - (At the risk of being wrong or omitting some important considerations, I shall do it anyway!).

a. The compression of the time scale between basic research and weapons system development was the most important single factor. The intense military competition between the U.S. and U.S.S.R. forced a rapid acceleration in the development of new weapons systems, with increased technical achievement in a shorter time. To obtain relevant scientific knowledge sooner, companies began to do some basic research of their own.

b. Non-American orbiting evidence (Sputnik I, 4 October 1957) of Russian technical competence brought the matter of basic research into the political arena. The congressional clamor that ensued, and the brief public interest and response, favored increased support of basic research (however defined). In this generally favorable if confused political environment, aerospace corporations seeking to expand research activities found a more receptive military, public and internal corporate situation.

c. As a result, much more government money suddenly became available for basic research. In a complete reversal of the policy of the previous year (1957), company basic research expenditures were encouraged and supported by the Department of Defense. Also, corporate earnings were at or near record levels, thus favoring increased company investment in basic research. Most of the large aircraft companies were already extensively engaged in research activity at this time, and there was a ready nucleus of scientific personnel about which to expand.

d. Expanding technical requirements forced aerospace companies to do much more of their own research. With the advent of the missile era, the research knowledge traditionally provided by NACA and the universities became inadequate. Also, the trend toward decreasing lead-time between scientific discovery and application made it desirable to have some formal basic research activity within the companies, both for its direct contribution of technical results, and as the best way of keeping up with what was going on generally in relevant scientific fields.

e. The decreased time interval between basic research and weapons system development, coupled with the increased technical requirements, caused an evolving change in military contract negotiations. Competition for contracts tended to be based more on preliminary study and research, than on traditional proven performance of prototypes. In general, much more detailed technical information was required in the contractor's proposal, and the prestige of technical and managerial personnel associated with a proposal significantly influenced its consideration. This trend encouraged companies to increase and display their technical capabilities.

f. As technical competition broadened, new competitors suddenly confronted the established and production-oriented aircraft companies. Smaller, more highly specialized companies successfully competed for components instead of entire weapons systems. Widely varying attitudes and methods of research came into competition, as the nature of military weapons changed. Also, the number of competing companies increased faster than the available funds. In the intensifying competition, companies that could sell their research competence (irrespective of its real value) tended to prosper at the expense of the rest.

g. Finally, scientific disciplines began to merge. As a result, airframe companies found themselves lacking in many areas of scientific knowledge and capability. With the new importance of technical prestige, companies found it desirable to establish "in house" many research activities (including basic research) formerly conducted for them by NACA and the universities.

3. Definitions of Research in Industry

In the aerospace companies, most research managers define basic research as fundamental research wherein the primary interest of the investigator is directed at increasing knowledge and understanding of physical and theoretical phenomena. A surprising number also include a defensive statement indicating that basic research is not product or process related, and has no useful purpose or planned application... (Thereby implying by definition that the research itself is really useless to the corporation!).

Applied research is defined as research directed specifically at a product or process-related problem area.

Development is defined as a combination of engineering and research efforts in specific problem areas after a project or process is well under way in terms of corporation effort. Fabrication of a prototype and most subsequent technical effort is usually called development. Development continues in and through the production stage, the research function decreasing as the experience factor grows.

4. Classification of Research Activities

a. The broad definition of basic research is subject to varying interpretations, and the recent emphasis on technical capability and prestige has magnified this situation. As a result it is of questionable value to compare levels of basic research activity between companies, since it is difficult to find two companies or even two individuals within a company who will agree on what constitutes basic research.

b. It is extremely difficult to clearly separate basic from applied research, since there is overlapping activity. An exploratory program begun as basic research may introduce promising product or profit potential. In practice, considerable use of basic research scientists and facilities in support of applied research complicates the situation. Basic and applied research costs and activities are analyzed in so many fragmentary ways that even company managers heartily disagree on levels of activity. Considerable management attention is now directed toward clarifying existing activities, as a first step in their improvement.

c. By definition, basic research is not oriented to support the corporate pursuit of profit and is in fact a drain on that profit. Hence, basic research is in direct conflict with the main stream of corporate orientation and activity. The resulting pressures often cause research activities to be classified by the corporate financial controls organization. Since the corporation is profit oriented, the maximum correlation of research to available funds is desirable, and research costs often tend to be disguised in available operating funds. The problem is who determines this correlation of research costs to available funds and how (and it is seldom the research scientist)? Also the same research activity may be classified in different ways, depending upon the existing corporate environment. This corporate environment is subject to rapid fluctuations as a function of profit, personnel, expediency, politics, contract requirements, and a host of other factors.

d. Another important consideration in determining what is called research is the corporate image. It appears that a forward looking corporation of today must include some basic research activity, however superficial. Although less than five years ago the very mention of corporate sponsored basic research was "taboo" in some leading aircraft companies, it is now unfashionable not to have something called a basic research group!

e. Finally, I would observe from my discussions with research managers and scientists, that the closer one is to the working scientist, the more applicable the definition of basic research as used in the introduction to this thesis. Though there is a surprising agreement on the definition of basic research at all management levels, the breadth of company scientific activities included in this definition tends to be much greater in the management echelons than among the practicing scientists. Consequently, when scientists and management use the term "basic research", they are likely to be talking about a significantly different scope of research activity.

5. The Financial Support of Corporate Basic Research

The aerospace companies are notorious for their violent profit-loss oscillations. The extreme instability of corporate markets, increasing costs of technical development, increased competition, and decreased earning potential on government contracts all imply a precarious corporate position and continuing economic risks approaching "brinkmanship". This economic environment is not favorable to basic research. It is decidedly hostile. The business position of exemplary corporations where successful basic research has flourished (American Telephone and Telegraph, General Electric and DuPont) is entirely different; i.e. a significant market monopoly exists. Bell Telephone Laboratories, the pace setter, operates within a parent company (AT and T) whose net income has increased steadily by $100 million a year increments to the 1960 record level of over $1.164 billion (estimated). Earnings at General Electric consistently top $200 million. Earnings at DuPont repeatedly top $400 million. The point here is this: The aerospace companies are in an entirely different business environment, and there is no established standard to prove that basic research activities can flourish in such surroundings. At the present time, however, Lockheed is pointing the way.

It is a recognized fact that stability and continuity are essential ingredients of sound basic research activity. Given the violent economic dynamics of the aerospace industry, how can some degree of stability prevail? Good or bad, the developing trend is Federal Government subsidy of corporate basic research. It exists on an increasing scale in all major aerospace companies.

I would estimate that over 75 per cent of all corporate basic research in the aerospace industry is directly or indirectly supported by Department of Defense funds. Direct contract research is a small part of the total (probably less than one-third). The remaining funds (which account for 50 to 80 per cent of the "company funded" basic research budgets), are provided out of general research funds on the basis of negotiations with one of the military services, representing the Department of Defense. These funds have become increasingly available for basic research in the last few years (notably after Sputnik I). They are made available through the Armed Services Procurement Regulation No. 15 (ASPR-15). Since ASPR-15 funds are the principal support of company basic research, and little known outside of the corporate offices, they will be discussed in some detail.

There is a tri-service committee, of general officer rank, that determines allocation of general research funds to the industrial corporations in support of engineering, development, applied research, and basic research. The level of support is determined by evaluation of and negotiation with each company separately. Company negotiators submit a proposal of planned corporate research activities (similar proposals are submitted in engineering activities) which includes a brief resumé of past accomplishments, present activities, research personnel and capabilities, and contemplated future work. Evaluation of the proposal's merit by technical agencies of the military research commands (Office of Naval Research, Office of Scientific Research, etc.) is based (obscurely) on relevance, capability, and other factors. The tri-service committee, after completion of negotiations with the company, determines the level of funded support the Department of Defense will provide. There is considerable speculation and little available information on how this level is really determined. The Department of Defense then releases the appropriate money by increasing existing contractual allowances in the company general overhead budget. No further formal and almost no informal report of expenditure is required. This machinery provides the major part of "independent" or "company funded" basic research budgets. The company is expected to utilize the money generally as planned (complete freedom without further evaluation is allowed), the idea being that the company can best determine its own research requirements as it goes along. This is a remarkably liberal and commendable procedure, and encourages flexible and dynamic research activity.

There are numerous shortcomings in the ASPR-15 funding process. First of all, and without such an elaborate mechanism, tax incentives could immediately provide a more stable and less obscure source of corporate basic research funds. The present dependence upon negotiated evaluations, though something of a control device (like a spur for instance!), is and has been subject to disrupting fluctuations. Also, the military agency determination of basic research relevance and competence is subject to criticism, and the entire process could easily become a lucrative target for congressional inquiry. Industry research managers, though glad to have the funded support, look upon the situation with considerable trepidation*!

The remaining portion of the corporate basic research budget (20 to 40 per cent) comes out of profit before taxes. Since corporation taxes are usually 52 per cent or more of gross profits, the estimated cost in net income to the corporation and its stockholders, is less than half of the actual expenditure. The direct cost of conducting basic research, to the aerospace companies, is probably about 10 per cent of the total basic research budget. (The true cost including capital equipment is somewhat higher.) Considered in this light basic research becomes a remarkably promising investment for the company.

6. The Environment for Basic Research

Considerable criticism has been leveled at the aerospace companies for creating unsuitable basic research environments. Though probably originally valid, such criticism is rapidly becoming obsolete. The research environments observed in the subject companies reflect a discerning awareness and response on the part of management to the particular characteristics of basic research. There is a studied evolutionary improvement taking place. Contrary to some popular opinion, the present industrial research environment is at least comparable and in many cases superior to that provided by

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* An involuntary trembling.
-Webster

universities. There are probably fewer budgetary, facility, and operating constraints on scientific freedom in the corporation basic research groups than in corresponding university research departments. In each category, of course, there are also some notable exceptions to this statement.

In terms of organization, each of the four subject companies places its basic research activity in a different operating environment. If centralized control is defined as high level authority vested in a few managers in the corporate offices, and decentralized control as delegated authority in the operating organizations close to the working level, then I would characterize the present basic research activities as follows:

Convair - Centralized control of centralized research

Boeing - Decentralized control of centralized research

Douglas - Centralized control of decentralized research

Lockheed - Decentralized control of decentralized research

I would further comment that there are few historical examples of successful delegation of responsibility without authority, the military services presently providing the classic example of this trend, and military history providing countless examples of disaster due to just such organizational doctrine. (Notable examples: The American Civil War, World War I, (possibly the recent Cuba fiasco?).... where centralized planning staffs kept tactical authority over field combat operations.) The point here is that operating authority must be preserved close to the operating level, wherever the latter may be located.

"Parkinson's Law is an effective deterrent to originality in research. With the growth in size and number of staff, there comes a multiplication of the managerial function, often falling on the shoulders of the more able research people. This administrative burden deadens the research sensibilities of those who could be most productive...The top management of research must be vested in highly competent scientists...There should be no compromising of this issue but the organization should be staffed in such a way as to handle the administrative work without excessively burdening the management"

---From the Report on the Conference on Research Goals. NSF, December 1959.

I consider the preceding quotation to be pertinent and valid. It is generally recognized in industry, and in some cases the scientists are literally being "helped to death!" The size of the basic research organization and its corporate location are not as important as the method of operation. The method evolves as a sort of matrix with scientific, organizational, administrative, economic, and personal elements influencing basic research.

Basic research activities should not be constrained to fit a predetermined pattern. A very interesting argument for this conclusion entitled "A Radical Proposal for R. and D.", by Dr. Burton Klein of the Rand Corporation appears in the May 1958 issue of Fortune magazine. Prominent management consulting firms* take issue with Dr. Klein's view that research is now suffering from too much direction and control. Although there are obvious questions of semantics involved, my observations heartily support Dr. Klein's view that "Research...is not a business that can be carefully planned and directed, not if you expect to make progress rapidly and economically". This is not to say that research is necessarily best managed when least managed, but

* Booz, Allen, and Hamilton among others.

rather that flexible sequential decision-making encourages creative research. The present trend in industry is toward this type of management.

On the other hand, a critical problem area at this point involves the defining of research goals. None of the subject companies has yet been able to adequately determine long range scientific research goals. What is needed is an elegant technique of formulating ignorance so that the basic research group advances toward common objectives in a guided yet unconstrained way! Resolving this paradox is extremely difficult and yet urgently required, for the alternative is continued fragmentary progress. The obvious problem lies in anticipating an uncharted and unknown future, and is the common dilemma of all scientific research directors. (I don't offer any profound suggestions!)

The problem of formulating specific research objectives is less fickle than the general problem stated above, but subject to the same pitfalls of lesser magnitude.' The collective judgment of the individual laboratory supervisors, considered in the light of probable future company interest, determines these objectives. Besides the collective judgment of informed scientists, there is no general procedure for evaluating proposed research, and each group follows its own method of analysis.

The word "environment" usually brings physical surroundings to mind. I believe that the operating environment is more important than the immediate physical environment. The physical proximity of other corporate activities is nevertheless very important. The basic research organization needs to be close enough to the main stream of company activities to be informed and in constant technical communication, yet isolated from associated pressures and engulfing "brush fire" projects. Much attention has been paid to this axiom, the early failures of some research efforts providing ample proof of its validity. I believe that separate basic research organizations and those integrally associated with company applied research efforts are about equal in overall effectiveness. Each has its own advantages, and although the separate facility is favored by the research scientist, there are advantages in communication and equipment for the integral group, particularly in the early stages of operation.

The intellectual environment can best be characterized by the spirit of the research personnel. This spirit is easier squelched than stimulated, and is dynamic in nature. There are some unique aspects to this part of the industrial research environment. Contrary to popular opinion, I believe there may be fewer constraints on scientific freedom in a well managed industrial basic research laboratory than in its university counterpart. Adequate funds and modern facilities may be more available, in less crowded surroundings. In the industry laboratories, the flexible organizational structure is probably more adaptable to rapid technological change than that of most universities. On the other hand, organizational change is unsettling to basic research and is seldom immediately necessary as a response to new conditions. Another very important factor in determining the intellectual environment is the number and diversity of scientific investigators. There seems to be a noticable isolation and resulting stagnation of scientific spirit when the number of research personnel is below a critical level. This level is undoubtedly related to the mutual interaction, stimulation, and enlightenment characteristic of scientific investigation among peers. This is one valid argument for centralized research, for the whole is probably greater than the sum of its parts. The very nature of basic research isolates it from most corporate activity. Some scientists maintain that a research organization is made up of "building block" units. To be effective, these units should contain about six or more competent research scientists, all working in a specific field and on fairly interrelated problems. The operating research organization is then a federation of individually sovereign research units. In small research groups the circulation and consultation of scientists may somewhat offset the size disadvantage, and the proximity of outside university or other scientific activity may stimulate intellectual interaction. My rough guess would be that about 100 practicing research scientists, in close proximity and frequent contact are necessary to create this critical mass. Of course, there are many other variables influencing this situation.

7. The Problem of Evaluation

The evaluation of basic research eludes systematic analysis. The problem extends through all levels of activity from the working scientist to top management. In the absence of well defined performance criteria, the considerable exercise of informed judgment is necessary. This requires scientifically current and experienced leadership. Generalized analysis techniques are worse than useless. Evaluation necessarily depends strongly on the evaluator's background and judgment.

The director of the research laboratory has more operating autonomy than most other corporate executives. The lack of valid performance measurements apparently causes this fortunate delegation of authority by default. It also places heavy responsibilities on the director of the laboratory. His individual judgment is crucial in determining the operating standard and environment of the organization. The director is the catalyst for a positive or negative reaction. In the rarefied intellectual environment of a basic research group, the negative sensitivity is particularly acute. A skilled director does not guarantee sound research, but a mediocre one guarantees failure.

The observed method of staffing new corporate basic research facilities is first to select the director. Maximum use is made of his professional associations, prestige, and initiative in selecting senior laboratory scientists and group leaders. Corporate top managements consider the scientific community to be an elite clique that communicates most effectively from within. The method of staffing is to select the director carefully and then to assist and accept his further judgments and evaluations in hiring scientific personnel. Most directors immediately attract their own nucleus of competent scientists, and this group in turn extends and broadens scientific association and evaluation. University graduate students should realize that the overwhelming majority of scientific positions are filled as a result of close professional association and recommendation, and not by personnel type interviews. Research scientists and managers do their own evaluation of prospective scientific employees.

There is no universal measure of individual scientific performance. Each research manager has considerable discretion in his methods of evaluation. In most company research organizations, he must establish an order of merit among the scientific personnel he is responsible for, but the method of evaluation is independently determined. In practice, three criteria emerge: 1) Does he produce publishable reports? Do technical journals solicit his advice and research results? 2) Is he sought as a consultant? How satisfied are his customers? 3) What is his scientific prestige level (education, experience, recognition, etc.)? The judgment factor inherent in applying these criteria is obvious. Managers frequently use outside consultants to aid their own technical evaluations. One other interesting standard, called the individual's "time span of discretion" was observed. This is a measure of the impact and responsibility of his decisions, and the supervision he requires in implementing these decisions. Considerable correlation between this "time span of discretion" and the individual's salary was observed.

8. The Expected Benefits of Company Basic Research

a. Management expects the most important benefit of basic research to be the real increase in technical capability, conscience, and prestige of the parent company. All research managers agree that an increase in the number and quality of scientific personnel is a major goal. The primary purpose of company basic research organizations is to create competent and available scientific groups that are familiar with company interests and requirements.

b. The prevailing attitude among managers is that a company cannot communicate with the scientific community unless it is contributing to it. A Boeing vice president stated that the basic research organization should establish an exemplary standard of excellence for the rest of the company. The basic research group is expected to maintain, through its own technical excellence, exchanges of information, and associations, constant and discerning communication with the basic scientific community.

c. Basic research is also expected to provide a scientific foundation for corporate growth into new and unanticipated areas of activity. In the last five years as the aerospace companies have changed from single product orientation to comprehensive technical activity, growth and diversification have frequently resulted from applications of promising new scientific knowledge. Corporate basic research organizations are expected to provide such fundamental knowledge, and (probably more important) to assimilate and evaluate technical activities throughout the scientific community. This is the particular area where company and scientific interests merge, and a principal reason for the establishment of corporate basic research activities. Management believes that company scientists can best judge the value and significance of new scientific knowledge to the company.

d. Basic research laboratories are expected to form the nucleus of a growing scientific community, within and around the parent company. Experience indicates that such organizations provide a continuous opportunity for scientific discussion and association. The key factor here is this: If a company can maintain a favorable research environment, it may attract outstanding scientific talent that would otherwise be unavailable. The basic research laboratory is a big part of the bait. It is anticipated that many of these key scientific personnel will evenutally move into positions throughout the company. This gradual process may orient company attitudes more along research lines, and thus improve the environment for the conduct of research. If successful, this will be a closed self-energizing cycle of increasing amplitude! Of course there are a host of dampers just waiting for the chance to act.

e. Continuity of research is another expected contribution of the basic research organization. In the operating divisions, business pressures and fluctuations force concentration on immediate problems. The basic research groups, somewhat isolated from corporate pressures, should achieve better long range scientific results, and thereby balance the sporadic research conducted in the operating divisions. A forward looking research program is more feasible in the basic research environment.

f. The scientists in the basic research groups are encouraged to make about 30 per cent of their time available for consultation. These company consultants, loyal to and necessarily more intimately acquainted with the interests of the company, supplement the outside consultants already available. Use of the basic research group consultants varies widely within and between companies, the character of the individual being the dominant factor. If internal friction is tolerated, the "in house" consulting role of the basic research organizations, though significant, may not develop as fully as some managers foresee.

g. Certainly, a major expected benefit of corporate basic research is the usefulness of the research results themselves. The transistor stands as a shining example for all fledgling organizations to emulate. The high percentage (50 to 75 per cent) of unsuccessful investigations inherent in research may be less evident. Negative results are not very valuable in a profit oriented environment. Managements have adopted a patient "wait and see" attitude toward their basic research organizations, and regard them as something like scientific insurance in a rapidly changing technical environment.

h. It should be evident from the preceding paragraphs that the actual value of scientific research results to the parent company may be less than the associated benefits of scientific activity. The publication of basic research results (the principal output of the basic research organization) is seldom restricted by proprietary considerations (say less than 5 per cent of the time). This is both sobering and encouraging. It is encouraging in that managements have recognized that companies have more to gain than to lose by prompt publication, since each company's contribution is such a small part of the total. It is sobering in that the competitive importance of the research results, which may in the long run be the deciding factor in determining research support, is not often of immediate or significant value to the parent company. Two tempering factors also influence proprietary considerations. First, the research scientists are unwilling to accept proprietary censorship unless it is indisputably in the company interest, since their professional reputations and prestige are determined in large measure by their publications. Second, the time delay inherent in publication, distribution, and utilization of new knowledge is thought to protect the prior interests of the originating company. Related to this delay is the fact that the evaluation and utilization of published research results is done by scientific peers in competing companies, where research results from competitors are evaluated in a decidedly negative environment! This phenomenon is known as the "Not Invented Here" (NIH) philosophy, and is fairly prevalent in most scientific groups.

i. <u>If the associated by-products of basic research are more important to the parent company than the research results themselves (which appears to be the case), won't a mediocre scientific organization evolve</u>? I believe this is a crucial question. It is somewhat balanced by the fact that the research results are more important to the individual scientist than the so-called by-products, since his reputation among his peers is largely determined by his results. There is an evident conflict of interest here between the company and the individual scientist. A delicate balance must ensue, for if either position prevailed to the exclusion of the other, failure would be assured. The paradox may be resolved by mutual enlightenment, so that the apparently conflicting interests in fact supplement each other. This may occur, (if discreetly managed), where the scientist is encouraged to work and publish free from unnecessary constraints, while remaining well aware of the primary interests and needs of the company. I would observe that the managements are meeting the reluctant scientists much more than half way, but that it is a dynamic situation, never in equilibrium, and always in need of discerning attention.

BASIC RESEARCH IN THE UNITED STATES

Long after the original dependence of American science on European mechanical invention and technology disappeared, dependence in the realm of basic research and theory presisted and even increased. Historically, the leading figures in American science were usually immigrants. World War II both accelerated and interrupted the tradition of importing basic research results and scientists from Europe. "Much of the technical advance during and after World War II was based, as is now generally recognized, on fundamental scientific knowledge that has been produced not in our own country or by individuals educated here, but rather by scholars in and of other countries". In the last decade, a new national awareness of the importance of basic research has been fostered by spectacular research applications such as computers, transistors, earth satellites, and radio astronomy. The term "basic research", (however defined, if at all) became identified with progress and growth. In the early fifties, basic research became a beneficiary of Federal Government funds on an increasing scale, and attempts to justify this situation led to considerable distortion in the public understanding of the nature of basic research.

The only available source of comprehensive factual information on the scope and nature of basic research in the United States is the National Science Foundation (NSF)*. The NSF derives its information

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* The NSF, completing its first decade as a federal agency in 1960 (and having grown in annual appropriation from $225 thousand in 1951 to $40 million in 1957 to $155 million in 1960), is broadly concerned with the advancement of basic research and education in the sciences. The NSF is also vested with primary responsibility for policy concerning the federal support of basic research throughout the country. The information in this section is drawn directly or indirectly from NSF publications, as nearly all independent publications are actually based on this source as well.

from a continuing program of questionnaire surveys based on the cooperative response of thousands of individuals and organizations throughout the country. For basic research activities, the basis of comparison is the compilation of financial data from respondents. The inherent diversity in the interpretation of basic research activities is acknowledged, but limited studies show a strong correlation between reported financial outlay and the volume of publication in scientific journals.

It should be pointed out that the cost and quality of basic research vary considerably between and within research groups in different areas of activity. Also, the reported expenditures should probably be adjusted for dollar inflation and for changes in reporting analysis and procedure as a result of increasing attention to and prestige of all areas of research activity (a phenomenon which may be called administrative inflation).

The total national expenditure on basic research is about 1/8 of 1 per cent of the gross national product, and represents about 8 per cent of the total expenditure on research and development. Figure 1 depicts the relationship between total and basic research expenditures. It is important to keep in mind that the cost structure of basic research differs considerably from that of applied research and development. The salaries of scientists and technicians constitute the largest expense in basic research, although facility and equipment costs are also rising. The operating costs of applied research and development---particularly development---consist increasingly of complex and expensive items necessary to product application, such as electronic

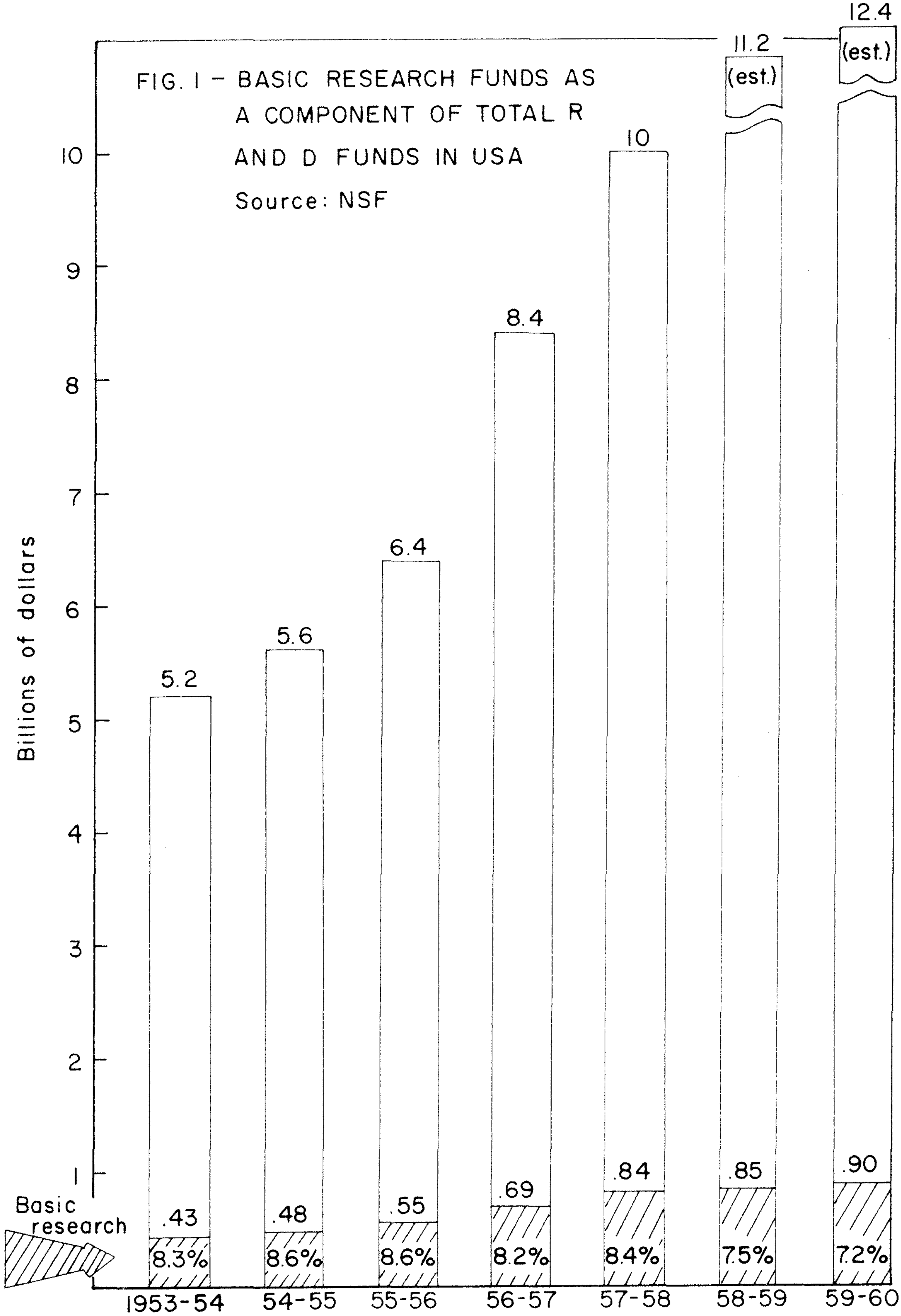
FIG. 1 – BASIC RESEARCH FUNDS AS A COMPONENT OF TOTAL R AND D FUNDS IN USA
Source: NSF
Billions of dollars
1
2
3
4
5
6
7
8
9
10
5.2
5.6
6.4
8.4
10
11.2
(est.)
12.4
(est.)
.43
.48
.55
.69
.84
.85
.90
8.3%
8.6%
8.6%
8.2%
8.4%
7.5%
7.2%
Basic research
1953-54
54-55
55-56
56-57
57-58
58-59
59-60

equipment, elaborate production facilities, etc. The point here is that basic research is relatively much less expensive. "The raw material consumed in having an idea is negligible; the incremental fuel cost of intense mental effort has been estimated as one peanut per hour."

A more detailed analysis of expenditures for basic research, based on statistical data compiled by the NSF, is presented in Figures 2 through 5. For analytical purposes, basic research activities have been grouped into four sectors: government, industry, educational institutions, and non-profit institutions.

1) The federal sector is made up primarily of the executive agencies of the Federal Government. State and local government appropriations flowing into basic research in colleges, universities, and other institutions are classified according to the receiving agency. Federal contract research centers, such as RAND, JPL, etc., are included in the sector of the administering organization.

2) The industry sector consists of manufacturing and non-manufacturing companies (including commercial laboratories and engineering services) and federal contract research centers administered by such firms.

3) The colleges and universities sector comprises institutions of higher education and affiliated research organizations including agricultural experiment stations, federal contract research centers, and hospitals.

4) The nonprofit (in some cases, non-loss is also implied!) institutions include private philanthropic foundations, nonprofit

research institutes, professional societies, and other organizations conducting basic research not related to the previous three categories.

Figure 2 depicts the sources of funds for basic research, and also the use of funds for the performance of basic research, by sector. An interesting fact is that the two reference years show a striking similarity in the relative distribution of sources of funds and use of funds, although the total funds available almost doubled (from $430 million to $840 million). The Federal Government grew as a source of funds (from 45 per cent to 51 per cent) while industry, university, and nonprofit sectors declined slightly. The distribution of funds used for the performance of basic research also changed but slightly. The sources of funds for basic research by volume are: (1) Federal Government, (2) industry, (3) colleges and universities, and (4) nonprofit organizations. The users of funds (performers of basic research) by volume are: (1) colleges and universities, (2) industry, (3) Federal Government, and (4) nonprofit organizations.

Figure 3-a depicts in detail the flow of funds for basic research. The transfer patterns resulting are significant, in that there is usually some control, direct or subtle, implied in the flow of funds from source to user. The sensitivity of the user to political, business, and other factors is also indicated. Figure 3-b shows the total major flow patterns for the reference years, and the percentage of basic research funds absorbed by the using sector.

Figure 4 depicts the distribution of basic research funds by user according to physical or life science. Funds for the performance of basic research in the physical sciences, including astronomy, chemistry, earth sciences, mathematics, metallurgy, physics, and engineering are about two-thirds of the total. The life sciences---agriculture, biology, and medicine---account for the remainder of the basic research funds. The largest volume of funds in the physical sciences is used by industry, with the college and university sector second. The reader is free to draw his own conclusions as to the relative cost of the same research excellence in one group compared with the other. The RAND Corporation has compiled some evidence to indicate that basic research advances of major significance come more often from the non-industrial sectors, although there are many notable exceptions; i.e., research that led to the development of the transistor at Bell Laboratories, research that led to the development of nylon at DuPont, etc.

American industry absorbs about 80 per cent of the total national research and development expenditure. Funds for the performance of research and development in industry totaled $9.4 billion in 1959, a 15 per cent increase over 1958. Over half (57 per cent) of this amount was federally financed. About 4 per cent of the total annual expenditure by industry is classified by the spender as basic research; the funds for basic research performed by industry in 1959 totaled $344 million. Although the funds for basic research in industry are relatively small compared to the total dollar volume of R and D funds in this sector, these basic research funds are a sizable portion (about one-third) of the national total for basic research performance.

The chemicals and allied products industry (including drugs and medicines), electrical equipment and communications industry, petroleum refining and extraction industry, and aerospace industry together account for almost three-fourths of basic research expenditures reported by the industrial sector in 1959. Figure 5 depicts the funds for performance of basic research by industry in 1957, 1958, and 1959. Attention is directed to the rate of increase in the aerospace industry.

The only comprehensive program for registration of the nation's scientists is The Register of Scientific and Technical Personnel, maintained by the NSF. Information compiled indicates a growth in the number of full time employed scientists from 127,000 in 1954 to over 170,000 in 1958. Of this total, about 27,000 are engaged in basic research, compared with about 24,000 in the Soviet Union. "The median annual salary of scientists employed full time during the years 1956-1958 is computed as $7900. About 50 per cent were in fields of chemistry and in life sciences, which include agricultural, biological and medical sciences. Almost half the registrants worked for private industry or were self-employed; 28 per cent were employed by educational institutions, and 19 per cent worked for various government agencies. Thirty-eight per cent of the scientists reported that they were engaged in research, development, and design, and 16 per cent reported that they were engaged in teaching".

Probably the most pronounced difference between basic research in the United States and in other major scientific countries is the scope and variety of performance. The recent encouragement of basic research in American industry and the extensive participation of scientists and engineers employed by and within industry are rapidly broadening the base of activity. Questions of qualitative excellence remain to be resolved. Economic and political pressures may be expected to increase as basic research expenditures increase. Annual federal or corporate budget fluctuations are highly disruptive to basic research, and it is by continuous progress, not by "breakthrough" as popularly supposed, that basic research advances. The principal official reason for Federal Government support of basic research is to advance the national health, security and welfare. This implies identifiable contributions.

> "It is important to emphasize that there is a perverse law governing research; under the pressure for immediate results, and unless deliberate policies are set up to guard against this, applied research invariably drives out pure or basic research."
>
> --Bush, Vannevar, Science, The Endless Frontier (1946).

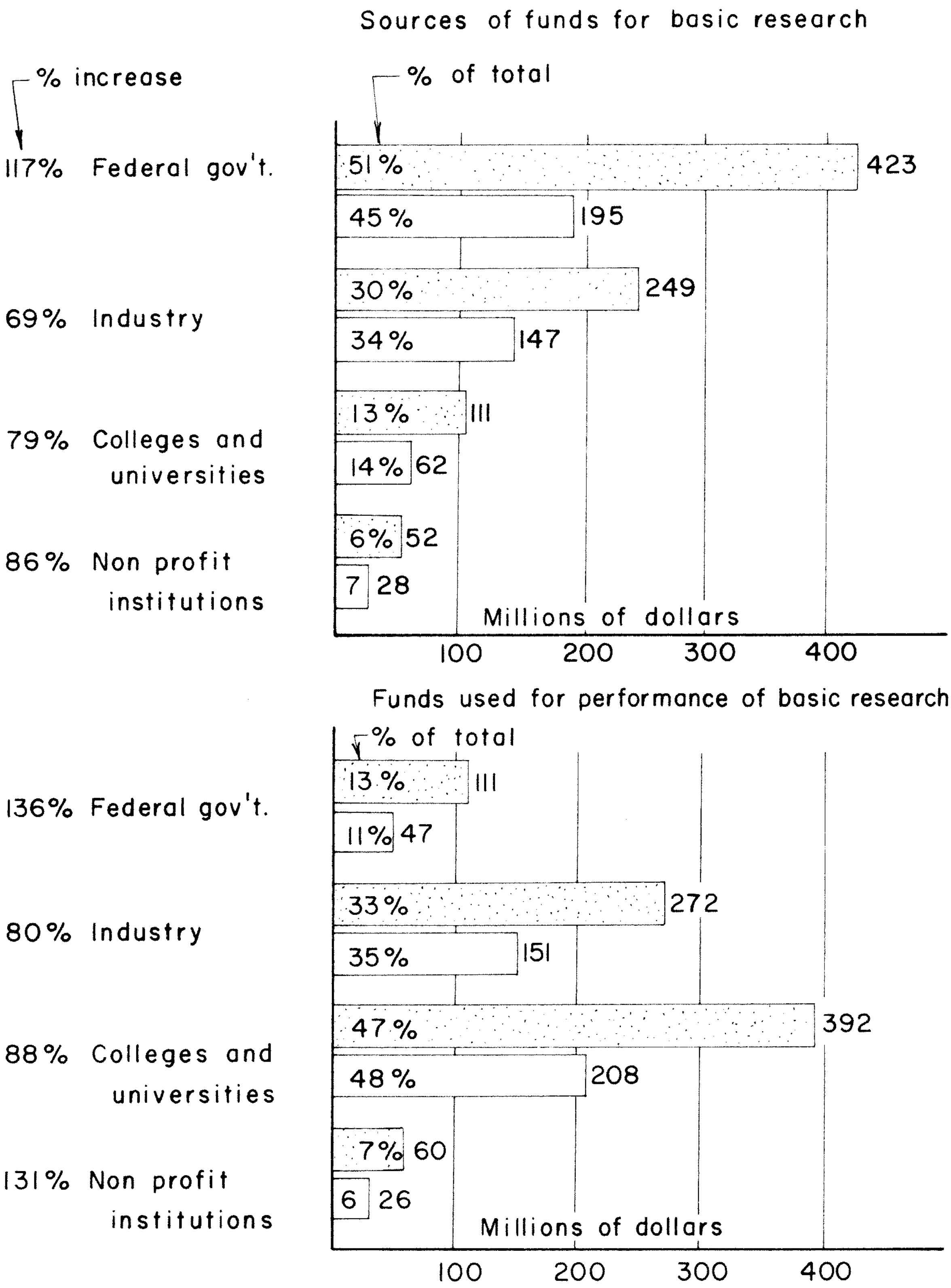

FIG. 2 - SOURCES OF FUNDS AND PERFORMANCE OF BASIC RESEARCH

Source: NSF

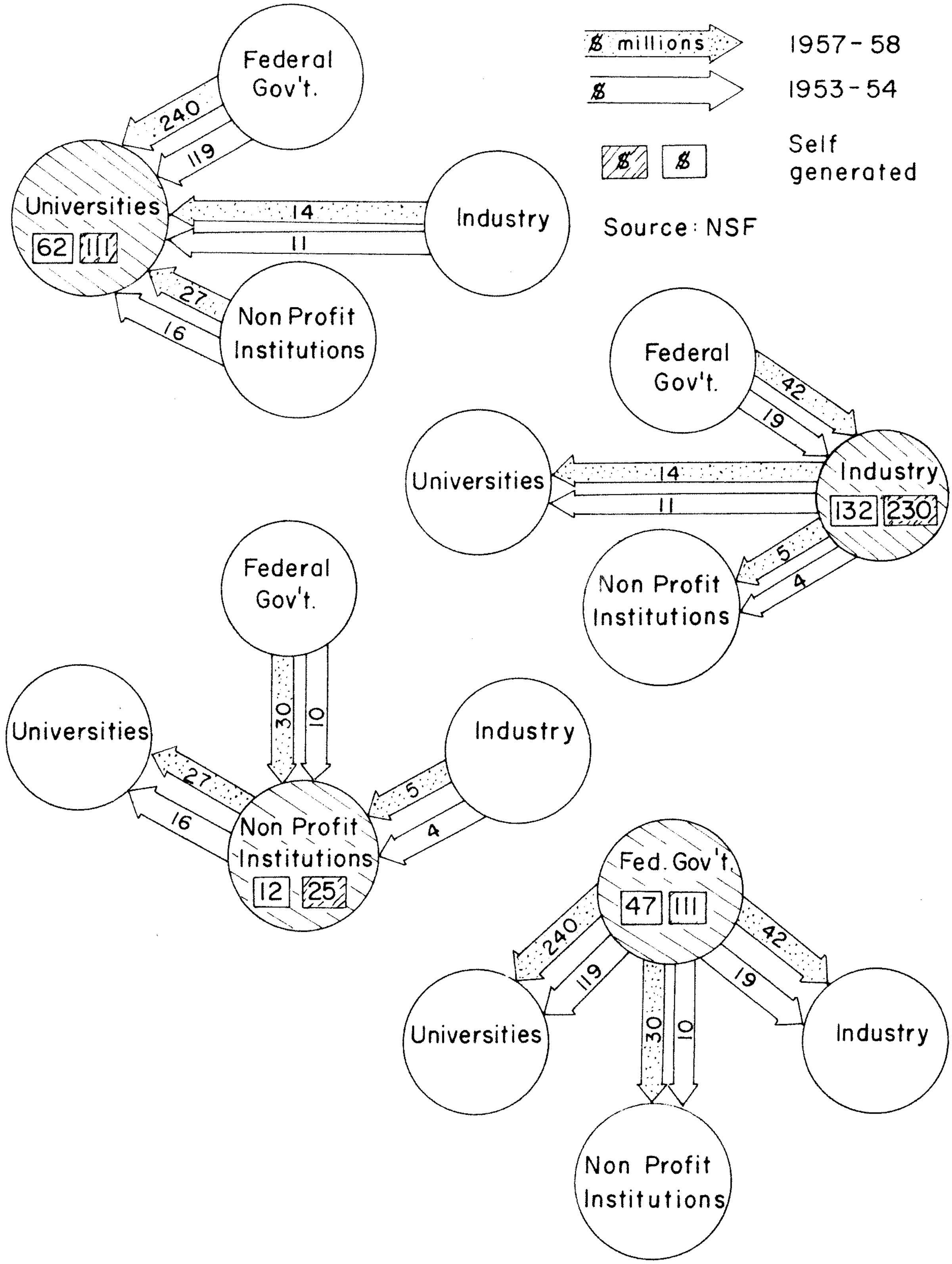

FIG. 3a – INTERSECTORAL TRANSFERS OF FUNDS FOR BASIC RESEARCH

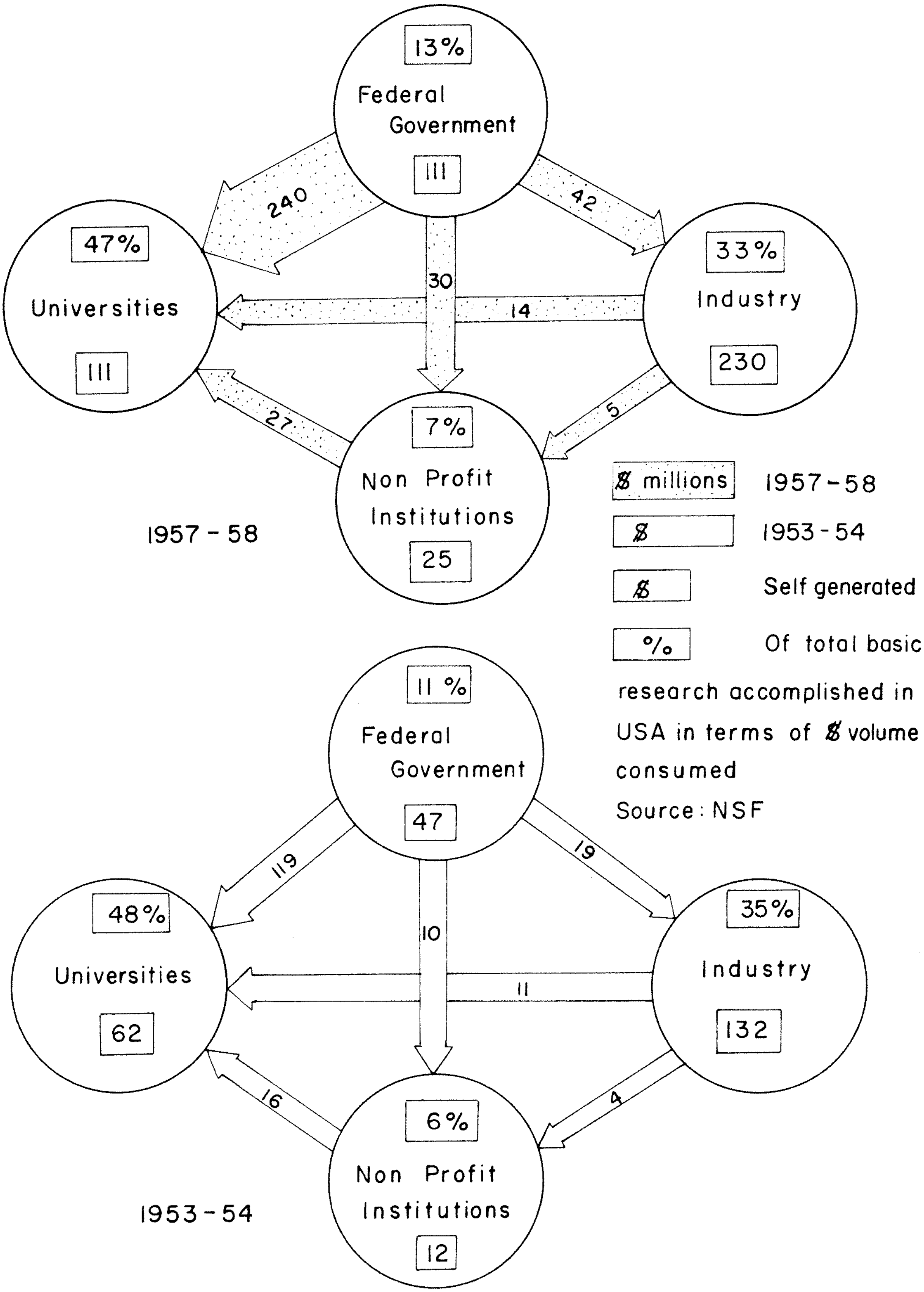

FIG. 3b - COMBINED TRANSFER OF FUNDS FOR BASIC RESEARCH

$ in millions

	Total $	Life sci	Phys sci
1957-58	$ 835	$282 34%	$553 66%
1953-54	$432	$132 30%	$300 70%

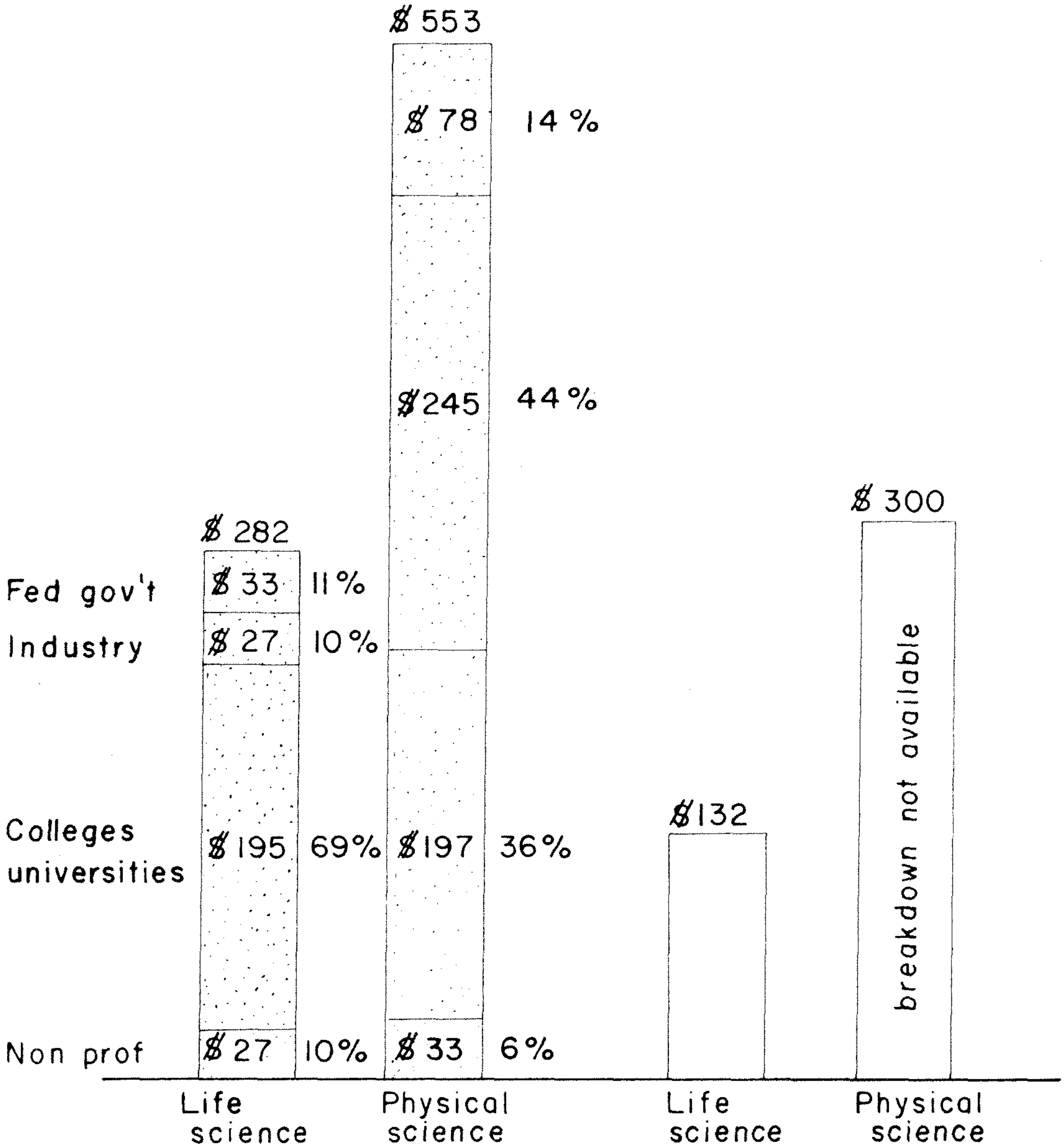

FIG. 4 - BREAKDOWN OF FUNDS SPENT ON BASIC RESEARCH FOR LIFE SCIENCES AND PHYSICAL SCIENCES BY SECTOR Source: NSF

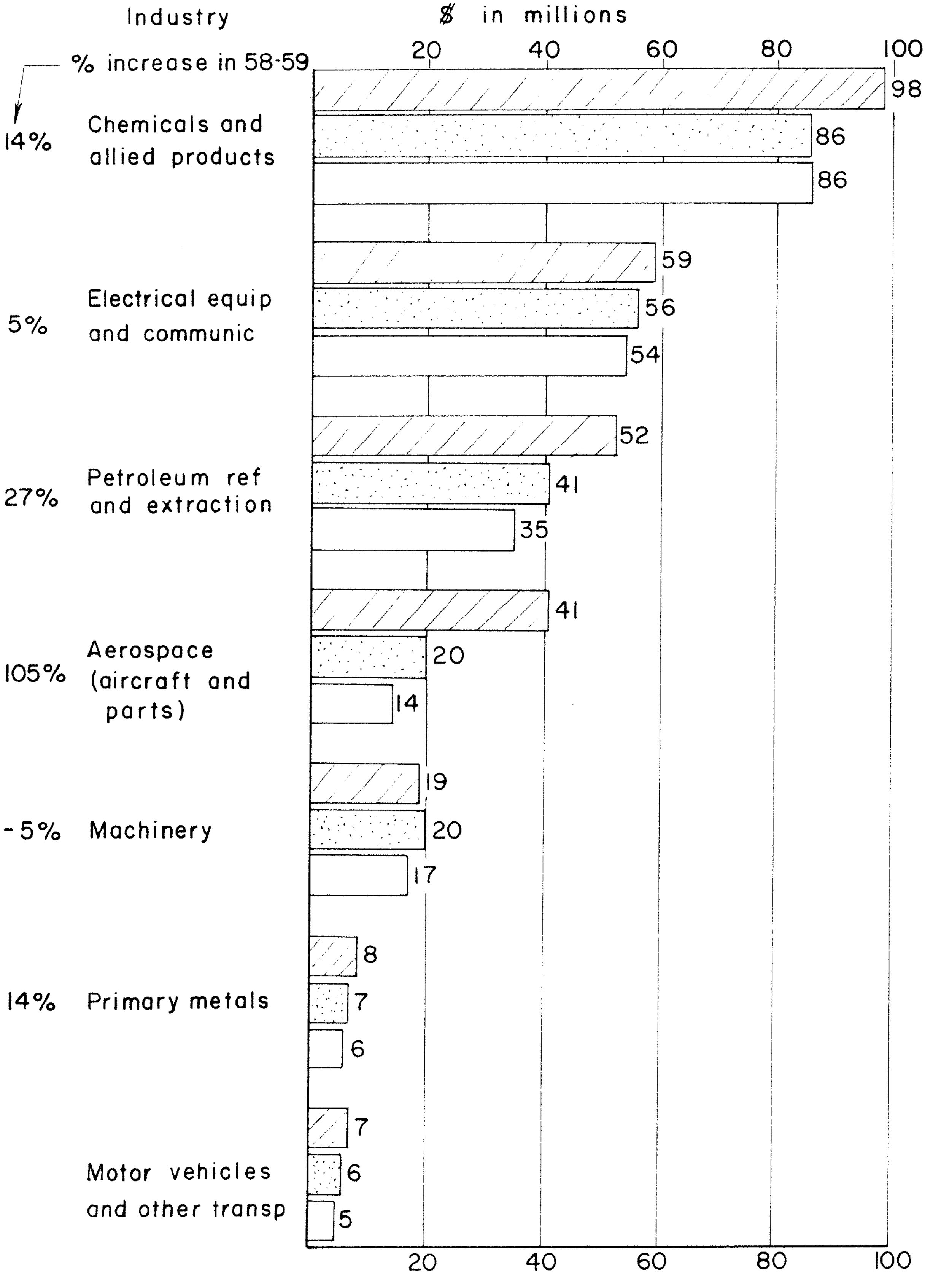

FIG. 5 - FUNDS FOR BASIC RESEARCH PERFORMANCE BY INDUSTRY

Source: NSF

THE AIRFRAME COMPANIES AND THE AEROSPACE INDUSTRY

The aerospace industry embraces research, development, and production of manned and unmanned vehicles and their supporting equipment for movement above the earth's surface. It encompasses about 100 major contractors and over 200,000 subcontractors, and like the aircraft and parts industry that preceded it, it is dominated by about twenty companies including eight major airframe companies.

These eight airframe companies do 60 per cent to 95 per cent of their business with the United States government and its military services. This overwhelming dependence on federal spending makes the companies highly sensitive to expenditure fluctuations. Although the total level of federal and military expenditures has been moderately increasing in recent years, the distribution of contracts has been very unstable. A contractor's business volume may vary by hundreds of millions of dollars in a single year, and the character of activity may also drastically change. This has created a critical economic and organizational problem for the companies.

Concurrently, the nature of business has changed from the fairly straightforward production of aircraft to a wide range of technical activity. The cost of operations has steadily increased while production volume has diminished (Figure 6). The aircraft companies have traditionally organized to maximize production profits. The recent emphasis on research and technology with only limited production has placed them under stress. Moreover, whereas twelve companies originally dominated the business, there are now more than twenty large companies competing for fewer contracts (of greater dollar value but less profit allowance). The economic result of these factors is termed "profit squeeze". The physical result is an urgent diversification effort to obtain new sources of profit. This rapid evolution is referred to by management as a "transition period" while their huge production oriented companies realign themselves to suit the new nature of business. Rather than a transition period, I consider it to be a permanent condition. In the dynamic and technically modern aerospace industry, the only constant requirement is that of rapid change.

Figure 7 illustrates the deteriorating economic condition of the airframe companies. (The heavy write-offs required for the development of jet transports aggravate the situation but are an integral part of doing business and must not be overly discounted.) The problem is that research and engineering contracts do not have the profit potential required to support a highly competent and technically advanced industry.

The precarious economic position of the companies impedes technological progress. The airframe companies bear a considerable share of the burden of national technological competition with Soviet Russia. The constant and rapid modernization of facilities required for this competition appears impossible under present conditions, unless the already substantial federal subsidy of such activities is increased (Figures 8 and 9).

Rapidly diminishing profits and the lowest return on sales of any major American industry characterize the airframe companies in 1960. Contrary to popular business opinion, the return on net assets of 8.9

per cent in 1959 and 6.1 per cent in 1960 is also among the lowest of all manufacturing industries. (The average is about 11 per cent.) The present level of company funded expenditures cannot be maintained with existing income levels. It is paradoxical that in this financial posture, several of the companies initiated extensive basic research activities.

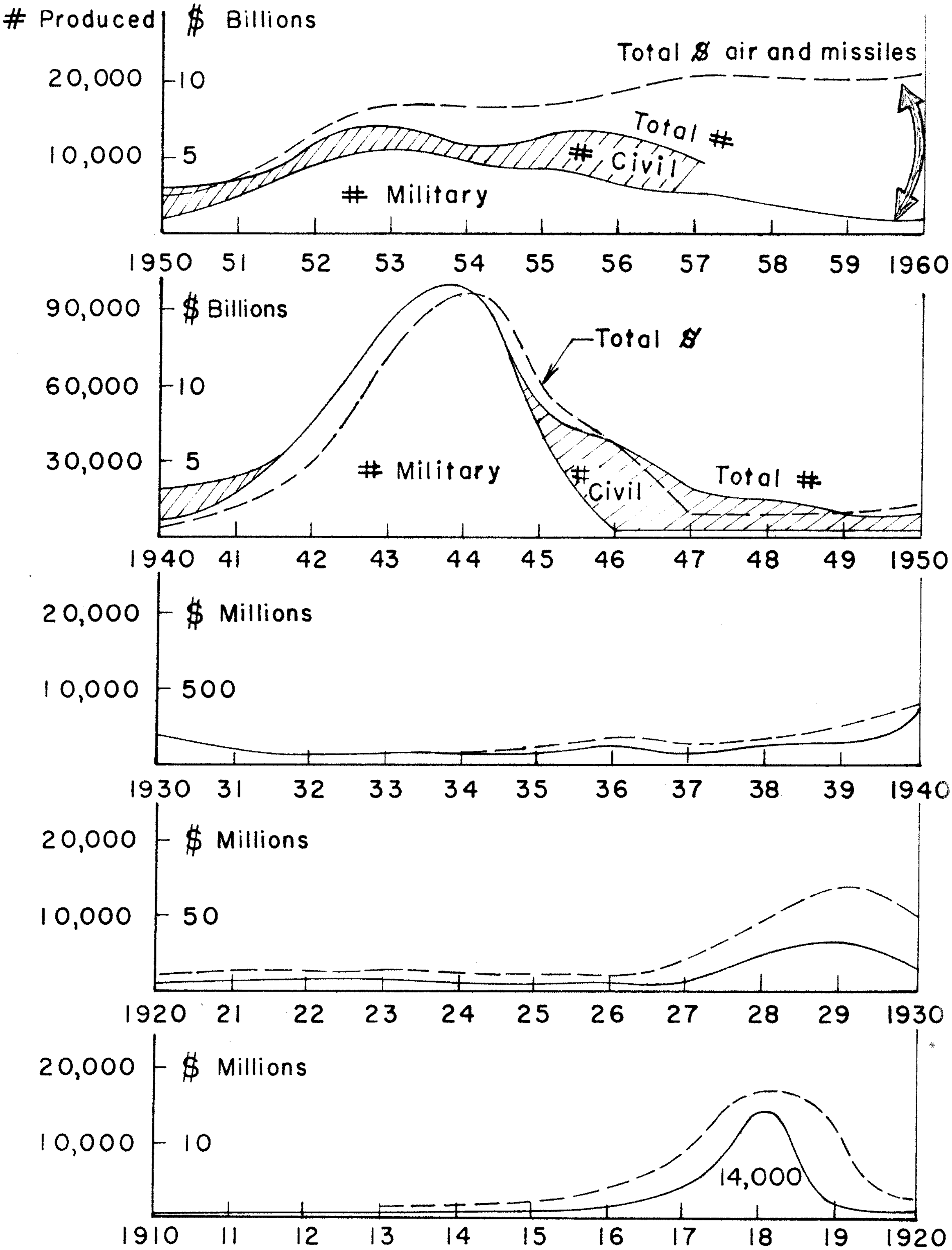

FIG. 6

UNITED STATES AIRCRAFT AND MISSILE PRODUCTION ————

VALUE OF PRODUCT (AIRCRAFT, MISSILES AND PARTS) — — —

SOURCE: AEROSPACE INDUSTRIES ASSN.

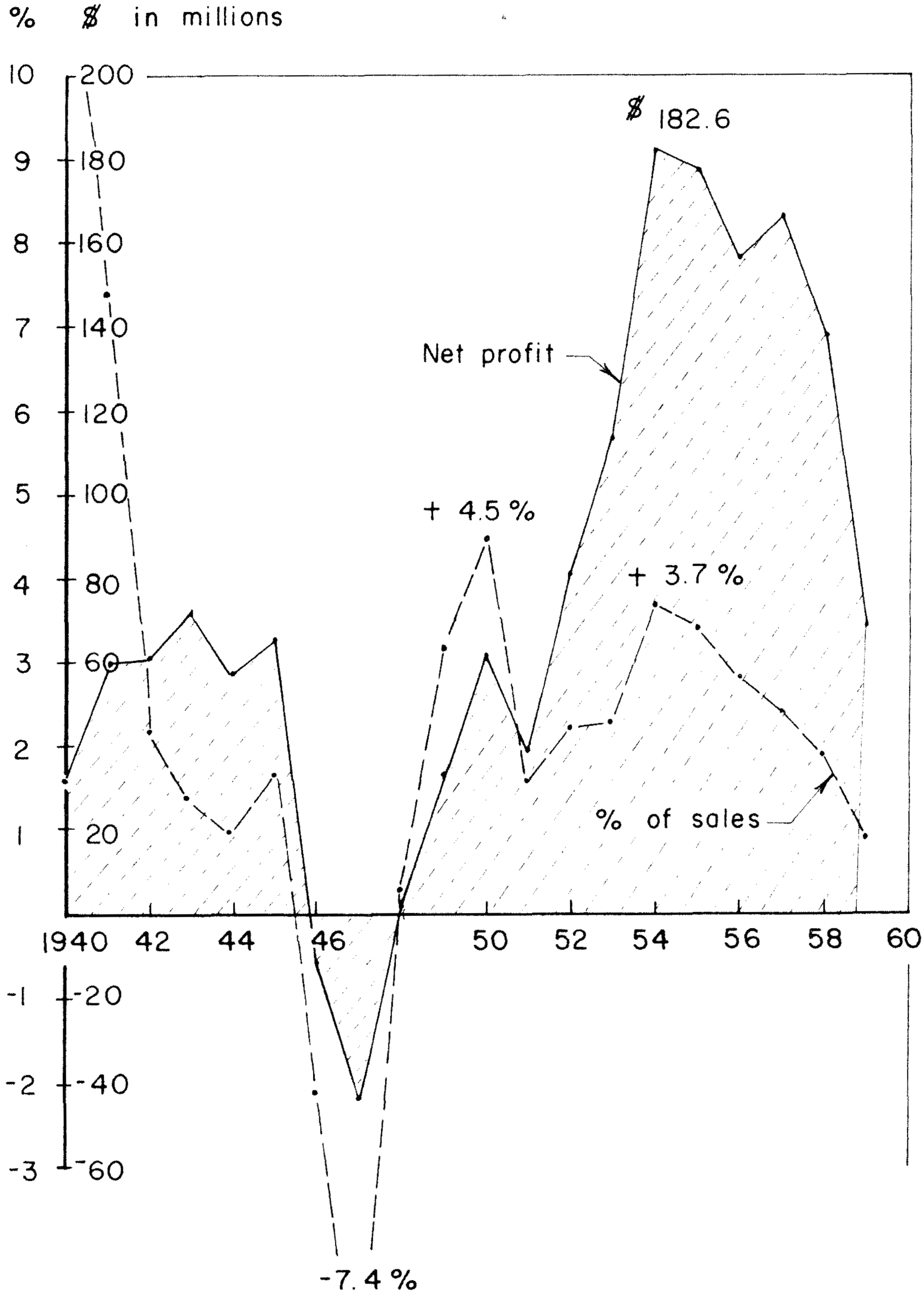

FIG. 7 - TWELVE MAJOR AIRFRAME COMPANIES (TOTAL)

Net profit in millions of $ ______

Net profit as % of sales _ _ _ _

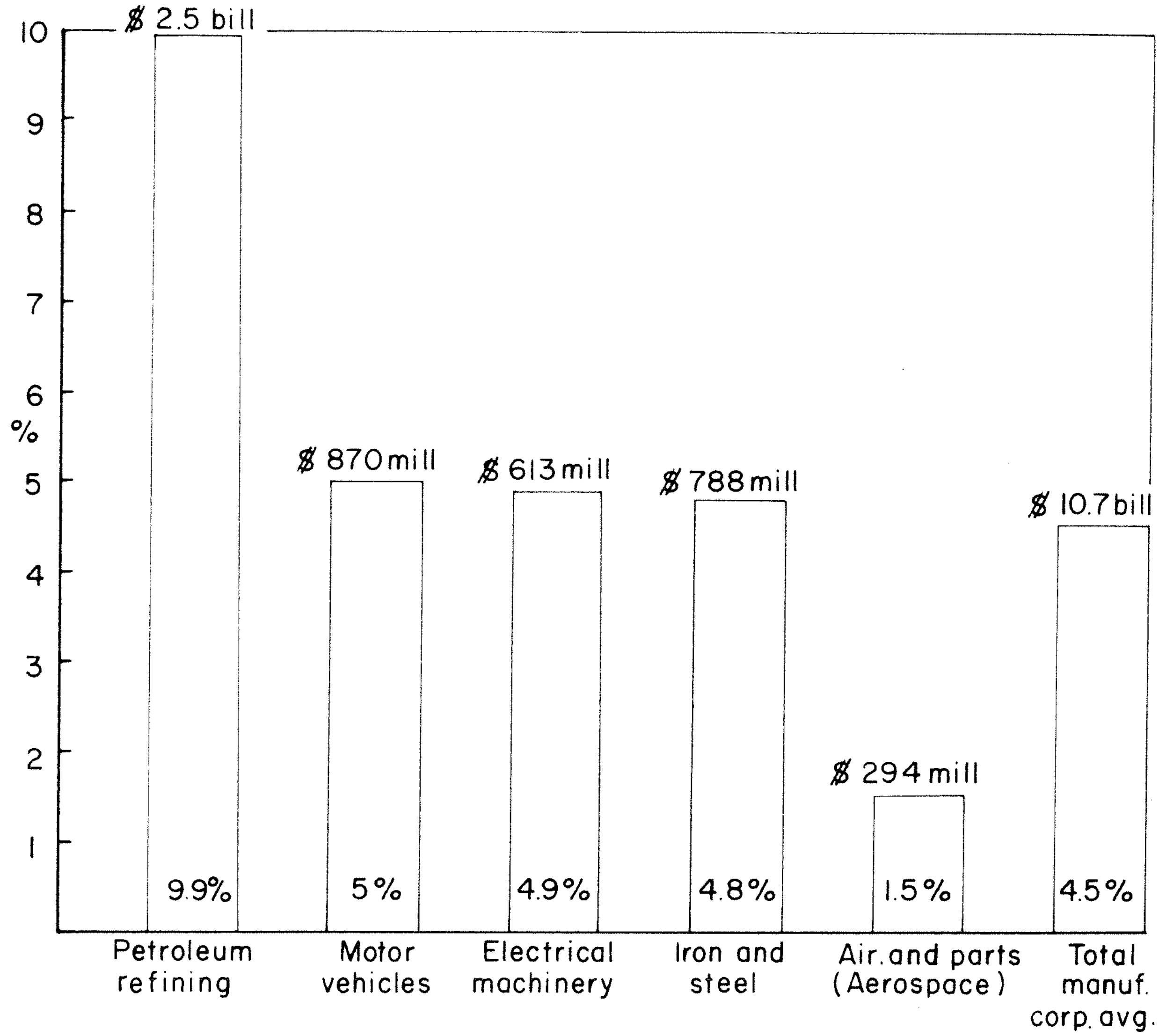

FIG. 8 - NET INCOME AS % OF SALES BY MAJOR INDUSTRY - 1959
Source: AIA

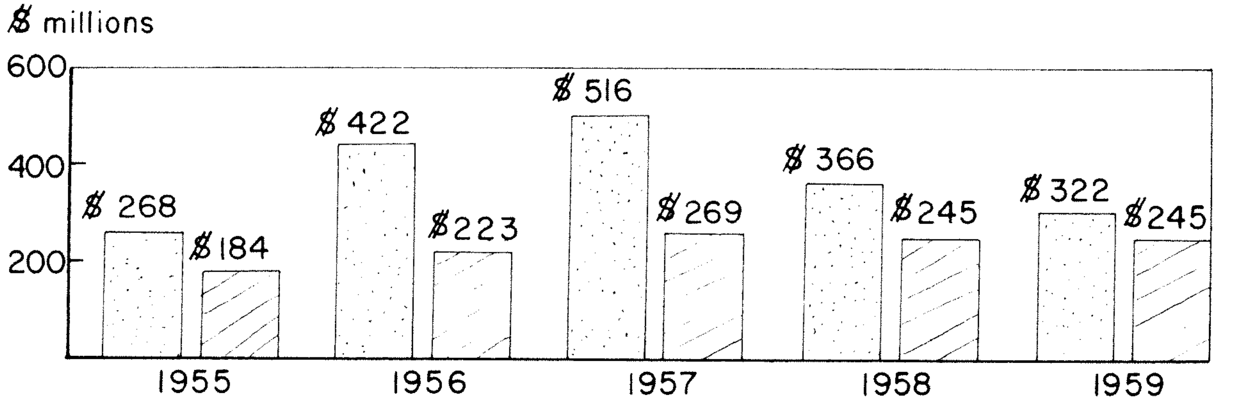

FIG. 9 - FACILITIES INVESTMENT IN AEROSPACE INDUSTRY (49 CO'S.)
Source: AIA

TABLE I

GENERAL COMPARISON OF COMPANY ACTIVITIES

The four companies were selected on the basis of 1) similar product activity, 2) widely differing approaches to basic research, 3) geographical convenience, and 4) management contact.

Company:	Boeing	General Dynamics	Douglas	Lockheed
Employees:	80,000	103,600	49,700	58,000
Major Products:				
Jet Transport:	707, 720, 727	880, 990	DC-8	Electra (propjet)
Missiles:	Minuteman ICBM Bomarc	Atlas ICBM Terrier Mauler	Thor IRBM Skybolt ALBM Nike-Hercules	Polaris IRBM Discoverer (satellite) Agena
Military Aircraft:	B-52 Bomber B-47 Bomber KC-135 Transport Helicopters	B-58 Bomber F-106 Fighter F-102 Fighter	Missileer A-3D-2, B-66 Bomber A-4D-2 Fighter C-133 Transport	F-104 Fighter C-130 Transport Jetstar Transport P-2 V ASW P-3 V ASW Jet Cargo Transport
New Programs:	Dynasoar	Centaur	Nike-Zeus Saturn 2nd Stage	Samos Midas
Net Sales:				
1958	$1,712,000,000	$1,512,000,000	$1,209,000,000	$ 974,000,000
1959	$1,612,000,000	$1,812,000,000	$ 883,000,000	$1,302,000,000
1960	$1,555,000,000	$1,988,000,000	$1,174,000,000	$1,335,000,000
Net Income:				
1958	$ 29,360,000	$ 36,730,000	$ 16,850,000	$ 18,850,000
1959	$ 12,440,000	$ 31,060,000	$ -33,820,000	$ 8,730,000
1960	$ 24,500,000	$ -27,100,000	$ -19,429,000	$ -42,900,000

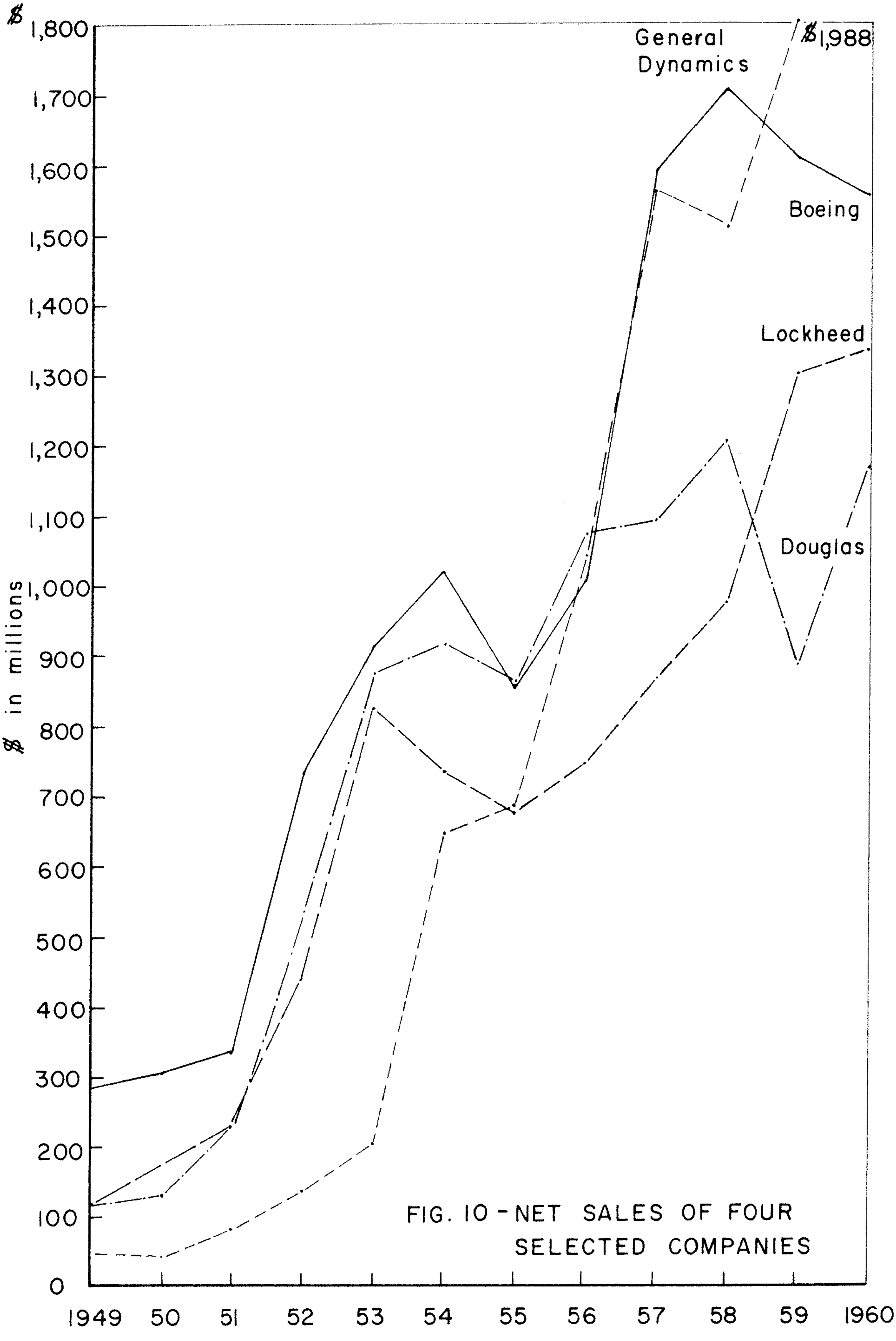

FIG. 10 - NET SALES OF FOUR SELECTED COMPANIES

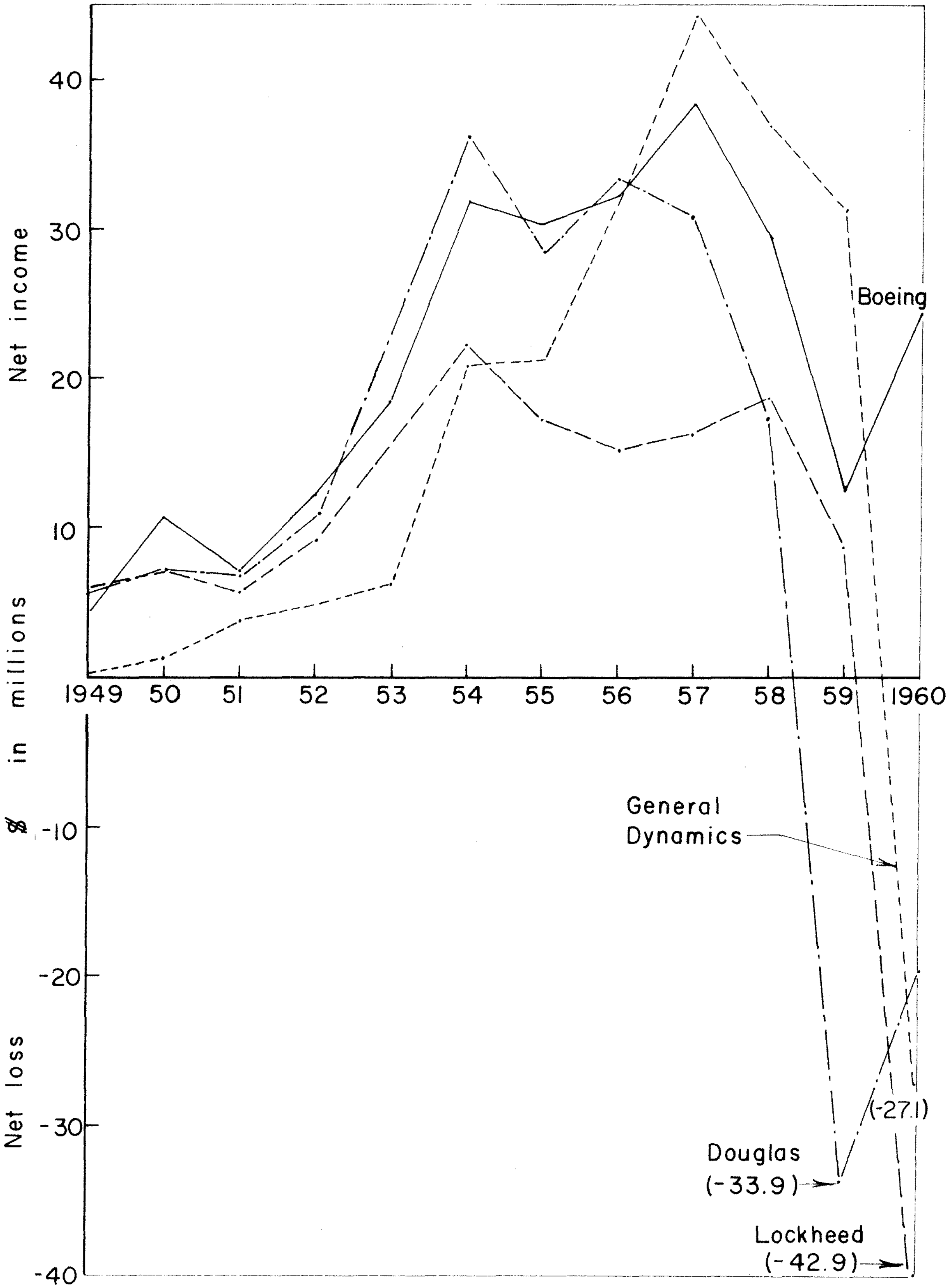

FIG. 11 – NET INCOME OF FOUR SELECTED COMPANIES

BOEING AIRPLANE COMPANY

The current (1960) sales of Boeing are divided into three major categories: military aircraft 38 per cent; commercial aircraft 32 per cent; missile, space and other activities 30 per cent. Future business prospects include an accelerated Minuteman program, the Dynasoar weapons system, an all jet cargo plane, a STOL-VTOL tactical fighter bomber, and a possible supersonic transport. Boeing has produced 42 per cent of the commercial jet transports in the free world, and is entering the helicopter market through its recent acquisition of Vertol Aircraft Corporation. Boeing also is developing a large hydrofoil ship under contract with the U. S. Navy.

Figure 12 indicates the current corporate organization. The company is moving from a concentrated corporate management toward a strong decentralized divisional management. This transition is intended to shift responsibility and authority farther down the line so that more programs of widely diversified nature can be effectively managed. There are presently about ten major projects under way, and management is looking to the time when fifty or more projects will be conducted simultaneously.

Top management states that the long term health of the company depends on a balance between research activity and production hardware. As more projects are undertaken in the diversification effort, more engineers will be required. Management must exert an increasing effort to maintain a healthy balance with production activity. The ratio of other personnel to engineers has already changed from the 10 to 1 figure of a decade ago to 3 to 1. The weight of product produced per engineer has decreased from 140,000 pounds for the B-52 to 1,400 pounds for the Minuteman missile. The method of maintaining the engineering-production balance is to replace old volume contracts with new work not requiring so much engineering. Commercial jet manufacture, although requiring considerable engineering effort, tends to balance the military programs which require a much larger proportion of technical activity.

Executives state that Boeing is definitely strengthening its competitive position within the aerospace industry. They attribute the success of their products sometimes to being first in a new field, but more often to sound engineering judgment as to the size of technological step appropriate, and cite the B-47, 707, and Minuteman as specific examples. Further, they state that regardless of contract type, success depends on the contractor's ability to go beyond the immediate scope of contractual requirements. A conscious design effort is made to allow for growth and improved performance.

Boeing wants more prototype competition for contract awards, and less preliminary paper study claim awards. Executives state that even in the missile and space era, limited prototype competition based on demonstrated rather than claimed achievement, would allow faster, cheaper, and sounder development of better equipment. There is considerable evidence (documented at RAND and elsewhere) to support this viewpoint, although it is contrary to the present public philosophy.

The Boeing Vice-President for Engineering described the company philosophy in project organization as:

1. Start with highly competent people who are interested in work.

2. Concentrate talent and then isolate from company pressures and reporting requirements.

3. Delegate real authority to working group and adequately support effort. Encourage free initiative.

4. Maintain a constructive management attitude.

5. Develop the maximum technological advance commensurate with time available, rather than meet minimum contract requirements.

6. Maintain close contact with customer during process.

7. Start early (if necessary with company funds, as in Dynasoar, Tac fighter STOL-VTOL, etc.).

Each of the Boeing operating divisions conducts applied research and development in its own product field. The divisions submit an annual R and D budget through the Vice-President for Research and Product Development, for top management approval. Efforts are presently being made to clarify the actual research expenditures resulting from the annual budget allowances. In the past, money spent has been classified so as to fit the approved budget, even though the actual usage may have been somewhat different. The complex formalisms required by government review and tax structures have tended to obscure real expenditures from the corporation management. The present procedures are under study and modification.

Money for research is either funded by contract with the customer or provided from company profits before taxes (company funded). The volume of company funded research money as a percentage of profits before taxes has been increasing yearly. During the present corporate transition period, executives state that an increasing chunk of company money and resources must be invested, even with diminishing profits, to provide the research base necessary for future products. Once the transition has stabilized it is speculated that product business will support the research and development effort more fully. There is an acute awareness of the importance of continuity in providing a research base for company activities.

Toward this end, the divisions have integral technical staffs specializing in their particular product and problem area. The staffs are organized on the basis of technical discipline rather than project or program. A "matrix" system is used in program organization; the technical staff member works on a program or applied problem under two lines of authority, one through his technical group and the other through the program leader. Questions of authority and responsibility are generated, but Boeing feels the improved environment for technical research among colleagues outweighs the managerial problems. Also, management responsibility and authority are encouraged farther down the line, resulting in earlier professional recognition and development. The technical groups at Boeing are separate and distinct from other engineering groups. About 10 per cent of the personnel in the technical groups are working on long-range problems not immediately associated with current business but closely related to future prospects. This is an important linking mechanism between basic and applied research, and is highly significant. The technical personnel, whom I shall call development scientists and engineers, must have training and interests that are broad enough to cover what basic research uncovers.

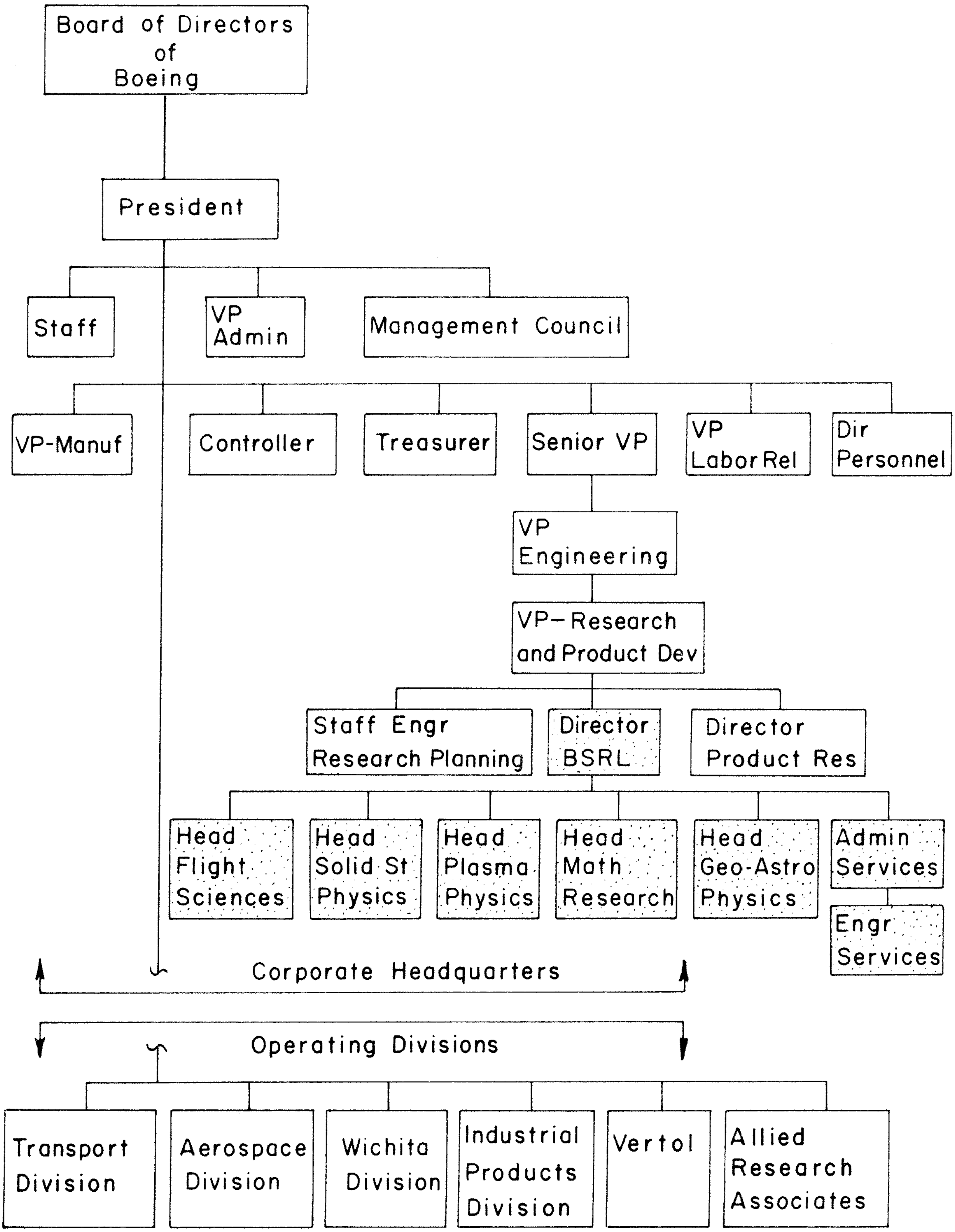

FIG. 12 – ORGANIZATION OF BOEING SCIENTIFIC RESEARCH LABORATORIES

Boeing Scientific Research Laboratories (BSRL)

1. Origin and Purpose

In 1939 there were 350 people in engineering at Boeing. Now there are over 15,000 engineers in the Seattle area alone. Coordination became difficult. The technical specialties increased greatly. Company organization separated to a divisional basis. More and more units specialized in the particular problems of the division in their technical specialty. The company as a whole was too concerned with today's technical problems.

Thinking developed that the formation of a corporate research laboratory would allow attention to longer range problems. The scope of research would be broadened, and would allow continuity of effort and concentration on knowledge, (not only knowledge gained in house, but throughout the scientific community) not just on products.

It was decided that the company must have an active program in basic research to understand and communicate with the rest of the scientific community, and that an organization operating under such conditions would attract scientific talent otherwise unavailable to the company.

In late 1957 the decision was made to create a corporate basic scientific research laboratory. The environment was to be carefully controlled to maximize scientific potential. The primary characteristic of the laboratory would be scientific excellence. It would establish a technical standard for the rest of the company, and also a library designed primarily to support scientific work.

The planned size and budget of BSRL were too small to go after people with highly established prestige. They were too busy bowing anyway! Boeing was interested in getting doers!

--From a discussion with G. Schairer,
Vice-President of Research and Product Development

BSRL was organized in January 1958. Corporate executives feel there is little if any time correlation to the October 1957 launching of Sputnik I. (I believe there may have been a significant, indirect relationship.)

The announced objectives of BSRL remain:

"1) Establish a close working relationship with the scientific community so that we, as a company, can appreciate and utilize in a timely fashion scientific discoveries throughout the world."

"2) Produce scientific discoveries that can be applied to products on a current and future basis."

"3) Provide a reserve of special knowledge and skills that will be available to the various engineering organizations of the company on a consulting basis, and that will aid them in undertaking projects in new fields."

2. Facilities

Basic research scientists working in the former engineering laboratories could not get away from product orientation and domination. A facility was needed that would be accessible to and yet isolated from the main stream of company pressures. The facilities planners came from the company developmental and engineering laboratories, and had a very good idea of the facility wanted. Control of the facility design was kept within the company, utilizing architectural consultation instead of vice versa. Authority was delegated along with responsibility for facility construction. The design concept was flexible and developed in close coordination with the key scientists who would utilize the facility. The building was carefully designed for scientific suitability. Alternate proposals were considered for the relation of laboratory to office. The final design incorporated a circumferential ring of individual offices (each with its own window... status symbol?) and a solid interior of laboratories convenient to the individual offices.

The selected geographical location of the building was across the Duwamish River in Seattle and about five minutes drive from the corporate headquarters and main engineering activities. The location alone acts somewhat as a semi-permeable membrane--remote enough to be a buffer but close enough to also be a conductor!

The building, of modern and apparently efficient design, has a floor area of 90,000 square feet, a planned capacity of 170 (research and support) personnel, and cost the company about $2.5 million, or $28 per square foot. (This figure compares favorably with ordinary office capacity where special structural and utility factors are not required.) Company representatives feel the building is outstanding in architecture, cost, and suitability. BSRL began operations in this building in June 1960.

Capital equipment for the laboratory, offices, and supporting activities is presently valued at about $800,000. In addition, all existing company research facilities in the engineering and applied research laboratories are available to BSRL personnel. Capital investment for these facilities has been much more extensive over a long period of time. Boeing executives state that the company research facilities are second to none in the industry. (Lockheed executives say the same thing about their company research facilities.)

3. Organization

The Vice-President of Research has over-all responsibilities for the Products Research Office (a corporate advance planning group) and the Boeing Scientific Research Laboratories (BSRL). He represents BSRL in top management activities. The Director of BSRL reports directly to the Vice-President of Research. The heads of the five research laboratories, of engineering services, and of the administrative section report to the director. The next echelon then is the working scientist in each laboratory. It is significant to note that there are only two echelons of supervision and control separating the working research scientist from top management. In the engineering activities of the company there may be ten or more echelons.

The operating budget controls the size of the organization. Maximum projected personnel level is 170 to 200, with a present staffing of 140. About half are professional members of the scientific research staff (having technical degrees and conducting research). Of the remainder, over half are laboratory technicians, the rest being in Administrative and Engineering Services.

The laboratories vary in size and structure. The head of each laboratory determines its organization and staff. Flight Science is the largest, followed by Solid State Physics. The Solid State Physics Laboratory plans to stabilize with ten senior scientists, ten junior scientists, and ten technicians. The other laboratories are Plasma Physics, Mathematics Research, and Geo-Astrophysics. Laboratory technicians originally were not included in the separate laboratory budgets, but this quickly resulted in overstaffing of technicians. Technicians are now included directly in each laboratory budget. Two scientists per technician is mentioned as a rough planning ratio in the Solid State Physics Laboratory.

The head of each laboratory has authority to hire and fire personnel, subject to the review of the Director. Each laboratory has its own method of recruiting and evaluation. Salary scales are reviewed by the Director, but the laboratories are quite autonomous both in policy and operation. This high degree of professional freedom has been carefully developed. It is jealously guarded throughout the research organization, and is apparently highly effective.

Consultants are hired by the individual laboratory and are charged to its budget. Their main purpose is to "wake up the group" in addition to suggesting new approaches and putting inbred ideas to a professional test.

The Engineering Services Group is unique. It is solely dedicated to serving the scientist, and designs all policies accordingly. It functions as an aid to the research laboratories, and not as a procurement control device. The individual scientists may purchase equipment directly, through Engineering Services, or through the company procurement organization. The cost levels are not disclosed, but apparently there is considerable freedom in equipment purchase. (This particular activity is a severe stumbling block in many research organizations.) Formal administration is kept at an absolute minimum, with considerable awareness of the horror of administration for administration's sake.

All research in BSRL is unclassified and the building is outside any security perimeter. There is a refreshing absence of badges, guards, and sign up rosters. Access and communication are similar to a university (just walk down the hall and knock on the door). BSRL has freedom to decide whether it will set up its own service functions (transportation, janitorial, etc.) or draw on company-wide ones.

The organizational doctrine followed at BSRL could be summed up as: Careful selection of research personnel and maximum freedom in which to operate. It appears to be the case in operation.

4. Budget

Significant comparative budget figures are difficult for an outsider to obtain. The annual operating budget is about $1.6 million (exclusive of amortization of real estate and capital equipment). This indicates a yearly cost of $20,000 to $25,000 per research scientist.

The operating budget, charged from company profit before taxes ($26 to $78 million), is wholly supported by company funds. The extent to which Boeing is reimbursed directly by Air Force general research funds is unavailable but probably is more than 60 per cent. Just how basic research activities figure in this total is unknown to the author, although it is speculated that the Air Force does support a significant amount indirectly.

The BSRL budget is included in the annual company funded R and D budget request and is derived in the standard method: the head of each laboratory estimates his total operating budget for the coming fiscal year and submits it to the Director. The Director and laboratory heads meet and thrash out levels of participation on the basis of estimated funding. Top management finally determines this funding. The significant thing here is that a Vice-President represents BSRL during top management budget negotiations.

Apparently the laboratory heads can make major changes in the expenditure of their allotted budgets with little justification necessary. They do submit monthly operating costs and these are compiled and transmitted to the Vice-President of Research. It appears, however, that the financial control groups so prevalent in other Boeing operating accounts do not directly monitor (control) the BSRL expenditures. The financial reporting procedures of BSRL are much less formalized as long as they remain within allocated budgets. These simplified accounting procedures greatly aid in establishing a sound research environment.

The size of the BSRL budget deserves comment. BSRL is wholly supported by company funds and accepts no contracts for the conduct of basic research. The basic consideration is apparently to operate at a level that will allow stability from profit, government, and stockholder influence. Laboratory personnel feel that 5 per cent of the net income before taxes is the upper limit of such stability, with 1 per cent to 2 per cent a better figure. The relative stability and continuity of the BSRL budget is of great importance. General discussion of this problem follows in a later section.

5. Personnel

The Boeing Vice-President of Engineering describes BSRL as being somewhat product oriented. The quality of scientific personnel is recognized as the most important factor in staffing BSRL, and considerable management attention is directed toward this end. Research scientists are selected on the basis of competence and interest in contributing research in areas of general company interest (such as fluid mechanics, solid state physics, etc.). By careful selection of individuals, it is felt that research will be relevant to company activity and yet not constrained by company directives. Previous close professional association with a prospective scientific employee is the rule followed in hiring whenever it is possible.

The Director of BSRL (G. L. Hollingsworth) describes himself as "an electrical engineer who's hung around physicists for so long that some of it has rubbed off". He is a long-time Boeing employee, experienced in many areas of basic and applied research and the corresponding requirements and problems. He has the confidence and direct support of top management.

The head of each of the scientific research laboratories was selected on the basis of professional competence and interest in an area relevant to company interest. The laboratory heads then used their own methods and judgment in recruiting their professional and technical research personnel. Laboratory policy varied considerably. One laboratory (solid state physics) requires a detailed written research proposal from prospective applicants. This proposal is requested and obtained prior to any salary offers. It is a detailed statement of proposed research that the applicant plans to conduct, related activities and equipment, and possible results. The proposal is intended to screen out the less serious contenders, and allows the laboratory head to observe in some detail the interest, initiative, and anticipated work of the scientific research applicant. The physics laboratory head states that he gets fewer applications but far more serious and capable scientists in this manner. Other laboratories at BSRL have entirely different hiring policies. The salary levels (or offers) are reviewed by the Director prior to submittal if they are above a certain level. (I did not find out what level.)

At the end of 1960 there were 60 professional research scientists on the BSRL staff, about half classed as theoreticians and half experimentalists. Fifteen of the 60 were in Boeing's employ prior to 1958, when BSRL began independent operations. Of the remainder, about half came from universities and the rest from other organizations and the government. The average salary of the 60 professional scientists is estimated at about $12,000. This is considerably higher (about 20 per cent) than the rest of the 8,000 professional R and D personnel at Boeing.

6. Operation

BSRL is new and still in a transitory state of development. The staff has increased from 15 initially in 1958, to 120 in August 1960, to 140 in December 1960. The working environment has been characterized by change, which is unsettling to basic research. These changes, however, have been toward a much better research environment, and conditions are beginning to stabilize.

The product of BSRL consists of technical publications, consultation, and liaison with the scientific community. No individual "publishing norms" are required, the attitude depending on the head of each laboratory. Top management does not appear anxious for BSRL to "justify itself". Boeing top management describes itself as being "engineering oriented". All the vice-presidents are long-time company men with considerable experience in applied engineering and research. That basic research is a different animal seems to be recognized, possibly because of the strong personality of its chief management advocates. It is significant to speculate that a "prove your worth" attitude toward BSRL is not evident at the upper management levels.

In the lower supervisory and engineering organizations of the company, this author detected considerable ill will and outright antagonism toward BSRL. The excellent facility, working conditions, salaries, and offices are of some concern. Some lower level ($12, 000 - $15, 000) supervisors have a negative attitude toward BSRL and the whole spectrum of industrial basic research. The main causes of friction seem to be (1) the superior working environment provided for the BSRL scientist, compared to his salary contemporary in other company activities; (2) the feeling that BSRL does little to bring business and financial profit to the company and is in fact an unnecessary expenditure of such profits; (3) the superior attitude some BSRL employees display toward the rest of the company; (4) the freedom of working conditions, hours, and environment; (5) lack of knowledge by BSRL scientists about other corporate activities. Other causes could also be cited and substantiated. The higher salary averages and prestige at BSRL are significant factors. This situation, then, is creating undercurrents in morale and attitude that may significantly affect the BSRL operation. Since Boeing promotes primarily from its own junior management, the dissenters of today may gain an increasing voice in corporate affairs. It appears this will create a demand for "justification of expenditures" and "proof of profitable research contributions" from BSRL. Sound basic research will be difficult if the above situation or trend (which I consider to be the natural one) is allowed to develop.

The BSRL management is keenly aware of the frictional and justificational problem areas. The Director acts as the primary outside representative for BSRL, and his record in the company is respected. The two Boeing vice-presidents, who are organizationally responsible for BSRL, are strong advocates of basic research and its institutional environment. The existing facility and research environment support the opinion that they have been highly effective in "research orienting" the present top management. Top management changes slowly as a rule, but the exception appears to be coming within the entire aircraft industry. Most of the established managers have proved their outstanding abilities in the aircraft industry, and have grown in stature, authority, and age, as the industry has grown. Two factors now appear: (1) a large proportion of top management is reaching retirement age; (2) the developing aerospace industry may be considerably different from the past aircraft industry, requiring more current and more diversified top management experience. The very formidable task that BSRL leaders and scientists must contend with is that of changing top management along with all the pressures of financial and product orientation.

The head of one BSRL laboratory feels that present Boeing top management is about equally divided in terms of attitude toward scientific research. The stronger personalities have prevailed to bring about the present conditions. That the scientists' professional futures rest on the intangible personality balance of future top management is a cause for considerable speculation, worry, and action. Many BSRL personnel are actively working to extend the scientific viewpoint, but it is much too early to anticipate real results.

Consulting is a primary means of professional contact and communication between BSRL and other company research and engineering activities. BSRL scientists are encouraged to consult within the company up to 20 per cent of their time. Consulting, though a prime organizational objective of BSRL, remains indeterminate. Demand varies widely for the individual scientist, with the BSRL man-hours presently devoted to consulting being well under 20 per cent for the over-all group. In a mutually competitive environment, many company organizations may be unwilling to request BSRL consulting aid in view of the relative recognition of status involved, etc. Such consultation, once solicited, may be subject to an extremely critical evaluation. One mediocre effort for any reason may result in no further relationships between working groups. I believe that such consulting problems, though somewhat petty, may significantly affect the establishment of BSRL. The engineering and developmental groups at Boeing are encouraged to use established channels of authority in requesting consultants from BSRL. Experience has indicated that such requests are of sounder technical necessity than those informally solicited. In this system, however, the shadows of group competence and prestige are subject to some critical analysis, and for this reason formal consultation requests may not be forwarded to BSRL. If (as I suppose) consultation is to play a significant part in the establishment of BSRL, a more satisfactory consulting relationship must be found.

It appears that the answer may involve some efforts on the part of the scientists to contact the working developmental groups, etc., instead of vice versa. The head of at least one BSRL laboratory is emphasizing this basic attitude toward consulting activity. Human nature constitutes the principal foe, since it is more likely for the individual scientist to appreciate the professional recognition involved in a request for his services, than for him to bother with offering his services personally on a "what can I do for you" basis. Also, the latter necessarily involves some wasted time, and futile effort on insignificant problems. The mutual contact, professional acquaintance, and company knowledge gained by the scientist for such leg work, in addition to the favorable impression created, may far outweigh the negative aspects. It appears to be a formidable managerial problem. In the free scientific environment, the individual working scientist must recognize his relationship to the rest of the company as well as to his own scientific discipline, and skillful leadership will be required to bring about such recognition and corresponding activity. There is evidence of such leadership in some groups at BSRL, although it appears to be notably lacking in others.

The BSRL scientist is not required to meet a formal working schedule. It is expected that he will be interested enough in his research to make working hours requirements unnecessary. The working environment has been kept as free from restrictions as is possible, and BSRL personnel realize the importance of maintaining personal discipline in order to avoid easily generated criticism. The senior scientists are fastidious guardians of their environmental freedoms.

Within BSRL, the principal point of concern is how to maintain the environmental freedom presently practiced. One senior scientist said he had observed no interference by higher administration to any degree in the scientific research programs at BSRL during the nearly two years he had worked there. He further stated that budgets were adequate and that capital equipment, though somewhat sparse, was being accumulated sufficiently to support the research activities. The big problem, stated several ways, was: "Privileges not in writing"; "nobody guarantees continued status and freedom from controls"; "status not established"; "who gets upper hand in top management determines policy", etc. That almost every scientist queried as to the principal BSRL weakness replied concerning the "transitory status" is highly significant. Some stated that Bell Laboratories and General Electric were the only successful production industry basic research ventures, and that most others, no matter how bright for a time, were only transitory and diminished into the research oblivion of strong product pressure and orientation. On the basis of this study, I agree with this concern about "transitory status", and believe that recognition of the problem by the scientific research personnel involved may be a major step in its resolution.

7. Publication

The immediate product of basic research is the technical paper or other publication of research results. These results may be presented at technical meetings, through periodicals and magazines, or through formal or informal circulation to organizations and scientific associates. As in university and nonprofit research organizations, this is the apparent product of BSRL. No publishing norms were mentioned, the determination resting with the head of each laboratory. The procedure for review and publication is similar to that of a university. The individual author prepares his paper with his working associates, and gains informal approval from the head of his laboratory. Written reports are not edited by higher supervisors and in only one case did a conflict arise between the author and his immediate supervisor that required resolution by the Director of BSRL.

The heads of the laboratories use their own judgment, the reaction of the author's scientific peers, and occasionally outside consultants to qualitatively evaluate research results. This problem of evaluation, common to all basic research results, is very comparable to university publications in overtones of individual group and organizational prestige. The corporate reputation is just one more arena of competition.

BSRL publishes a semi-annual Progress Review which abstracts all research reports published during the review period, and briefly describes research being conducted. The Progress Review is distributed widely to government, university, and industrial technical libraries.

The individual research author initially distributes his work through his peers and associates, and later in response to specific requests arising from distribution of the Progress Review. This method of distribution allows BSRL to gauge the impact of the research and, by monitoring demand, to locate groups and individuals with similar fields of interest. It serves as both an evaluation and communication device. In practice, about 200 - 300 copies of each report are distributed, with about one-quarter of the total within Boeing. In reply to direct questioning, no instances were cited where publication of basic research results was delayed due to potential product application and hence business economics. The "Not Invented Here" (NIH) philosophy was cited as sufficient to protect company interests, the thought being that even potentially useful information would be slowly and reluctantly adopted by competitors, since their managements might draw some disruptive comparisons in relative research competence! Also, the time and difficulty of creating a similar competing activity "protects" the originator, as does the fact that good results are evaluated by his peers who in this case are not only his professional but also business competitors.

Patent policy was mentioned several times as an illustration of the liberal Boeing management attitude toward the creative scientist and his research. The company will process a patent if it appears promising, or will aid the applicant in obtaining his own patent. Either way the applicant submits his proposal to the Patent Engineer and his staff for review and coordination. If the company decides to file a patent, it pays the developer 20 per cent of the gross return to Boeing of any licensing. There are some notorious examples of the company's failure to appreciate promising proposals that resulted in significant profit for outside agencies, but in general scientific personnel believe the Boeing patent policy supports them more liberally than that of any other aircraft company. It was suggested that patent policy might be a good indication of management attitude toward research. I was unable to follow up this suggestion due to time and scope restrictions.

8. Personnel Evaluation

This topic in the final analysis may well determine the outcome of BSRL's "transitory status". In any basic research environment it is complicated, inexact, and often intangible. At BSRL, the heads of the laboratories determine the company evaluation of scientific personnel. They use the reaction of peers and scientific colleagues primarily, although I speculate that their personal judgment is at least of equal importance if not dominant. Outside consultants also may be utilized, with or without their knowledge, for evaluation of researchers. Demand for the individual as a consultant, both within and outside Boeing, may also be an indicator. The reputation, number of publications, university affiliation and degree of an individual prior to his BSRL employment may be highly significant. In short, all the complexities of personnel evaluation compounded by the pressures of industry and the unique nature of basic research work combine to make accurate evaluation very difficult.

BSRL supervisors write a semi-annual performance description which is normally read to the individual by the evaluating supervisor. As in the military, this easily becomes a contest in composition of flowery phrases and praises. The significant rating is quite distinct and separate. It is a semi-annual rating in terms of value to the company, of all individuals under each supervisor, and takes place throughout the company at the middle executive levels and below (in the case of BSRL, the laboratory level). Employees in similar activities under a supervisor are arranged in order of metit, from first to last, and their corresponding salary is indicated (called "Totem Pole Rating"). Salary reviews are based primarily on this evaluation and not on the written performance report. The percentage varies, as does the procedure, but supervisors generally can adjust and raise the salaries of their employees by about 2 per cent to 4 per cent of the group total. In some groups this merit raise system is fairly automatic and not necessarily related to merit. In others it is used as a major management tool. First, discrepancies between relative merit rating and salaries are adjusted (upward only). In a fairly stable situation, the people in the bottom half get no raise, the top 10 per cent get a 10 per cent raise, and the next 20 per cent get an 8 per cent raise. There is no fixed policy. In any case, nearly all supervisors and scientists receive raises at less than the average rate for engineering personnel. It is stated that in about 3 to 5 year cycles the supervisory and scientific personnel receive a large boost to regain relative position. There is a professional union, Society of Professional Engineers and Architects (SPEA), that represents engineers in salary negotiations. Three per cent per year plus merit increases is the going rate for professional engineers, which is better than that for scientists. The scientists may advance organizationally (i.e., from junior to senior scientist) where the engineer for a comparable increase must become a supervisor, a promotion subject to more age, personality, and numerical constraints. It should also be pointed out that both scientists and engineers are well treated at Boeing, and that considerable company loyalty exists.

GENERAL DYNAMICS CORPORATION (CONVAIR)

General Dynamics has eight diversified operating divisions:

(1) Convair is by far the largest, and is extensively engaged in the research, development, manufacture, and operation of aerospace products. Convair accounts for an estimated 75 per cent of General Dynamics sales.

(2) Canadair, Ltd., a subsidary, makes the CL-44 turboprop cargo plane and other aircraft and parts. It is the largest builder of aircraft in Canada.

(3) Electric Boat is the leading manufacturer of submarines in the U.S., and is presently the primary source of nuclear submarines.

(4) Stromberg-Carlson produces a widely diversified line of electronic and communications equipment for industrial, commercial, and military use.

(5) Material Service, a recently acquired company, makes and distributes building materials primarily in the Chicago area.

(6) Liquid Carbonic is the foremost producer of carbon dioxide and produces other gases and chemicals.

(7) General Atomic is engaged in research and development of military and commercial applications of nuclear energy.

(8) Electro-Dynamics produces motors and generators.

Convair has four operating divisions: Convair San Diego, where the F-106 interceptor and 880 and 990 jet transports are manufactured; Convair Astronautics (suburbs of San Diego), where the Atlas missile and related equipment are manufactured; Convair Pomona, where the Terrier and Mauler air defense missiles are manufactured, and

<u>Convair Forth Worth,</u> where the B-58 and B-36 were developed and produced. Convair is geographically decentralized with operating divisions producing somewhat similar products. The corporate management (General Offices in San Diego) exercises a moderate degree of centralized control over the operating divisions. There is some concern in preventing excessive duplication of effort since more than one operating division is often active in a particular research area. This brings the general offices into a coordinating and monitoring role at a fairly low level. One major concern of the Convair management is to allocate funds for research in the most effective manner. There is a natural tendency for each division to maintain some capability in all technical fields relating to its product area. In addition to duplication, the resulting dilution of funds among several groups of varying competence and composition is recognized as a management problem. There is an effort to concentrate particular technical activity within one division where possible, so that it can be fully and adequately supported, rather than allow it to develop fractionally with marginal funding in more than one division.

After considering the advantages of concentrating technical capability within the existing corporate structure, the Convair management decided to form a basic research organization at the corporation level so that all of the operating divisions could draw on its available capacity for consulting and scientific research. It was thought that a basic research group would consolidate considerable activity already under way in the operating divisions, and that the resulting environment would improve the quality and availability of scientific effort. This program was implemented in 1956.

Much technical research of a basic nature still takes place in technical groups located within the operating divisions. One prominent and highly productive group doing considerable basic as well as long range applied research is the Physics Section, in the engineering department of Convair San Diego. Major source of funds is from contracts and this fact implies a strong product relationship. Many of the contracts are of such a fundamental nature that lines of definition between basic and applied research are obscure. The major point here is that these technical groups seek and solicit basic research contracts in addition to their primary activity of applied research support for their operating division.

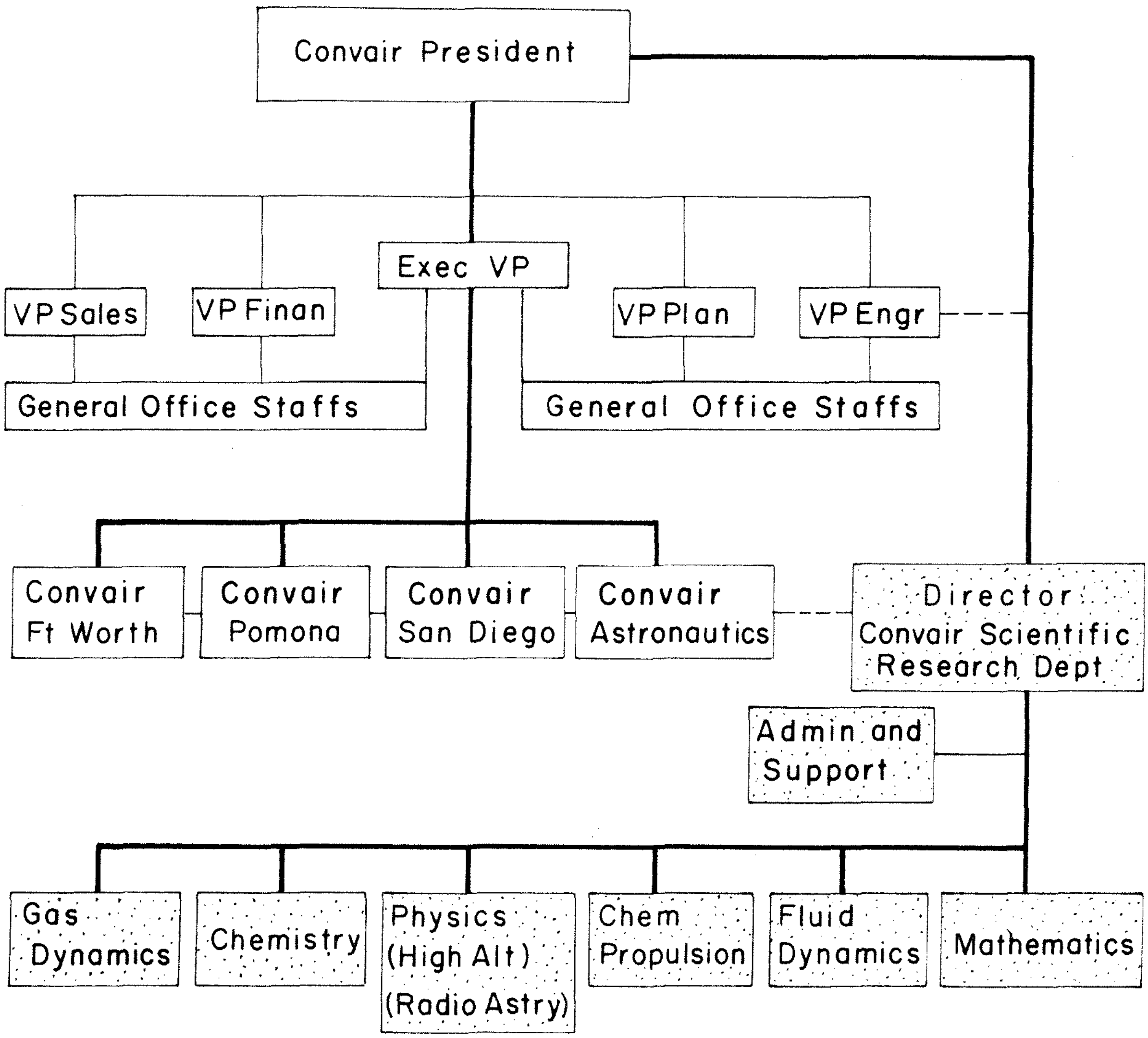

FIG. 13 — ORGANIZATION OF CONVAIR SCIENTIFIC RESEARCH DEPARTMENT

Convair Scientific Research Department (CSRD)

1. Origin and Purpose

Planning for the organization of a corporate basic research organization began in 1955. At this time, Convair was extensively engaged in the Atlas missile program, as well as in the F-102, F-106, and B-58 development projects. The Atlas program brought a new set of requirements to the company. Experienced technical personnel with knowledge of missile systems were scarce, both inside and outside the company. About this time considerable criticism was brought to bear on Convair for the technical conduct of the Atlas program, and the Air Force decided that Convair did not have sufficient technical capability within its own organization to conduct the development program soundly. National political and military pressures forced the Convair management to re-evaluate their own technical and scientific capabilities. It was in this critical but financially prosperous environment that the Convair Scientific Research Department was planned and initiated.

"The program for CSRD was planned in detail in 1955 and, upon approval by Convair's Policy Council and President, was implemented in strength in 1956. It was envisioned that scientific research would be supported by Convair in three ways by this program:

1) By staffing and equipping a Convair Scientific Research Laboratory
2) By sponsoring research by individuals within the operating divisions of Convair, and
3) By awarding research contracts outside of Convair."

The program has been vigorously established in all three areas, and continues with little change in basic purpose. "Scientific Research" as defined by the Convair management, "consists of the investigation of natural phenomena with the objective of discovering and understanding the underlying physical laws".

2. Facilities

The Convair Scientific Research Laboratory is located within the Engineering Laboratories Building of the Convair Astronautics Division at Kearny Mesa, about 20 minutes drive from the Convair General Offices (headquarters) in San Diego. The parent Convair Astronautics facility was built for the Atlas missile project at a cost of $40 million; the company provided $20 million for the physical plant and the U.S.A.F. matched this sum with $20 million for research and production equipment. The Convair Scientific Research Laboratory occupies some 22,000 square feet of laboratory and office space, and research facilities and equipment have been continuously developed since 1958. In addition, very extensive research and computing equipment of the Convair Astronautics Division is immediately available to CSRL scientists on a rental-use basis.

The CSRL facility was not built or tailored to its present use. Some inconvenience has resulted in both administration and operation. Since it is within the strict security perimeter of the Astronautics Division, access restriction has plagued staff personnel and consultants until recently, when security requirements were specifically liberalized for CSRL activities. The close proximity to development research and engineering acts as a source both of friction and of contact and communication. The resulting environment is reasonably well suited to basic research and enjoys advantages in equipment and communication.

3. Organization

The Convair Scientific Research Department is a corporate organization within the General Offices. The Director of CSRD has responsibility for the three areas of corporate basic research activity, and reports directly to both the Convair President and the Vice-President, Engineering. It is the only operating group in the company with direct line contact to the president, and as such is well represented.

The operating budget controls the size of the Convair Scientific Research Laboratory, which has stabilized at 60 people. Of this number over 40 are professionals of whom about 20 are Ph.D.'s. The laboratory effort is organized according to the background and interests of Senior Scientists as: Gas Dynamics (3); Chemistry (9); Physics - including high altitude radiation and radio astronomy (15); Chemical Physics - propulsion (7); Fluid Dynamics (13); and Mathematics (3). The individual laboratories are supported by an administrative group (10), and by shop, electronics instrumentation, materials procurement, and equipment specialists.

The Director of CSRD plays an active role in determining the operating procedures of the research laboratories. Due to the relatively small size of his organization, he participates extensively in decisions at the operating level. The laboratories are not autonomous, but this does not imply unnecessary constraints. The small size of the organization simplifies management, and the Convair Scientific Research Laboratory has served as a model for subsequent research organizations in other aircraft companies.

The Director of CSRD also allocates funds for projects of a basic nature to the four operating divisions, and to universities and nonprofit research organizations on a contract basis. The Convair operating divisions submit requests for basic research support with their annual budgets. If approved, such research may proceed either in the requesting division or in CSRL depending upon the situation.

4. Budget

The Convair Scientific Research Department budget is included annually in the corporate research budget. The operating budget for 1960 ($1.6 million) was 10 per cent less than requested as a result of an across-the-board reduction in the overall corporate research budget by that percentage. It is highly significant that the basic research activity did not bear a heavier percentage cut than applied and development sectors of research. Of the $1.6 million CSRD operating budget, all but $37,000 was company funded out of profit before taxes. The extent to which Convair is reimbursed by Department of Defense General Research Funds is not disclosed, but a 70 per cent figure is an informal guess for basic research overhead reimbursements. The $37,000 in outside funds included an unsolicited $10,000 AEC contract and a request for ONR support for $27,000 out of the $200,000 allocated to company-funded radio astronomy activity. $350,000, or about 22 per cent of the CSRD budget, was assigned to the four Convair operating divisions and to outside agencies for scientific research support.

The apparent cost per professional research scientist in CSRL is about $30,000, with $22,000 mentioned as the cost per year per person including administrative and technical supporting personnel.

Formal accounting controls are sparingly used to monitor CSRL expenditures, as long as budget allocations are not exceeded. The Director keeps a running monthly record of expenditure, and is consulted when new or unanticipated expenditures develop. The small size of the organization reduces requirements for formal reporting, as does the significant fact that the Director reports directly to the Convair President.

5. Personnel

The basic research program at Convair places its faith in the research capabilities of individuals. The projects chosen for sponsorship are based upon the experience and training of the principal investigator or investigators, and considerable freedom in project selection is apparent. It appears that CSRL is not a scientific end in itself, but rather a flexible scientific organization whose interests and activity depend on the particular group of practicing scientists at any given time. Strong attention is paid to the documented qualifications of the individual, the best men available being hired on this basis even if they are not necessarily working in areas of existing CSRD activity. Research relevance to company interest and activity is certainly considered, but I believe individual qualification to be the dominant factor. In any case, the two are not mutually exclusive, and a flexible policy exists.

The Director of Convair Scientific Research Department (Dr. J. C. Clark) is a physicist and was former director of over fifty U. S. atomic bomb tests prior to being brought to Convair to assist in formulating countdown techniques for the Atlas. When this work terminated, he was retained as a research advisor. He replaced Dr. Critchfield, the former director and prominent scientist under whose direction CSRD was planned and established.

Prominent outside consultants are frequently utilized by Convair. The Convair Scientific Consultants Board, composed of about twenty of the most outstanding men in American science, meets once a year to consider broad questions of corporate interest and scientific activity. In addition, these well known consultants are available to the divisions from time to time upon request to lend advice on recent scientific developments, suggest policy measures, review research, and give detailed counsel on work in their field. The CSRD makes some use of these consultants when available, and other consultants are extensively used. In addition to their usual "problem solving" and "fresh approach" uses, consultants are used to check and evaluate the activities of regularly assigned research personnel. Some consultants are hired on a yearly retainer, but most are under contract for per diem consulting work. The CSRD yearly expenditure for consultants varies between about $10, 000 and $15, 000. The Convair General Offices hire and fund the much more extensive corporate consultant program and the Convair Scientific Consultants Board.

6. Operation

The principal operating characteristics of CSRL are simplicity and flexibility due to small size. Formal operating requirements are kept at a minimum. Each senior scientist submits a monthly progress report on his particular area of technical responsibility. This is the primary administrative mechanism between the researcher and management. The CSRD Director has an office both at the Laboratory and at the corporate headquarters. The nature of his management and executive responsibilities requires his presence at the corporate General Offices most of the time. His administrative assistant and the rest of the CSRD supporting staff are housed in the laboratory complex. The immediate proximity of the Convair Astronautics research and production facilities and personnel creates a natural avenue of contact and communication between the preliminary design engineers and the CSRL research scientists. As a result, considerable consulting and technical assistance between these groups is expected.

As previously mentioned, administrative norms are not in evidence at CSRD. A publication output of one paper per year is mentioned as a desirable goal, but so far cases are judged on their individual merit. Considerably less "brochuremanship" was encountered at CSRD, compared to some other company activities.

It seems to this author that the reasons for establishing CSRD are more evident than are its present goals and purposes. Possibly basic research is enhanced in this way, but I believe that a more definitive operating objective within the corporate structure would benefit CSRD. This need not imply unnecessary constraints on the scientific freedom of the researchers. I had the impression, to some extent, that the researchers were somewhat isolated from their disciplinary peers due to the small size and physical location of CSRL. The major advantages of small size in creating a desirable working environment may be somewhat offset by this situation if it in fact exists. Also, the advantage of operating directly under the Convair President may be reduced somewhat by the fact that few other managers will be in contact with CSRD and hence a balance in attitude of top management may not develop. New Convair Presidents are likely to have had little previous experience or contact with CSRD, and its status could be dependent on the President's individual view of basic research.

DOUGLAS AIRCRAFT COMPANY

The Douglas Aircraft Company has several major operating divisions. The principal division and corporate headquarters are located in Santa Monica. The Santa Monica Division including the Missile and Space Engineering Center, located in Culver City , in addition to operating extensive laboratory facilities, is developing the Skybolt missile, the S-IV stage for the Saturn program, the Douglas-built Caravelle jet transport, and the Nike-Zeus missile. The Long Beach Division produces the DC-8. The El Segundo Division produces the A4D series of aircraft, and administers the Douglas Aerophysics Laboratory. The Tulsa Division conducts modification, overhaul, and repair of aircraft and missiles. The Charlotte Division, (North Carolina), manages the production of the Nike series of air defense missiles, and an improved Honest John tactical missile. Other company activities include the Product Support Division (employing 3,000 with sales of $170 million), and a recently organized subsidiary, Astropower, Inc., formed to conduct research and development in advanced propulsion systems and power equipment. In 1960 the company's interest in Data Graphic System, Inc., formerly owned jointly with General Analine and Film Corporation, was sold in order to direct diversification efforts into fields more directly utilizing the company's skills and experience.

The 1960 Douglas total sales of $1.174 billion were divided into three major categories: military aircraft - $307 million (26 per cent); missile and space activities - $319 million (27 per cent); and commercial aircraft - $548 million (47 per cent). Extensive deliveries of DC-8 jet transports caused commercial business briefly to dominate company sales that have traditionally been about 80 per cent military and government. A net loss of $33.8 million in 1959, and $19.4 million in 1960 were reported, due to the high costs involved in developing and producing the DC-8.

In 1960 military and government sales declined to $626 million from $779 million in 1959. This decline was attributed largely to the phasing out of the Thor IRBM and to a reduced level of activity in the Nike-Hercules missile program. The recent cancellation of the Missileer long-range air defense aircraft and the doubtful status of the Nike-Zeus further complicate the company's financial position. Top management stated recently that "After two of the most difficult years in our corporate history, darkened by substantial losses, ... there is encouraging evidence that the company is moving steadily along the route to recovery".

The backlog of government orders at the end of 1960 was $747 million, with missile and space activities accounting for 72 per cent compared to 42 per cent in 1959. Work presently in progress includes the development of the second stage liquid hydrogen-oxygen booster (S-IV) for the Saturn program, a re-emphasized Skybolt air-launched ballistic missile program, development activity on the Nike-Zeus anti-missile system (which could expand rapidly into the nation's largest program), production and further development of the A4D series of naval attack aircraft, and extensive engineering and development activities.

The history of research activity at Douglas is difficult to summarize. For many years, Douglas was considered the strongest and most prosperous of the major aircraft companies. In the mid-1950's, Douglas business was booming while other major aircraft producers were realizing lesser returns. About the time that other aircraft companies were searching for new sources of income, Douglas was fully engaged in engineering and production runs of modern military and commercial equipment. The decline in this traditional source of activity and profit did not immediately affect Douglas, since the company's engineering and production facilities were fully engaged. Douglas management decided to specialize in engineering and production skill, while other companies were diversifying and increasing their research activities. Douglas was also extensively engaged in applied research and development, but the company policy was directed toward engineering excellence in applying research gains to product and production applications.

As military requirements changed, the time between early research and final weapons system diminished and more engineering and research effort (at substantially higher cost) was required in a shorter time. This decreasing time span forced research and production together with the result that companies had to engage extensively in research in order to compete successfully for engineering and production contracts. This situation, coupled with the recently increasing trend of awarding contracts on preliminary design rather than prototype competition, tended to favor research capability and prestige over engineering competence. Also, as the technological pace of activity broadened and accelerated, available research information became much less adequate for engineering purposes. In this newly developing set of circumstances, Douglas was probably later than its competitors in sufficiently adapting to the broadened research requirements.

In 1960 Douglas was listed as eighth among the 500 leading companies in total contracted research and development sales to the Department of Defense, so conclusions relating relative research activity and competitive success are difficult to substantiate. The fact that management favored engineering excellence does not exclude extensive research activity, particularly in areas closely related to development and testing. Of more significance may be the unfortunate fact that several recent important weapon system contract competitions won by Douglas have failed to develop as anticipated due to changing military, technical, and political conditions.

Research at Douglas

The organization and evaluation of research activities at Douglas have recently been changed to allow a more exact analysis of company activities and expenditures. Research is divided into contract-supported and independent (company funded) categories. Contracts are actively sought in all research areas as a source of profit and of support for broadened scientific activities. The independent research budget, funded out of net profits before taxes, will be discussed in detail.

The Department of Defense, based on technical evaluation and negotiations, supports the Douglas independent research budget with funds on a yearly basis. The amount and percentage of support vary. (In the past, 55 per cent to 80 per cent of the independent "company funded" research budget has been directly provided by the Department of Defense.) These funds are not specified as to immediate purpose, and are independent to the extent that the company, within the broad estimates provided as a basis for the negotiations, determines where and how the money will be used. Research capability, (evaluated by the Office of Naval Research for the Department of Defense in 1960 and based on past performance, technical level of personnel, relevance of activities, and other factors) determines the amount of money provided. These funds are extensively used to support advanced research activities that are necessary but not immediately profitable, and to maintain a broadened scope of technical competence to keep pace with "state of the art" and basic research advances not occurring within the company.

The independent research program is divided into basic research, applied research, development, and proposal activities. The budget is derived in the corporate headquarters. Requests for funding are received from the operating organizations, divided into the four categories, and are considered in the light of probable company interest. Expected business conditions and Department of Defense support determine the total allowable budget. If the company expects to have $1 billion in sales, about 10 per cent ($100 million) will be research and engineering development activity. About 10 per cent of this amount (i.e., $10 million) will be required to support and extend the remaining $90 million of contract supported activity. This $10 million then becomes the rough planning figure for the independent research budget. This budget has primarily developed in the last three of four years, to allow for rapidly expanding technical requirements. Of this $10 million independent budget, about 30 per cent is spent on engineering and development (work that leads to models and equipment not yet determined), about 20 per cent is spent on proposals (work on specific preliminary projects and programs); about 40 per cent is spent on applied research, and the remaining 10 per cent ($1 million) is allocated for basic research. The proposed 1961 independent research budget allows $6.8 million for applied research, $4 million for development, and $580,000 for basic research. Less than 5 per cent ($300,000 to $400,000) of past independent research budgets have actually been used for basic research, since more urgent activities have drawn away both the funds and the research scientists.

Basic research at Douglas has been conducted as a modest part of activities in the company research and engineering development laboratories. There are 74 separate laboratories, (if subject matter is different enough to require a separate supervisor, then the group activity is known as a laboratory), over half being in the Santa Monica Division. The laboratories are staffed with 1,300 people, occupy 600,000 square feet of floor space, and have about $65 million in capital equipment. Until recently, basic research was done when good people happened to be available, and very little corporate attention was paid to these activities. The Chief Engineer, with line supervision over the particular research laboratory, determined the extent and nature of scientific activity. In this highly variable situation, some excellent basic research was accomplished. The top management technique applied to basic research (ignore), though adequate for a modest level of activity, was not suited to a rapidly increasing emphasis on basic research. Hence, a corporate basic research director was appointed in 1960 to study, improve, and expand existing activities. One immediate result was that basic research requests, formerly an integral part of the engineering budget, were considered and supported directly through the Director of Advanced Planning (Director of Basic Research). Also, active planning was begun for a new corporate basic research facility.

The Douglas Scientific Research Laboratory (Proposed)

"Scientific research, both basic and applied, is an essential element in support of the company's engineering and manufacturing functions. Perhaps the most important move in this field during the year (1960) was the decision to establish a separate laboratory for basic research. The laboratory is expected to conduct fundamental research aimed at discovering new scientific knowledge so necessary to the maintenance of a leading position in the highly technical aerospace industry.

The additional laboratory will have a staff of 80 to 100 scientists and will occupy an area of approximately 40,000 square feet. Fundamental research will take place in those branches of science generally allied to the company's current and forward-looking fields of interest, such as physics of materials, gas dynamics, plasma physics, geo-astrophysics, and nuclear physics. Its findings, and the availability of its staff for consultation, will supplement the existing applied research laboratories which presently employ a staff of nearly 1,000 in an area of 350,000 square feet of laboratory facilities."

--From the 1960 Douglas Annual Report

The proposed scientific research laboratory is designed to add new technical competence to the company, rather than to consolidate existing basic research activity. Planning is directed to avoid the transfer of existing activities to the new laboratory, since it is additional and increased basic research activity that is sought. The implementation of the plan is two to four years away, and detailed architectural drawings are not yet formulated.

1. The Scientific Directorate

The company is taking steps to form a new group, known as the Scientific Directorate, that is scheduled to begin operating in May 1961. It will be composed of eight of the most eminent* men of contemporary American science. The Scientific Directorate will operate at the top management level of corporate headquarters, and will meet periodically as a committee to recommend policy related to the company's general scientific activity. It is expected to provide guidance in formulating and implementing the plan for the new scientific laboratory, and to assist in the selection of a competent director and scientific research staff.

2. The Research Staff

Present planning estimates for the Douglas Scientific Research Laboratory indicate a research staff of about 100 people, composed of a director and associate director, 5 branch (laboratory) chiefs and their assistants, an engineering services manager, 40 - 50 Ph.D.'s, about 40 assistants from the company engineering laboratories and departments, and about 100 people in administrative support. A director with the following qualifications is sought: 1) old enough to have experience and an established reputation (probably early forties); 2) Ph.D. degree; 3) broadest possible experience and reputation in fields of company interest; 4) some experience in a technical role with the U. S. government. The latter qualification is stressed since 80 per cent of Douglas business is traditionally conducted with agencies

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* Standing out clearly; evident; notable. Distinguished as being above others, whether by birth, high station, merit, talent, or virtue.

--Webster

of the government, and there is a need for the company to keep plans and thinking closely allied with future government needs.

A permanent professional research staff of about 50 young Ph.D.'s is sought. The company expects these scientists to grow into the research laboratory activity, and hopes to select branch chiefs and associate branch chiefs mostly from this source on the basis of their ability and performance. Management has carefully shunned commitments to presently employed scientific personnel, in order to avoid saddling the new laboratory director with previous obligations.

The proposal to use 40 to 50 young research assistants from the company engineering and applied research activities is unique. The plan is to pick out young engineers who have scientific training and inclination, and to assign them as "graduate students" to the professional research scientists for instruction and education. These assistants will remain in the Scientific Research Laboratory for one to three years, without a permanent position, and then recirculate back to the engineering activities. It is planned to upgrade the engineering departments technically and provide ready communication of technical results in this way. Also, the possibility of union trouble arising from the use of laboratory technicians is avoided. The temporary status of the research assistants is emphasized to avoid the gradual deterioration of technical prestige which might result if engineers diluted the ranks of the laboratory Ph.D. scientists. The proposal for engineering assistants has considerable merit if it is workable. Severe difficulties may be expected in establishing the delicate working relationships necessary to the successful operation of such a plan.

3. Organization

It is proposed that the Director of DSRL will report directly to the Vice-President of Engineering, (the closest corporate office to the president). The Scientific Directorate will act as senior staff advisors to the top management. The Director of Advance Planning, who is presently also the acting director of basic research, will occupy a position parallel to that of the Director of DSRL. The exact working relationship which evolves is dependent on the personalities involved, with the two offices roughly on a balancing level.

The Douglas Scientific Research Laboratory will have four or five branches (laboratories) with the branch chiefs reporting to the Director. The proposed branches are: 1) Materials, 2) Gas Dynamics, 3) Space Physics, 4) Propulsion, and 5) Communications. It is emphasized that the scientists who are available will determine the exact areas of technical activity within the broad range of company interest, and not vice versa. The composition of the branches is expected to evolve with time, and no forced pattern is planned. No mathematics research group is proposed. The difficulty involved in finding highly competent research mathematicians who are willing to work in an industrial environment is considerable. The Douglas management believes that mathematics research can be done more successfully in the universities, and plans the continued use of consultants in this area.

The Engineering Services section will support the technical program by operating a machine shop, glass blowing shop, a resident purchasing group (a tenant with joint responsibility both to the laboratory and to the company purchasing organization), and the usual maintenance and support functions. The company would like to have a scientifically trained manager for this function, but is more likely to utilize a fairly senior research engineer.

4. Facilities

Facilities planning is still in the early stages. A rough floor plan incorporating flexibility and simplicity is presently being drawn up within the company for architectural analysis. The plan proposes one long multiple-story 40,000 square feet research building, with utility pipes and lines extended outside along a blank wall and fed through the wall to the laboratories. Offices would be along the front side of the building in close proximity to the laboratories. The layout incorporates the most recent trends in laboratory design. (Two such structures placed blank wall to blank wall with a utility corridor between are proving very successful at Scripps Institute of Oceanography in La Jolla.)

Two locations are under consideration, one near the Aerophysics Laboratory in El Segundo and the other on the northeast corner of the Santa Monica Division property, adjacent to the corporate headquarters and main engineering laboratories. A separate campus-type location is not desired. An environment with free access but close enough to the main company activities to be in constant contact and communication is sought. The Santa Monica location near the corporate general offices is preferred.

The approximate cost of the proposed laboratory is $1,000,000 ($25 per square foot). An initial capital equipment budget (which will include a Van de Graaff generator and possibly a nuclear reactor) of $1,500,000 is contemplated. Implementation of the proposed plans is highly dependent on company earnings, and an improved financial position is necessary before work will be actively initiated.

5. Operation

The earliest anticipated start of extensive basic research activity in the proposed laboratory is 1964. Poor earnings could considerably delay, alter, or even cancel present plans.

DSRL plans to budget on a company-funded basis. If basic research contracts of a suitable nature are available, the laboratory will actively solicit contract support, since it allows a broadened scope of activities above and beyond the company funded budget.

The Douglas Aircraft Company seeks to sponsor real excellence in basic research. The size and scope of the research organization and other factors such as the quantity of published results are secondary factors in establishing an initial reputation, when compared with research excellence. The company management recognizes the fact that it will take five to ten years of operating experience before valid evaluation of scientific productivity will be possible. (It is stated that even if nothing of real scientific note is achieved, the company would reinvest anyway - much like insurance.) The Scientific Directorate is expected to provide evaluation and guidance by periodic review of activities and publications.

One of the functions DSRL is expected to perform, in addition to excellent basic research, is that of critically appraising the technical position of the Douglas Company itself. The rapid increase of new technologies and their impact upon the company will be a subject for scientific as well as management study.

The principal purpose in establishing DSRL is to obtain new scientific knowledge, and to obtain it first. The industry competition really determines the pace of activity. (The delay in the publishing cycle of the recognized technical journals, and the further delay in digesting research results for industrial application once they are published, places a company without extensive basic research activities at a severe disadvantage with its competitors in times of vigorous technical competition.)

Considerable consulting activity is expected from DSRL. This is one important factor in selecting the location of the facility. The consulting activities of the scientists, along with the circulation of young engineers, is expected to be the principal means of communication between DSRL and other company research and engineering groups. In addition, consulting is thought to refresh the research scientist by exposing him to challenging problems outside of his immediate research project.

Continued use of outside consultants (there are 35 on yearly retainer at present) is planned. In addition to their present consulting roles, it is expected that this will provide a means for DSRL to let the universities and government know what it is doing. Outside consultants are also mentioned as a very important source of information on promising scientific graduates.

THE LOCKHEED AIRCRAFT CORPORATION

The estimated distribution of sales volume for Lockheed (1960) is: 48 per cent manned aircraft and spares; 39 per cent missiles, satellites, and spacecraft; 9 per cent military modernization and servicing; and 4 per cent diversified activities such as shipbuilding, heavy construction, electronics, nuclear reactors, consulting, and miscellaneous research. About 77 per cent of sales was to U. S. military organizations, 21 per cent commercial, and 2 per cent to foreign governments. The backlog of orders remains high. Lockheed recently was awarded a large military contract for the development and volume production of a jet cargo-transport. The Polaris missile program and three leading military satellite programs (Discoverer, Midas, and Samos) continue on a major scale with growth potential. The F-104, Electra, Jetstar, and C-130 manned aircraft programs are continuing. The present corporate position can be characterized as one of growth, diversification and prosperity. In short, business is booming.

Lockheed has three major operating divisions: the California Division (aircraft, services, and general manufacturing); the Georgia Division (aircraft and nuclear products); and the Lockheed Missiles and Space Division at Sunnyvale and Palo Alto, California. Subsidaries include Lockheed Air Terminal, Inc.; Lockheed Aircraft International, Inc.; Lockheed Electronics Company (formerly Stavid Engineering Inc. of New Jersey; acquired in 1959 with stock exchange worth about $15 million); Puget Sound Bridge and Dry Dock Company (purchased in 1959 for about $8 million); Commercial Steel Fabricators Inc.; Colby Steel and Manufacturing, Inc.; and

Colby Crane and Manufacturing, Ltd. Affiliated (partially owned) companies include Grand Central Rocket Company (half interest purchased in February 1960 for $6 million); Aeronautica Macchi (Italy); Lockheed Azcarate (Mexico); and a 22 per cent interest in the Pacific Finance Company. The recent ambitious diversification is emphasized by the corporate policy of "Concentricity" (defined as selective expansion into contiguous fields), and is intended to extend the corporation into new but related areas of activity.

The organizational doctrine of Lockheed is decentralization. Though a geographical necessity, it is also a studied corporate management policy. The operating divisions report through two group vice-presidents and the executive vice-president to the Corporation Offices. The Corporation Policy Committee is the top level management council and determines broad matters of policy and planning. The Corporation Offices and staffs are monitoring organizations. As such they are coordinators and not managers. The main autonomy exists at the division level.

Lockheed is extensively engaged in research and development, and was second among the 500 companies listed by the Department of Defense for 1960 research contract volume. (Top five - (1) North American Aviation at $567 million; (2) Lockheed at $511 million; (3) General Electric at $395 million; (4) General Dynamics - Convair Division at $313 million; (5) Martin at $284 million; also (8) Douglas at $208; (10) Boeing at $156 million.) In 1958 Lockheed performed $349 million of work in R and D (two and a half times that of 1957). In 1960 total contracted research was $511 million and company funded research an additional $33 million, a total increase of 70 per cent over 1958. Company funded expenditures for research have increased during periods of sharp decrease in net earnings, and for 1960 are 75 times the amount of 10 years ago. These enormous increases in research activity indicate: (1) a corporate management very strongly supporting research; (2) a rapid build up of scientific personnel and facilities; (3) a vigorous search for new areas of company business; (4) successful competition for contract awards; and (5) a greatly increased scientific base for future corporation activities. Lockheed management supports research because it is firmly convinced that research bears a positive direct relation to corporate growth and future health.

Within the company, there are 22 geographically separated centers of research activity. Within these decentralized research activities considerable basic research is being conducted. Management estimates of the cost of basic research vary in the range from $5 to $12 million dollars. Definitions of basic research are surprisingly uniform for such a variance in estimated volume. The principal reason (along with the usual intangibles) for this variation is that basic research is not budgeted or conducted separately, but is an integral part of the general research program. Research administrators in the corporate management tend to agree on the lower figure of $5 million (or less) depending on the application of the definition. There is general agreement that Lockheed Missiles and Space Division does more than 80 per cent of the total, or an estimated $4.2 million in basic research. All the divisions are increasing their basic research activities, the

California Division budgeting about $400, 000 and the Georgia Division $250, 000 out of company funds for research of a basic nature.

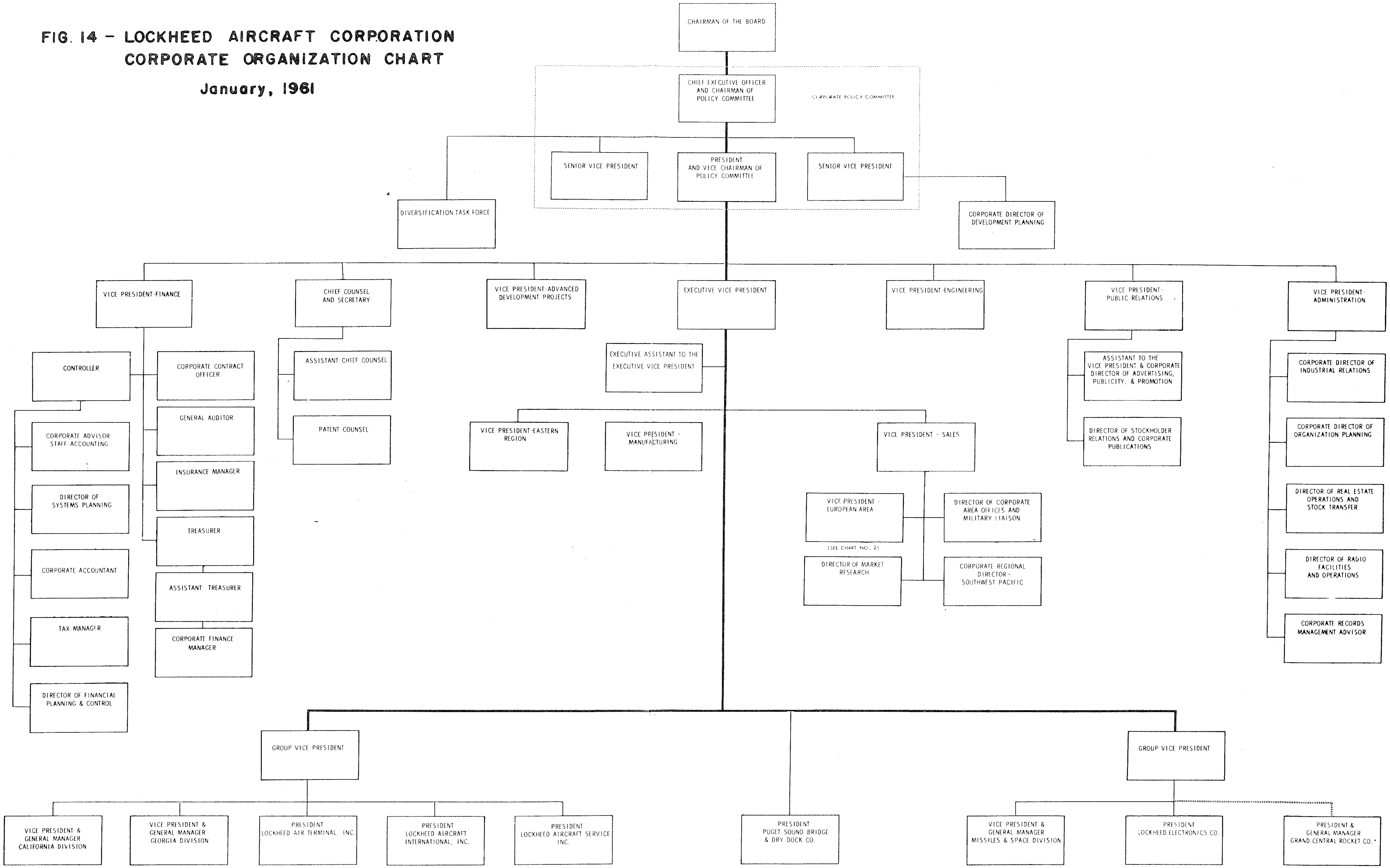
Basic research is supported because it is a promising source of future product growth, being dissociated by definition from present products. Also, the management states that the best product is derived when some basic research is done in reasonable conjunction with engineering and development programs. Further it is stated that applied research (here defined as the application of new concepts to useful purposes) is most successful when approached from both sides by engineers for practical application and by basic research scientists for sources of ideas.

The Lockheed Missiles and Space Division (LMSD)

LMSD accounted for over half of the gross sales of Lockheed in 1960, and was the major source of profits. Two-thirds of the 27,000 people it employs live in the San Francisco bay area. (One out of every 13 adults in Santa Clara County works for LMSD.) LMSD ranks as one of the largest aerospace companies in the industry, occupies 2 and 1/2 million square feet of floor space and nearly 5,000 acres of land, all devoted to the research, development, manufacturing and flight testing of missiles, satellites and space vehicles. The three principal functional branches of LMSD are the Research Branch, Satellite Systems Branch, and Polaris Missile System Branch. Research and development is conducted in all three branches, with most work of a fairly fundamental nature being done in the Research Branch. LMSD as presently constituted began operations in Sunnyvale, California in 1956, with the consolidation of missile and space activities conducted at Van Nuys and several other locations. The growth and expansion of facilities, sales and activities has been remarkable.

FIG. 14 – LOCKHEED AIRCRAFT CORPORATION CORPORATE ORGANIZATION CHART

January, 1961



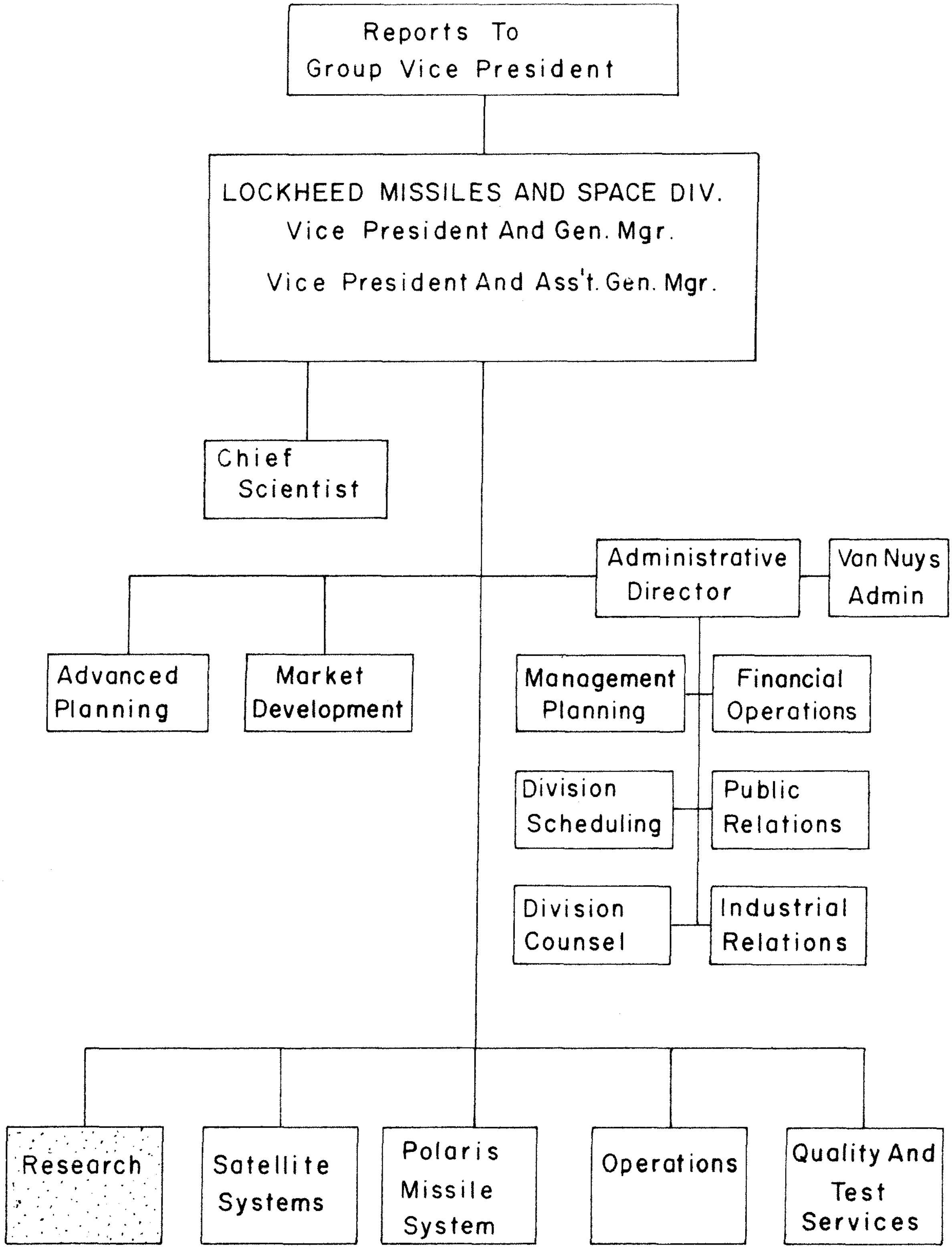
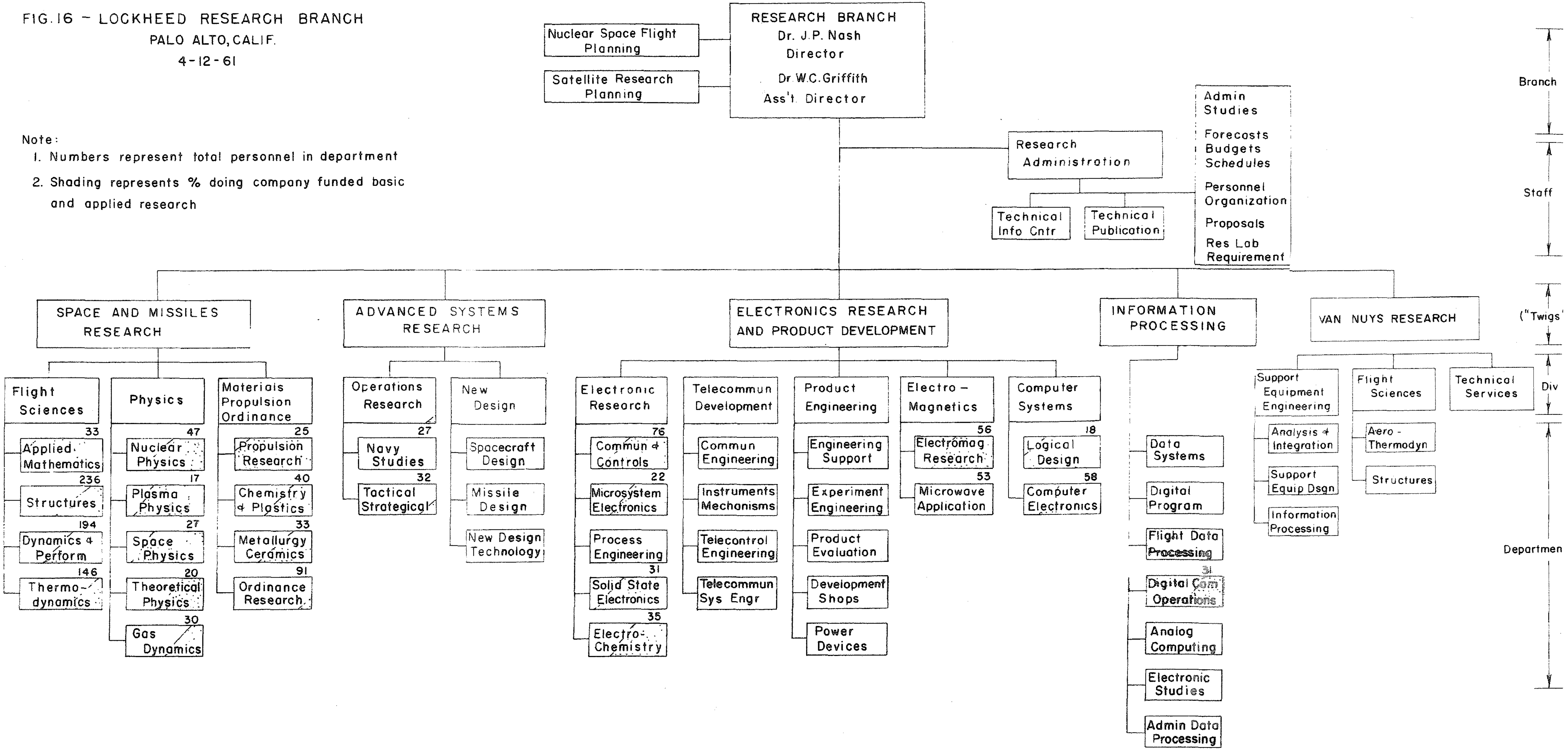


FIG. 15 - ORGANIZATION OF LOCKHEED MISSILES AND SPACE DIVISION

FIG. 16 – LOCKHEED RESEARCH BRANCH
PALO ALTO, CALIF.
4-12-61

Note:
1. Numbers represent total personnel in department
2. Shading represents % doing company funded basic and applied research



Research Branch (LMSD)

1. Origin and Purpose

To understand the nature of basic research at Lockheed, one must study the evolution of the company. Until five years ago, most of the corporation activity was directly related to aircraft. Missiles were not so important then. Most of the necessary research was done by NACA and the universities, and not much was done by the aircraft industry.

As business changed from straightforward aircraft production to missile and space activity, it became necessary for Lockheed to become more involved in basic research. Actually, effort worked back down from engineering to applied research to basic research. As business demanded more stretching of company capabilities, more research was done. The rapid expansion of aircraft activity leveled off. The company was interested in growth and had to consider new kinds of business. Basic research fit in nicely since it was not directly related to existing products. This provided more incentive to do basic research. The scope and field of possible research activity were no longer constrained by single product considerations. Top management recognized the growth potential implicit in basic research. It put more support into basic research to provide an input for unseen future business. At an early date (1954-56), Lockheed management firmly committed the corporation to the vigorous support of research in general.

About this time there was a severe perturbation in the scientific composition of the company, when 20 senior LMSD research personnel resigned charging favoritism for engineers and an unsuitable research environment. The resulting cure was to combine research and developmental engineering activities in a new organization, the Research Branch. To separate this group and thus provide a more suitable scientific environment, a new facility was urgently desired. Lockheed bought plans and rights to the present facility in Stanford Industrial Park from the Ramo-Wooldridge Corporation, the intended tenant. The buildings had been designed for Ramo-Wooldridge as a research and engineering laboratory, and by taking over the plans intact LMSD cut about a year off the lead time to occupy the facility. This year was to become highly significant, for by virtue of an early start Lockheed had a greater opportunity to select scientifically trained personnel than has been more recently available. This selectivity was both necessary and beneficial since there was not a large technical labor supply available in the bay area. Selection of the Stanford Industrial Park location (immediately adjacent to Stanford University in Palo Alto) was a controversial but sound decision. The selected location is about fifteen minutes drive from the main LMSD plant and headquarters at Sunnyvale.

Though other divisions and subsidiaries of Lockheed conduct some basic research, the Research Branch at LMSD is the only Lockheed organization whose charter clearly calls for the conduct of basic research. The primary objective of this basic research is to support LMSD, but the scope and charter of basic research is so broad that Research Branch activities are applicable to all of Lockheed. Basic research as originally defined included both fundamental and applied research. The definition has evolved to that more generally in keeping with this study, the present distinction being based on the purpose or aim of the scientific investigator. It should be pointed out that there is no real distinction, either in policy or practice, between basic or fundamental and applied research, and as a result estimates of scope and activity are highly dependent upon their individual source. In general, the closer one is to fundamental research, the narrower the definition, and this in fact tends to evaluate the source!

2. Facilities

The Research Branch conducts a little basic research in a lot of places. There is no separate basic research center as such. Since basic research is integrally associated with applied research and engineering activities, the physical facilities supporting basic research are used for other purposes as well. About 10 to 20 per cent of the 235,000 square feet of floor space is occupied by basic research activities at any one time. The present Palo Alto facility occupies four large single story buildings, with laboratories in the central portion of each building and a ring of offices around the perimeter. The investment in land and buildings is about $6 million. The cost of the buildings is estimated at about $18 per square foot. The first two buildings were completed and occupied in 1956, the third in 1957 and the fourth in 1958. The present estimated value (based on original cost) of land, building, and capital equipment is $14 million. The total capital invested in and administered by the Research Branch is estimated at $21 million. (This includes additional facilities at Sunnyvale, Santa Cruz, and various other locations.)

The physical resources available to basic research deserve comment. The Structures Laboratory includes a 10,000 lb. capacity controlled load and temperature testing machine, a 50,000 lb. tensile and compression testing machine, photo-stress and photo-elastic equipment, and creep machines. The Thermodynamics Emissivity Laboratory contains a wide variety of equipment to determine thermal radiation characteristics of materials. The Nuclear Physics Laboratory contains a 1000-curie hot cell laboratory, a 3.5 Mev Van de Graaff accelerator and considerable handling and testing equipment. This laboratory, which provides fundamental nuclear research capability, is unique within the aircraft industry. Additionally, there are Plasma Physics, Space Physics, and Space Medicine Laboratories. The Gas Dynamics Laboratory includes three major facilities: (1) a complex of four shock tubes; (2) an arc-heated ("hot-shot") tunnel, and (3) an intermittent high temperature hypersonic tunnel complex. The Propulsion Chemistry Laboratories include test facilities at the Santa Cruz Test Base, making possible the thorough development, evaluation, and testing of new chemical systems for propellants. The Propulsion Physics Laboratory has several high vacuum systems for exploration of thermionic and ion propulsion devices. There is a completely equipped 148 acre ordnance test facility. The Instrumentation Laboratory has facilities ranging from high vacuum to oceanographic instrument development, including an ultra high pressure chamber capable of sustaining pressures of 25,000 psi. Solid State Physics, Communications, Electrochemistry, Electromagnetics, and Infrared Research Laboratories are also well equipped. The Palo Alto computer facility has two Remington Rand 1103 AF digital computers, and an IBM 7090 is due for installation in 1961. Additional computer facilities are available at Sunnyvale. The Palo Alto Research Library stocks about 73,000 books and reports, and has a monthly circulation of about 8000 items. In addition, many facilities of the Stanford University are immediately available. Although the basic research scientist must share the laboratory facilities with the applied research and engineering groups, the equipment immediately available is the most extensive that this author observed among the subject companies.

3. Organization

The Research Branch is managed by a Director and Assistant Director of Research. The Director reports to the Vice President and General Manager, LMSD, and to the Group Vice President. This management team has a strong voice in company affairs and a high degree of financial and operating autonomy.

The organization of the Research Branch does not functionally separate research and engineering activities. Figure 16 illustrates the present organization, which is designed for engineering supervision. Basic research is functionally separated at or below the department level. In departments where both basic research and engineering development are conducted, a separate manager within the department is responsible for basic research. It would appear that the basic research scientist is smothered in the organizational maze, but in practice this does not appear to be the case. Although research and engineering were originally combined at all levels, in practice a separation has resulted due to the differing nature and requirements of the two activities. The senior research scientists have direct and frequent contact with the Research Branch Director. The several echelons of reporting responsibility between the Director and the basic research laboratories create an unwieldy management structure for the scientist, since the normal communications channel is usually direct. The rapid growth and change within the research branch have confronted department managers and scientists with an organizational and procedural framework not designed to their task. As a result the department manager must constantly compromise between what should be done and what can be done within the existing organizational framework. These constraints are not the result of an inflexible policy, but are inherent in rapid growth and change. The existing structure is extremely flexible. It has grown where and when promising research competence has developed. This very freedom to grow and exploit capabilities at any level has led to the present scientifically responsive but administratively cumbersome organization. It is significant that research growth and activity have not been forced to fit a predetermined pattern. The resulting environment encourages initiative and scientific progress. There is an evident flow of ideas from the scientist to the management, and a receptive and considered climate.

A research administration staff of 80, with able and technically qualified managers, supports the entire organization. Staff functions include personnel and organization, projects and proposals, research facilities and equipment, administrative studies, budget coordination, technical libraries, and technical publications. The main burden of administrative coordination is carried by this staff, leaving the scientists relatively free from such chores. Additional administrative assistants and clerks are assigned directly to operating groups as the need arises.

4. Budget

The total 1960 operating budget for research in the Research Branch was $42 million, and was divided into direct and indirect budgets. The direct budget was derived from two principal sources: (1) weapons system research support for Polaris, satellites, etc.; (2) separately negotiated research contracts. The indirect budget is derived from funds allocated by the LMSD management on the basis of negotiations with the Department of Defense.

About 10 per cent of the budget was allocated for basic research. Most of these funds were provided from the indirect budget. For 1960, Lockheed negotiated an agreement with the Air Force (representing the Department of Defense) which authorized expenditures of $4.2 million by the Research Branch for basic research. Of this amount, Lockheed contributed 25 per cent out of profits before taxes, and the remaining 75 per cent was provided by the Department of Defense. As basic research costs are normally shared by the government on a lesser scale (say 40 per cent - 60 per cent), this represented for Lockheed a very favorable agreement which the management attributed to a high evaluation of their basic research program. It should also be pointed out that basic research is currently closely related to satellite and space activities, and that Federal Government interest and support at a high level might be expected where research competence is shown.

The indirect research budget of $4.2 million was divided so that 77 per cent went to basic research. This sum provided a working budget for between 100 to 150 scientists. The range of personnel is indicated since projects do not necessarily coincide with fiscal years.

Also, interpretation of the definition of basic research may include or exclude some research activity that is both basic and product related.

The extent to which Lockheed is reimbursed by the Federal Government for basic research activity is negotiated on a yearly basis, and as such is subject to fluctuations. In 1957, an enormous perturbation was caused by a 7 per cent decrease ordered in federal research spending; basic research activities bore the major share of these reductions. Since negotiations are the basis of funded support for most of the basic research activity, a major effort is being directed at improving the stability of funded support. In the meanwhile, the Research Branch management has selected a group of about 100 scientists thought to be most qualified to do basic research, and has "guaranteed" a certain minimum level of support. This amount varies with the individual, but an average grant is about $10, 000. The purpose of this "grant" system is to assure continuity of support, reducing the effects of budget fluctuations. It is well received by Research Branch scientists, and has improved confidence in their support by management.

The Research Branch activity seeks contract-supported basic research, when such direct support does not severely constrain the scientific effort. The variety of government agencies with available basic research funds, and the variety of their requirements for administering these funds, are awesome. In general the constraints involved in such contracted support are decreasing, and about 20 per cent of Research Branch basic research is contract supported. Work on a continuing basis with such agencies as Office of Naval Research, Air Force Office of Scientific Research, Atomic Energy Commission, and others provides mutual confidence and tends to reduce reporting requirements. One constraint always required by contract funding is the publication and distribution of results. It is estimated that proprietary interests are involved in only two of the approximately 200 research projects presently under way, and this is not often a serious limitation. Where proprietary considerations are involved, the company funds the effort itself.

A measure of the decentralized Lockheed management policy is the way in which the annual research budget is derived. The major operating divisions do not itemize their proposed expenditures in detail, and may make major changes or reallocations during the fiscal year without prior top management approval. Budgets are reviewed for coordination and to prevent duplication, with the corporate policy intended to encourage self sufficiency within the operating divisions. As a result of this policy, considerable initiative is allowed at the lower levels to suit particular requirements. In the Research Branch, different departments are supported in keeping with their individual needs and requests. The mathematics department, for example, is experimenting with budgets for up to 18 months. There are extended grants to scientists within this department, free from any strings, that encourage initiative and effort. This type of flexibility is certainly commendable and could only exist in a decentralized management structure.

There is a separate capital equipment budget submitted annually along with the research budget. Control and procurement of capital equipment is centralized at LMSD and closely monitored throughout the company to control purchasing and to prevent duplication. There is a specialized branch of the LMSD procurement organization located physically in the Research Branch. There are several storerooms for openstock items, and the major laboratories have equipment stockrooms to support their activity.

Capital assets are defined as meeting the three criteria of (1) initial cost over $122, (2) useful life of more than 2 years, and (3) a controllable item. If the item does not meet all three criteria, it is charged directly to the operating budget. Capital assets costing more than $25,000 require corporate approval prior to purchase. Those costing less than $2,500 are classified as miscellaneous and do not require approval. In practice few items fall above the $25,000 level, and there is considerable leeway in classification. It is significant, however, that the apparently centralized control of procurement requires basic research scientists to follow the same purchasing channels as engineers and technicians. It is reported that these purchasing channels have improved considerably in recent months, and that they are not a major source of friction and delay.

One might well ask why a management that is flexible and research minded requires such formalized purchasing requirements, especially when these were not required originally in the operating research organization. The problem has not been overlooked. As the Research Branch grew, experience developed the need for control in purchasing. Without review of purchasing requests duplication, shipping acceptance, power and utility source, calibration and test, fire inspection, and maintenance problems arose that were costly to resolve. Scientific personnel tended to be less than cognizant of these problem areas. The management was firmly convinced that the way to handle equipment procurement and item purchasing in a large organization efficiently, and still stay within company policy directives, was to get a resident branch of the procurement function located physically in the Research Branch. I would speculate that the present purchasing structure will evolve into two branches, one for engineering activities and the other solely for basic research support.

5. Personnel

The 3,100 employees of the Research Branch are classified as: professional (B.S. degree and higher or an equivalent qualification) - 1,900, technical - 700, and administrative (including data processing) - 500. The professional group contains 167 Ph.D. and 357 M.S. degree holders. The total number of persons engaged in basic research is estimated at about 300. The majority of advanced degree holders and senior scientists are active in basic research, although it occupies less than 10 per cent of the total staff. About 30 per cent of the basic research scientists are supported by contract, and the remainder by company funds.

In response to a questionnaire circulated among the professional salaried personnel, 40 per cent said advertising influenced their decision to join LMSD. Of the remaining 60 per cent, about 40 per cent learned of job openings and opportunities from associates already employed by Lockheed, and a nearly equal number personally inquired about employment. Respondents indicated the following factors were important in making work at the Research Branch desirable: nature of work 90 per cent; geographic location 78 per cent; potential of company 63 per cent; starting salary 38 per cent; facilities 30 per cent; other reasons 16 per cent.

The Research Branch hiring program is slanted mainly towards engineers. Persons are hired for basic research only after extended contact and negotiation. Research managers have seldom located valuable new staff members through a survey of individual applications, and feel that advertising is not very useful. Instead they look to experienced scientists and professors for recommendations of promising individuals. Each research manager has his own method of obtaining new scientific personnel. One department manager (a senior scientist responsible for the work of 20 Ph. D.'s and several junior scientists) summed up hiring and firing policies in this way:

"We want the finest people we can get. We know the scientific fields within our discipline that we don't want in our department. We look to experienced scientists, consultants, and professors to recommend up and coming young scientists. We invite promising people up to work with us for a few days at a time, several times if possible. The prospective employee is discussed with members of the department, for a summary of opinions. Sometimes we try to learn the worst first ... We look for technical competence and personal character. Initiative is particularly important. We want people who can find their own problem and work with little supervision. Without initiative, there is no research capability...."

..."Those who are hired and who don't work out are encouraged to move on. A management selection group determines placement. If a department manager fires a man he cannot be rehired in the company".

New scientific employees tend to be assigned to project areas in applied research and development, rather than basic research. Basic research work tends to be a reward for demonstrated scientific ability. Some managers believe that the opposite sequence would be better, where the young (?) Ph. D., fresh from his university research work, begins in basic research for which he is technically prepared and works toward applied research. I believe the present situation is excellent, since it is easy to shift a scientist into a suitable job with a minimum of disturbance. In a sense, this protects the basic research activity from mediocre effort, since no change of organization or administration is immediately involved. This advantage may be lost in the proposed functional reorganization.

In hiring, the department (laboratory) manager recommends a salary level based on training and experience (T and E). The T and E system is something like this: An individual is awarded 48 points for a B.S. degree, 60 for M.S., and 90 for Ph.D., plus one point per month for related experience. Additional factors such as academic record, university, professional references, publications, and personality are considered in the evaluation. In general the T and E point count determines the salary bracket, and the evaluation of references determines the salary level within the range of the bracket. The starting salary for a promising young Ph.D. is about $230 a week. Department managers can hire up to the $12,000 annual level without prior review and approval. Up to $14, 300 the offer must be reviewed by the salary review board. Special cases are considered separately on their merit. The salary range for the senior scientist level is $223 to $317 a week. There are higher pay scales for qualified scientists, but the normal progression is the range indicated. In exceptional circumstances, senior scientists may make more than their own department managers (who are also senior scientists - the thought being that it takes more skill to do excellent research than to manage. Right or wrong, this is a refreshing thought for the scientist!) It is probably true that the Research Branch has a higher salary structure than other Lockheed organizations, but not for equivalent people. Also, "degree consciousness" is increasing due to several factors, the most important being that the degree level is thought to determine the status of a research organization. It certainly is one indicator (however valid) in an area where evaluation is difficult. Additionally, the Ph. D. degree from a good university is a mark of excellence. Finally, a Ph. D. scientist will seldom work happily for a manager of less educational prestige. The trend then is toward more and higher academic qualification. There are 70 graduate students working in the Research Branch on a part time basis. They work a 30 hour week and summers for Lockheed, usually in an area immediately related to their graduate studies, and incur an obligation in return for payment of all school expenses by the company (on completion of the graduate program).

One of the most significant factors in the Research Branch operation is the proximity of Stanford University. There is a growing relationship of mutual cooperation and benefit between the University and the Research Branch. The graduate student program has already been mentioned. Enrollment in technical and business courses is increasing and is encouraged at all levels. A mutual program enlists distinguished scientists for summer research and lecture work. About 12 top level scientists are supported during the summers, with the University and the Research Branch sharing expenses equally. Also, about 20 per cent of the 67 Research Branch consultants come from Stanford University. The biggest bonus of the mutual cooperation is probably the broadened association with peers and the corresponding scientific climate. This reduces the isolation sometimes attributed to basic research efforts in an industrial environment, and stimulates excellence.

In the Research Branch, there is a new Professional Standards Committee, composed of scientists, which formulates policy and makes recommendations regarding scientific matters. In basic research work, there is a tendency to pay the individual, not the job. Professional evaluation is a critical factor which does not lend itself to standard solutions. Three measurable criteria have been established: 1) Does the scientist produce publishable reports?; 2) Is he sought as a consultant, and does he produce satisfactorily when called upon?; 3) What is the "time span of his discretion"?... That is, how long can he work effectively without supervision and how far reaching are his decisions? These three criteria in complex combination with other judgment factors determine an individual's merit. The yearly raise fund (varying in recent years between 2.9 per cent to 8.3 per cent of total salaries) is distributed on the basis of merit. The distribution is determined by the department manager. As a rule an individual does not receive a merit raise of more than 15 per cent per year, although raises of 35 per cent have been awarded in exceptional cases.

6. Operations

In the Research Branch, basic research occupies less than 10 per cent of the 3,100 personnel, and about 10 per cent of the annual research budget. The remaining 90 per cent of activities are in applied research and engineering development. One might expect that basic research would be subordinate to the product-associated activities, but this does not appear to be the case. Both the director and deputy director of the Research Branch are former professors, not engineers. The importance of research excellence is recognized and fostered, and if anything the basic research personnel enjoy a favored position with respect to offices, facilities, and working requirements. This may cause some friction with the engineering and applied research personnel, but evidently it is minor. The original reasons for combining research and engineering have diminished to the point where organizational separation by function seems to be indicated. This is proposed for June of 1961, with a grouping of departments doing solely basic research into a separate division, and engineering and applied groups into an engineering division, both under the Research Branch director. This functional separation would allow inherently different types of activity (i.e., one is the search for understanding, independent of budget and schedule; the other the application of technology within the competitive framework of budget, schedule, and deadline constraints) to proceed in close contact with less interference. An immediate resulting problem would be the unsettling effect of reorganization in displacing people, patterns, and present working relationships.

Considerable thought and initiative have been applied to management in the Research Branch. There is an awareness of the need for improved practice, and the resulting environment is receptive to new ideas. The flexible management structure, sympathetic to research, and with the authority to govern its own organization, is unusually responsive to the interests of the scientist. The management attitude is one of guiding, counseling, and refereeing. This encourages individual initiative and responsibility, but it requires a delicate balance and evaluation of personnel. Along with this freedom of action there is a healthy respect for sound application of proven management techniques and practices. I was impressed with the careful and self critical attention that the management was applying to its own activity. There was more than a casual interest in assembling factual information as a basis for decision.

Since the Research Branch has been functioning for several years some operating maturity has developed. The major organizational and managerial techniques have been refined and established. The proposed reorganization will upset this pattern, but will probably be less disruptive than in a newly formed basic research organization. The autonomy of the basic research department will be preserved and strengthened, and the existing lines of responsibility clarified. Such a reorganization, based on extended operating experience, should result in a substantial improvement in the scientific environment.

The rapid and continuing growth of the Research Branch, in terms of both annual budget and personnel, seems to indicate that Lockheed management is satisfied and encouraged by the record of past accomplishments. That the Research Branch is recognized as a successful and established operating unit is significant. This provides a measure of stability and future health within the corporate structure. The grant type of individual budget program encourages confidence and reflects this stability at the scientific level. The Research Branch seems to be quite advanced along the sequential path toward becoming a permanent and productive basic research organization.

7. Publication

The procedure for review and publication of an individual scientist's work is intended to encourage qualitative results. The author submits his report to his department manager for review. The department manager assigns a technical referee from either inside or outside the company. The technical referee is usually the most competent man available in the author's area of study. The author and referee confer, and frequently the technical referee offers a fresh or stimulating viewpoint that is welcomed by the author. This policy also encourages outside contact with the scientific community. When the author, referee, and department manager agree, the report is cleared by legal, proprietary and clerical sections, and forward to the divisional manager (within the Research Branch) for approval and publication. The principal judgment regarding publication merit is the responsibility of the department manager. If the author, referee, department manager, and research divisional manager cannot agree on a report, the issue is automatically appealed to the Research Branch Director. This seldom (naturally) proves necessary. If an article is submitted to a recognized technical journal, the assigned technical referee is optional since the journal editorial board performs this judgment.

To assist communication within the company and throughout the scientific community, the Research Branch publishes the LMSD General Research Annual Report, which summarizes the scientific work in progress under the General Research program. The description of each item of research is followed by the names of the principal scientific investigators responsible for the work described, and their annual working budget. In addition, each section is followed by a list of pertinent publications and technical presentations. Research work is classified as either basic or applied. The LMSD General Research Annual Report is widely distributed to industry, government, educational institutions, and technical libraries. It serves as an excellent communication device. The extent to which it is known and read is not determined, but as research results continue it should become well known and recognized as a standard for other scientific research groups.

Lockheed encourages attendance at scientific meetings and symposia. A corporate document emphasizes the objectives of scientific attendance from the company viewpoint, as: (1) Increase sales; (2) Advance technical position; (3) Improve public relations; (4) To enhance professional development. Listed in the given order, the objectives are somewhat less than statesmanlike, but closer to the working scientist there is a more acceptable interpretation. The fact that the company exists on sales should not be entirely overlooked in considering the merit of objectives. Public relations before professional development is absurd from the scientist's viewpoint, (but is an excellent example of the fairly innocent irritants that lurk in aging corporate policy documents).

The output of basic research activity in the Research Branch, LMSD, takes the form of published and corporate papers, consulting, and scientific liaison. Since the Research Branch has been operating for several years, there is interest in quantitative and qualitative analysis of this output. (The Research Branch management desires to measure the comparative effectiveness of its organization, as well as to inform top Lockheed management and Department of Defense negotiators.) Publication, particularly in recognized scientific journals, is thought to be the best single standard. An analysis of basic research publications in the major recognized journals of physics, chemistry and mathematics (Lockheed Technical Report LMSD-703736 entitled "Basic Research in American Industry" by M. H. Hodge, Jr., September 1960) indicated a rapidly increasing scientific productivity at Lockheed by this measure. It was further stated that "like any management measuring tool, it must clearly be used with restraint lest what it measures - scientific publication - replace what it seeks to measure - scientific productivity - as the primary goal of the company's scientists".