COOPERATION BETWEEN UNIVERSITIES AND INDUSTRIES IN BASIC AND APPLIED SCIENCE

Hiroshi Inose

Computer Center
University of Tokyo
Tokyo, Japan

Tetsuji Nishikawa

National Laboratory for High-Energy Physics
Tsukuba University
Tsukuba, Japan

Michiyuki Uenohara

Central Research Laboratories
Nippon Electric Company, Limited
Kawasaki, Japan

I. UNIVERSITY VIEW

The pattern of the university-industry collaboration in Japan seems to be quite different from that in the United States. In Japanese national universities, which perform a major portion of

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academic research, no part-time consulting activity has been done for industry as professors are considered to be full-time government employees. In the United States, business ventures are often found which center around universities and which involve university professors and graduate students as active participants. Such agreements are very scarce in Japan. Although there are a number of research contracts between Japanese industries and universities, the amount of funding has been relatively small and has not covered stipends.

There are, however, significant collaborations between Japanese industries and universities. Quite a few industries provide generous support to university research activities by providing computers, instruments, experimental systems, materials, and devices free of charge or at a very low price. For instance, computer manufacturers provide very large computer systems to the inter-university computer centers for nationwide service, at a price 60 percent to 80 percent lower than the list price. At no cost to the university, electronics manufacturers often provide university professors with exploratory semiconductor devices fabricated in their facilities, or experimental systems built by their plants in accordance with the professor's specifications. At a very low charge to the university, a good amount of software for computer network architecture or data base management has been designed, produced, and tested by industries in collaboration with the universities. Industries allow professors to use their testing facilities for highly powered machinery, large structures, etc., free of charge.

University professors often join as project leaders, advisors, or investigators on large, government-sponsored projects, such as pattern information processing, large-scale integration, direct steel manufacture by nuclear heat, integrated traffic guidance, optoelectronic instrumentation for production, etc. These projects are carried out mainly by industry. Professors who join such projects are usually permitted to use, free of charge, expensive facilities installed in government research institutions and in industrial laboratories and, after the completion of the projects, some of these facilities are given to the universities.

II. INDUSTRIAL VIEW

Effective management of creative organizations, such as scientific laboratories, is a very difficult, very challenging, never ending problem. One of several key elements in effective management is the coordination or cooperation of scientists across professional and organizational barriers. These barriers are unavoidable as they are often necessary to maintain healthy activities for long-range objectives. The organizational or institutional barrier between universities and industry is usually very high, and the subject of university-industry cooperation has been the target of strong public debates.

Japanese universities have played important roles in the rapid advancement of Japanese industries by:

1. providing ample engineers and scientists for industrial growth;

2. supporting industry in the selection and implementation of appropriate technologies to their needs; and

3. promoting infant, high-technology industries through the development and procurement of special equipment and facilities for laboratory uses.

However, the university-industry interaction has been mostly indirect in nature, especially after the campus disorders during the transition period from the rapid industrial growth period of the 1960s to the depressed period of the 1970s, and the direct cooperation of universities and industries in basic and applied sciences has been limited. The subject of university-industry cooperation had been a taboo until very recently.

As the technological level of Japanese industries approaches those of advanced nations and as the creation of original technologies is strongly demanded by the domestic as well as foreign markets, the need for much closer cooperation between scientists in industry and scientists in universities has been strongly voiced in industrial and governmental circles.

A. *Historical Background*

The pattern of Japanese university-industry cooperation changed significantly prior to and after establishment of the Japanese industrial foundation in the early 1960s. Soon after the Meiji restoration, Japan began to industrialize very aggressively. To meet the rapidly increasing needs for scientific and engineering manpower, the government made a very large effort to establish a nationwide educational system by organizing the numerous local and private schools that already existed. Many national universities and technical colleges were built and schools of science and engineering were established in the university. These schools were oriented toward practical needs since they were either reorganized from existing engineering schools or organized by members of the Ministry of Commerce and Industry. This was typical of Japanese institutions for higher learning as they were geared to catch up to the level of western industrialized nations by the national policy. Hence, the university-industry cooperation during the period of rapid industrialization, or the "catch-up" period, was very smooth and fruitful.

Other factors influenced closer university-industry cooperation during the early part of industrialization. Highly educated scientists and engineers were very scarce and most of them were attracted to the national universities and government institutions rather than industry. University faculty members had better opportunities to study abroad while members of industry had practically no opportunity to do so. As a result, the universities soon became national centers of research and development and the gateway to foreign technologies.

Industry relied heavily on scientific knowledge and technologies from universities, and universities with strong motives for establishing industry, responded to industrial needs. Most university researchers had close relations with related industries and often provided basic designs and specifications of new products during early stages of development. This close cooperation extended into joint research and development as industry increased their R & D capabilities and reached its height from 1934 to World War II. At this time the flow of western technology was almost completely stopped as the country moved onto a virtual war footing. During this unfortunate period, Japan had strengthened her technological foothold, but the technological gap between western nations and Japan had widened. The university-industry cooperation had played an important role in strengthening Japan's technological foothold.

After the Second World War, seeking to catch up with the prevailing level of technology in the industrially-advanced western nations, various Japanese enterprises made very energetic efforts to import advanced technology from the United States and Europe (following the enactment of the "Law on Foreign Capital" in 1950). One reason for this was the need to manufacture many needed products domestically at a time when the balance of payment followed a deficit trend due to structural reasons. Another reason argued was that it was more advantageous, both in terms of financing and time, to pay to import advanced technology.

A further point that must be mentioned is the special circumstances in which Japanese industry found itself before and after the Second World War. Before the war there was a tendency to deny industrial property rights for technology developed by private industry and to pressure donation of the rights to further the nation's industrial power. After the war it was discovered that many publicly-owned technologies in Japan infringed upon the patents of foreign enterprises. There were numerous cases where Japanese enterprises, in spite of possession of their own technologies, had to obtain patent licenses from foreign companies. Furthermore, the then existing patent rights of the Allied Nations were extended for an additional period of ten years by order of the Occupied Forces. This put Japan in a very inferior position concerning industrial technologies.

Under such circumstances, patents and know-how were imported. This rapid introduction of new technology reached its peak between 1955 and 1960 and was absorbed and improved upon in a comparatively short time because of the strength of the technological base and scientific and engineering manpower. During this period, the majority of university faculties had industrial experience in one way or another, and they extended very helpful hands to industry while challenging the frontiers of basic and applied sciences.

While close university-industry cooperation helped in the rapid recovery of industrial and economic activities, strong barriers that hindered direct university-industry cooperation steadily increased. The reasons for this are very complex and mixed. However, some explanations are necessary in order to understand the current dilemma.

A strong, anti-war feeling prevailed in the academic community and hindered cooperation with the industry that once supported Japanese armament so strongly. This sentiment was very strong among the faculties of the social and the natural sciences, especially the younger members who were educated after the War and who did not have any industrial experience. An undercurrent of pressure against the professors who had cooperated closely with industry gradually built-up and finally erupted during the campus disorders.

Another barrier to cooperation was a distrust created between universities and industry during the industrial technology catch-up period, especially during the period of importation of technology after the War. Japanese industry has always been oriented toward social need and has adapted any technologies that were appropriate to their needs without regard to the origin of the technology. Until very recently, most of the needed technologies had been met with those invented and developed in the United States and Europe. Therefore, Japanese industry had rarely been challenged to put into practice inventions and discoveries of university scientists. The values of such research had not been highly regarded even in the Japanese academic community itself. Their value was often recognized by foreign scientists and some of them were developed overseas and reimported back into Japan. The university scientists were very unhappy with industry's expectation of a quick return on R & D investments, and industry was unhappy about university research that was too remote from industrial problems. During the rapid catch-up period of industrial technology, such R & D environments had created gradually, feelings of distrust not only in the academic community but also in industry.

B. Current Dilemma

The nature of the university-industry cooperation demanded by industry differs broadly, depending on the size and technical area of the industry's segment. Smaller companies tend to ask for direct cooperation in practical technological development and for consulting assistance in order to alleviate their inability to invest sufficient resources for needed R & D. In fact, many technical colleges and some universities had provided such cooperation prior to the 1940s and even during the 1950s. However, after the War, direct cooperation was discouraged for various reasons, and mostly indirect cooperation has remained with industry. Some reasons previously mentioned were the tightening of the government employees rule as it related to university professors, anti-war sentiments against university-industry cooperation, and a distrust of industrial R & D management. As new members of faculties and scientists (those who joined after the War and did not have any industrial experience) have increased in number and dominated the university, the ideas of minorities who are strong believers in the benefits of university-industry cooperation have often been overruled by democratic process. Even the compulsary subject of industrial experience for engineering students was amended to a selective subject, and the communication channels between university and industry have narrowed very rapidly.

Many of the reasons which limit the university-industry cooperation to only indirect types are no longer justifiable with the current state of social environment. The private university has no legal restriction against a tie with particular companies, but many emotional and institutional barriers still remain that must be removed in order to enable direct university-industry cooperation.

Considering that the primary responsibility of the university is to educate students who will be the core of the society to come, and since the industrial structure and their practical technologies changes so rapidly in modern times, it is very difficult to predict what specific practical knowledge and experiences should be provided to the students. It may even be harmful to commit the university to R & D which is too close to the current industrial developments. Larger companies tend to reinforce this point and ask the universities to pursue basic research that will create basic knowledge and that will develop technologies for the better education of students and thereby help the industry's future progress. However, a large percentage of university graduates now devote their life-time careers to medium and smaller companies and many useful subjects exist, in current technological developments, for their educational purposes. Therefore, the framework of university-industry cooperation is very difficult to define. The framework should be determined by individual university, department, and faculty based on their educational objectives and the characteristics of students.

C. Current Practices

The problems of university-industry cooperation have been widely discussed in government, academia, and industry. Some university faculties are pursuing very effective cooperation within the institutional framework, but such faculties are still very much in the minority. In 1978, universities spent about 712.6 billion yen for R & D; the national and public universities spent 435 billion yen, and private universities spent 277.6 billion yen. More than 98.8 percent of the expenditures at national and public universities were paid by the government, and only 1.2 percent were paid by private institutions. Industry contributed much less than 1 percent. Industrial contributions to private universities are much smaller than their contributions to national universities.

Table 1 shows the numbers of research cases and budget amounts (in million yen) contracted to the universities by public and private institutions from fiscal year 1977 to 1979. Tables 2-5 show itemized data of contract research in 1979. Table 2 shows the number of contracts received by universitites and technical colleges and the amounts received. Table 3 shows the distribution of contract research in numbers and percents by major professional areas: social science, national science, engineering, agriculture, and medicine. The school of engineering received the most contracts. Table 4 shows the distribution by contract grantors: national government (ministries other than the Ministry of Education, Science and Culture), prefectural government, city government, industry, and private foundations. Table 5 shows the distribution by the amount of money granted: less than 1 million yen, 1 to 4 million yen, 4 to 10 million yen, and 10 million yen or more. Most industrial contracts are in the category of less than 1 million yen. Tables 6 and 7 show the numbers of research cases and budget amounts (in thousand yen) contracted to seven representative national universities and seven private universities respectively.

TABLE I. Numbers and Amounts of Research Cases Contracted to Universities

	1977	1978	1979
Number of cases	1164	1040	1132
Amount (million yen)	1144	1742	1951

TABLE II. Distribution of Contract Research by School Level

	Univ.	College	Total
Number schools	73	11	84
Number cases	1118	14	1132
Amount (million yen)	1925	26	1951

The contract research granted by industry specifies the area of interest, but often does not define a specific goal. Therefore, one cannot clearly determine from the donation provided by the industry, which specific faculties have been promoted by the

TABLE III. Distribution by Major Professional Areas in 1979

S. Sci.	N. Sci.	Eng.	Agri.	Med.	Total
7	69	460	378	198	1132
0.6%	6.1%	40.6%	35.2%	17.5%	100%

TABLE IV. Distribution by Contract Grantors in 1979

Nat. Gov.	Prefecture	City	Industry	Foundation
248	249	86	198	351
21.9%	22%	7.6%	17.5%	31%

TABLE V. Distribution by Size of Contract in 1979

Below 1 million yen	1 to 4 million yen	4 to 10 million yen	10 or more million yen
519	493	105	15
45.8%	43.6%	9.3%	1.3%

activity. The total amount of such donations is comparable to that of contract research. Besides the industry contributions that show up in the statistics, there are many other donations from industry which go to particular faculties in the form of free loans, gifts of equipment, and experimental samples. But the majority of faculties have not been able to enjoy such fruitful cooperation.

The Japan Society for the Promotion of Science has long been promoting industry-university cooperation. The Society

TABLE VI. Distribution of Contract Research for Seven Major Universities

University	1978		1979	
	Number of cases	Amounts 1,000 yen	Number of cases	Amounts 1,000 yen
A	64	110,380	64	131,091
B	60	75,201	41	105,892
C	185	404,604	114	364,826
D	18	22,665	24	31,908
E	90	155,666	79	189,449
F	25	40,594	34	57,268
G	31	43,105	40	54,935
Total	473	852,215	396	935,369

TABLE VII. Distribution of Contract Research for Seven Representative Private Universities

University	1978		1979	
	Number of cases	Amounts 1,000 yen	Number of cases	Amounts 1,000 yen
A	1	3,500	2	1,402
B	24	56,010	23	64,676
C	118	197,208	143	191,967
D	2	1,850	3	3,620
E	16	26,490	27	35,830
F	2	1,900	2	2,000
G	55	20,770	58	28,394
Total	218	307,728	258	327,889

organizes opportunities for scientists in universities and in industries to exchange information and to present their research findings. Currently, approximately three thousand scientists participate in thirty-three cooperative research committees in specified subject areas. The committee members consist of scientists who are both active in the field and who have volunteered to contribute. The direct expenses of committee activity are covered by the membership fees which are paid by industrial members. Therefore, continuation of individual committee activity is strictly dependent upon the interest in a respective committee's activity. Half of the committee members are university faculties, and the rest are scientists from government and private research institutions. Committee members are quite interdisciplinary and provide valuable information that tends to be lacking in Japan's discipline-oriented academic societies. However, these participants are a minority among the more than 90,000 research scientists registered as university research members.

In order to encourage university research into areas which assist industrial development, the Research Corporation of Japan provides limited funds to a contracting company. This assistance takes the form of an interest-free, risk-insured loan; if the development is commercially successful, the company has to pay back the loan. The average loan is 300 million yen per project over a three-year period. Currently, 10 to 15 projects are being sponsored. Since the fund is limited, the subject of the cooperative development is carefully chosen so that it is not too risky. This puts a large burden on the university scientists as it extends their research into further, more practical stages. However, many successful examples of past, cooperative development have encouraged industry to look into less-developed and more risky technological developments of university research.

The Science and Technology Agency has just started a new project that promotes the creation of innovative seed technologies. This project supports very creative scientists in universities and in industry. They are organized in several small groups by specific areas. This structure increases cooperation between the universites and industry. The Research Corporation of Japan is responsible for the administrative management of the project.

In spite of the fact that various efforts have been made to increase cooperation between universities and industry in the basic and applied sciences, considerable dissatisfaction exists in industry. This is due, mostly, to poor communications between universities and industry which results from the rapid decrease in the number of university faculty who have had industrial experiences or who have been willing to understand the problems of industry. As noted earlier, there still exists a strong distrust between industry and the universities as a result of developments during the period of rapid growth when technologies were imported. Industry should share the responsibility in this current situation. In order to increase the cooperation, industry has to contribute more to the university-managed, applied science projects.

D. Proposed Models of Interactions

Extensive studies and discussions on university-industry cooperation by many industrial groups have revealed that, if the existing models of interactions are fully utilized (although they are far from ideal), considerable advancement in cooperation can be accomplished. Much effort is needed, on both sides, to improve communication. Industry should clearly understand the charter of the university and then expand existing communication channels.

Industry is willing to provide instructors, without renumeration, to reduce the teaching load of the faculty and to better inform the academic community of basic scientific and technical problems that industry is facing. Industry is also willing to accept university scientists into their laboratories to enable faculties to acquire practical experience by participating in basic industrial research. This will undoubtedly increase mutual understanding and improve communication, and thereby strengthen university-industry cooperation. In order to pursue these practices, however, minor institutional amendments may be necessary.

In order to challenge the very complicated social needs of modern times, Japanese industry has to create more original technologies and products. To reach that objective, industry needs close cooperation in the following areas:

1. education of more creative scientists;
2. creation of basic knowledge and technologies that are based on basic social needs in universities and their effective development in industry; and
3. joint development of continuing education systems for scientists in both industry and in universities. This is a very basic function and is within the charters of the universities. However, in order to accomplish this objective, much closer and more effective cooperation is needed, not only between the universities and industry, but also among all parties involved. Also, many institutional barriers have to be removed.

These are not easy tasks, but Japan has to pursue them rigorously.

III. AN EXAMPLE OF THE KEK

After the establishment of a laboratory, KEK extended its activities, not only in the field of high-energy physics but also in the application of accelerator science to other fields. Many such engineering and technical developments have developed in collaboration with Japanese industries. Because of industrial collaborations on accelerators, excellent performance has been achieved in their stability and reliability. In turn, industries have learned many new technologies such as low-temperature and ultra-high vacuum technologies. The use of high-energy accelerators for industrial development, like the synchrotron light source, is rapidly growing in KEK activities. Based upon experiences over the last decade, brief comments relative to the collaborations between universities and industry are given in the following sections.

A. Merits of Collaboration

The merits obtained through KEK-industry collaborations are as follows.

1. Development and Use of Advanced Technologies

In the construction of accelerators and experimental instruments, many advanced technologies have been used in collaboration with industry. Typical examples are:

a. electroplating copper on steels for fabricating large and complicated RF-cavity structures;

b. computer technologies for accelerator control and data analysis, including automatic pattern recognition of bubble chamber pictures; and

c. aluminum engineering for vacuum equipment with the new welding and manufacturing method.

Although they are still in progress, superconductivity and ultra-high vacuum technologies should also be included here.

2. Innovations and Improvements of Industrial Materials and Products

The development and use of advanced technologies leads to new production procedures at the industrial site or to new products.

A new magnetic material, i.e., a grain-oriented, low-carbon steel, has been developed to achieve higher energies in accelerators by means of increasing the magnetic field by as much as 1.5 times more than those so far obtained. Cooperation between KEK and steel production companies made possible development of the process control system used to obtain the homogeneous qualities required over a large amount of such a special material. This new technology contributed to the increase in exports of steel and steel products.

Another interesting example is the story of a small TV parts company which became one of the leading manufacturers in the world in the production of photomultiplier tubes. Collaboration between engineers at that company and physicists at KEK started in the early 1960s. At that time, photomultiplier tubes for experiments had to be imported from western companies. This company is now developing the largest photomultiplier tube in the world, 20' in diameter, for experiments on verification of the theory on grand unifications.

3. Application of New Technologies like High-Energy Accelerators to Industrial Development

The accelerator itself can be used for the development of new technologies and new products for industrial use. Material research done with pulsed neutrons and muons, provided by the KEK booster synchrotron, has actively contributed to the investigation of unknown properties and of chemical reactions in many industrial materials.

Intense pencil beams of photons from the synchrotron light source, the Photon Factory, will develop much wider application in industries like x-ray lithography or micro-fabrication technology for super LSI production, structure analysis of bio-medical substances, trace element analysis for material science and pollution problems, etc. Experience with cancer diagnosis and therapy by use of these accelerator facilities indicates promise of a new field in radio-therapeutics.

4. Exchange of Information and Cultivation of Talent and Specialists

The merits of this kind of exchange are described in-depth in another chapter in this volume. The KEK also has contract-research programs for the retraining of engineers and scientists in industry.

B. The Problems of Collaboration

1. Sharing Functions between KEK and Industry

It is most important that the leadership in development and the accumulation of know-how be retained at the laboratory site. This is particularly important for a national laboratory as it enables the laboratory to collaborate with the most advanced industries and also to arrange fair collaborations with many other industries.

A typical example at KEK is the development of superconduction technologies. KEK collaborates with several leading industries in Japan on this subject and has successfully fabricated large superconducting magnets based upon the know-how developed through KEK's own R & D program.

2. Patent and Proprietary Information

This topic also requires proper attention and is discussed in-depth in another chapter in this volume.

3. International Cooperation

International cooperation, including industrial collaboration, will become more and more common in the field of large-scale basic research. The patent and proprietary information problem, however, may cause some difficulties in the development of such cooperation. In principle, such problems should be solved case by case. For example, KEK is promoting a very high-power klystron development program in cooperation with SLAC and two Japanese industries. The proprietary problems on this project are executed in accordance with the Implementing Arrangement on the United States-Japan Cooperation in High-Energy Physics which was signed between MESC and DOE in November 1980. An elaborated negotiation was held on the proprietary problem before the signing. More difficulties are always encountered in cooperative agreements with communist countries because most of them have no patent policies.

THE RELATIONSHIP BETWEEN NATIONAL GOALS AND R & D PROGRAMS IN FOUR UNITED STATES GOVERNMENT AGENCIES

Michael Radnor

Center for the Interdisciplinary Study
of Science and Technology
Northwestern University
Evanston, Illinois

I. INTRODUCTION

A number of United States federal agencies perform R & D to support their national missions. One question that arises, especially in periods of budget cutting, is how closely do the R & D portfolios reflect the goals for which the agencies are responsible. Such questioning is almost always tinged with the perjorative implication that R & D contributes very little to agency operational programs. To the contrary, the point is frequently made that R & D activities develop their own dynamics and rationales leading, in extreme cases, to "research for research's sake."

Two years ago, in response to a request from the U. S. Office of Management and Budget and from the National Science Foundation,

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a study was carried out to compare agency R & D portfolios with applicable national goals and plans. The fields studied were education, law enforcement, and housing. One additional study, on civil aeronautics, was added later in order to provide a mix of fields that varied across several dimensions. The variance allowed exploration of the differences to be observed in the relationship between agency R & D and operational programs in different fields.

II. OBJECTIVES AND LIMITATIONS IN THE USE OF THE ANALYSIS

The primary reason for such a study is to determine whether R & D investments, priorities, and efforts are being focused on the important problems, needs, and opportunities of present and future action programs. Since such action and such R & D programs may be carried out by many actors, in federal government, in local government, in private organization, or by individuals, it could be misleading to focus only on what is going on, or being planned, within federal government.

Allowing for the above cautions, policy-makers in federal government could use the findings to evaluate R & D programs for direction and emphasis. These policy-makers could be agency heads, R & D division managers, those concerned with government-wide budgets [such as the Office of Management and Budget (OMB) or the General Accounting Office (GAO)], or agencies concerned with the health and directions of national scientific activity, such as the National Science Foundation (NSF).

However, if useful information for future policy-making is to result from the analysis, certain conditions and requirements must be met and the results used properly. One conclusion of the study was that these necessary conditions can be only partially met at the present time and the dangers of misuse of the findings are substantial The analyses did produce some useful results (albeit with certain limitations) that could lead to important policy-relevant insights. The concerns regarding inadequacies in the assumptions underlying the analyses, the data bases upon which the analyst is forced to depend, and the possibilities of misinterpretation of the results, means that the findings must be tempered by an understanding of the dangers and limitations. These will be detailed later.

III. METHODOLOGY USED

A similar approach was taken with respect to each of the areas analyzed.

A. Identification of National Goals

Using a variety of documents, supplemented by interviews, a ranked listing of goals was developed for each agency. The types of documentation used were legislative records (actual laws authorizing the agency, hearings records, etc.), budget-related documents (appropriations, zero-based budget documents, etc.), agency program and project descriptions, various statements from the Office of the President and from various other sources, special study reports, and any other relevant materials that could be located. The interviews were carried out with agency officials and other knowledgeable persons.

The period involved was 1978-1981 although this varied somewhat across the fields being studied. The focus was on forward plans as well as current goals, an appropriate basis for relating to R & D programs.

Because of the variation in views of goals and plans that comes from different sources, the approach taken was, as far as possible, to:

1. establish the areas of general consensus across sources;

2. give greater emphasis to goals and plans that seemed to be pervasive across time, programs, and sources; and

3. resolve major remaining differences by giving precedence, in order, to the Office of the President, the Congress, and the agency.

A combination of methods was used to extract the goals and to set up priority ratings, direct use of priority statements, content analysis, and level of funding allocated to various program areas. In each instance a final prioritized list of goals was developed. These ranked goals were compared with a prioritized R & D portfolio list, both as discrete items and, in some cases, as grouped sets of recognized goal interrelationships among clusters of specific goals and plans.

B. Identification of R & D Portfolios

A similar analysis was carried out to identify agency R & D programs and priorities. The analysis was made easier by being able to use the actual R & D budgets and expenditures. But it was also made difficult by the uncertainty of what was to be included within the R & D domain.

The definition of the R & D domain is very broad for all areas, but particularly in the social areas (education, law enforcement, and to some degree, housing). It goes beyond carrying out research and development projects on well-defiend problems and then handing ready-made and fully implementable solutions to the operating units. Instead, considerable efforts may be involved in identifying problems and needs, in demonstrations, dissemination and transfer of new knowledge and technologies to users (including significant marketing aspects), follow-up, field assistance and training, maintenance and on-going improvements in new approaches, and evaluation programs, as well as the research and development work which has been traditionally viewed as the R & D domain. Seen this way, R & D-I (research, development, and innovation) is a more apt description of the range of activities in which the R & D arms of the agencies become involved. The above is far less true, however, for the case of aeronautics research (as carried out by the National Aeronautics and Space Administration—NASA).

Using this basis, an analysis was carried out on the R & D portfolios in the four fields again using documentary data (R & D program plans and descriptions, budgets, etc.), and supplementary interview data. A prioritized list of R & D areas was developed for the same periods as the goal statements.

C. *The Analysis*

A simple analysis was made comparing the national goal lists and their ranked priorities with the R & D programs lists and priorities.

Several questions were explored including:

1. To what extent did the same items appear on two lists?

2. To what degree was the ordering similar?

3. What might account for any observed gaps in either list compared to the other?

4. What might account for any observed differences in ranking?

The analyses and discussion are given in Section IV in a very highly summarized form for each field and then comparatively. Following the presentation of findings, a more detailed discussion will be given of the numerous problems (and disclaimers) regarding the analysis.

IV. ANALYSIS OF INDIVIDUAL FIELDS

A. *Education*

In the United States, the principle programmatic arm of the federal education establishment is the Office of Education (OE). There are also certain other agencies concerned with serving groups with special needs, such as minorities, the handicapped, the elderly, etc. R & D is performed largely by the National Institute of Education (NIE), but also by OE, by the various units concerned with special problems or needs, by NSF (through its science education directorates), and by a variety of other public and private institutions (many of them funded by NIE and OE, but others funded by independent sources). Included in this last group are universities and specialized research institutes. The Office of Education and NIE are parts of the new Department of Education; at the time of the study they were units within the Education Division of the Department of Health, Education and Welfare (which also conducted certain relevant programs, e.g., the gathering of educational statistics).

Despite this apparent complexity, for most practical purposes it could be taken that the key federal programmatic actors were, at the time, OE for practice programs, and NIE, OE, and NSF for the R & D programs.

1. Educational Goals.

An examination of stated goals, priorities and major programmatic thrusts in educational legislation, zero-based budget (ZBB) statements, Congressional hearings (and supporting agency documents) on appropriations, annual reports, and other significant documents permitted development of a 34-item set of potential priority goal areas ("key goal words"—see Table 1). These 34 goal areas were further subdivided into those which focused on specific *groups* and those which focused on specific *topics* (issues).

The 34-item goal area coding list was used throughout the analysis. The general form of the analysis was to examine specific documents (via content analysis) to determine the relative ranking of priority given to each of the 34 goal areas. Thus, content analyses were made of: 1) general statements and discussions of an agency's overall goals and priorities; 2) budgets; and 3) program or project summaries. Specific analyses depended on the nature of each document.

Two bases were used for the prioritization: 1) level of funding allocated; and 2) pervasiveness of the goal—how broadly and how frequently the issue appeared across the range of programs. There are substantial problems with these two measures. Level of funding is a measure of level of commitment but can be misleading; an agency may have little control in setting funding levels; some goals are inherently more costly to attain than others. Pervasiveness is also a measure of commitment, but it too may be misleading: simply reflecting "political wisdom" in "saying the right words;" it may represent an "inexpensive" goal which can thus be easily "tacked on" to programs.

The main analysis was focused on the discrete goals shown in Table 1. In addition, however, a secondary analysis was carried out using the grouped goals based on structures found in original source documentation, supplemented by our analyses and syntheses.

These are shown in Table 2.

TABLE I. Potential Priority Goal Emphases ("Key Goal Words")

Topics	
1. Basic Skills	14. Productivity
2. Achievement	15. Finance Management
3. Learning Process	16. Management
4. Instruction	17. Planning and Evaluation
5. Curriculum	18. Governance
6. Individualized Instruction	19. Education and Work
7. Technology	20. Urban
8. Guidance/Counseling	21. Rural
9. Access to Postsecondary Ed.	22. Desegregation
10. Lifelong Education	23. Safe Schools
11. Testing	24. Other National Needs
12. Evaluation	25. Dissemination
13. Training of Teachers and School Personnel	26. Compliance
Focal Groups	
1. Language Minorities	5. Handicapped
2. Racial-Ethnic Minorities	6. Neglected-Delinquent
3. Disadvantaged	7. Gifted
4. Women	8. Veterans

TABLE II. Grouped Goals

A. Access and the Underserved

B. Instruction and Educational Excellence

C. Strengthening the Educational System

D. Education, Work and Life

E. Dissemination

F. Evaluation

Table 3 shows the result of averaging the rankings based on the two criteria mentioned above: funding and pervasiveness. It is to be noted that some of the discrete goals can be covered by more than one grouped goal, as shown in the above tables. Also, as shown in Table 3, the goals were split into three levels based on what appeared to be natural priority sets.

*TABLE III. Averaged Priority Rankings**

Level	Averaged Rank	Rank Order	Goal Area	Group Goal
I	5.0	1	Evaluation	F
	5.0	1	Training for teachers and school personnel	B
	5.0	1	Dissemination	E
	5.0	1	Handicapped	A
	5.5	5	Disadvantaged	A
II	6.5	6	Access to postsecondary ed.	A, D
	7.0	7	Instruction	B
	7.0	7	Management	C
	7.5	9	Education and work	D
III	11.0	10	Curriculum	B
	11.5	11	Basic skills	A, B
	13.0	12	Compliance	A, C
	13.5	13	Lifelong education	D
	13.5	13	Governance	C
	14.0	15	Technology	B
	15.0	16	Urban	A
	16.0	17	Neglected/delinquent	A
	17.0	18	Individualized instruction	B
	17.5	18	Language minorities	A

(table continued on next page)

TABLE III. Averaged Priority Rankings (continued)*

Level	Averaged Rank	New Rank Order	Group Goal
I	(3) (3)	1 1	A. Access and the Underserved
	(4)	2	B. Instruction and Educational Excellence
II	(6)	3	C. Strengthening the Educational System
	(7)	4	D. Education Work and Life
III	(10)	5	E. Dissemination
	(11)	6	F. Evaluation

**In instances where a goal area was listed in only one column, we have arbitrarily assigned a ranking of 20 for averaging purposes.*

2. Educational R & D

Table 4 shows a composite summary of rankings made from thirteen separate analyses across the various federal R & D performing agencies described above. The point total shown results from these analyses which were derived from examination of documentary data on laboratory and center funding, research plans, ZBB documents, congressional presentations, etc. Again an attempt was made to identify levels by grouping clusters of ranking as shown.

The following should be noted:

1. For the most part, the rankings appeared reasonable from the knowledge of what was going on in federal R & D in education. This was confirmed by the judgment of several "expert" persons who reviewed the findings.

TABLE IV. Composite Summary of Rankings, Education R & D Agencies

Rank Order	Composite Point Total	Goal Area	Goal Group
1	38	Dissemination	E
2	34	Education and work	D
3	33	Instruction	B
4	28	Racial/ethnic minorities	A
5	24	Management	C
6	23	Basic skills	A,B
	23	Disadvantaged	A
8	22	Women	A,D
9	20	Testing	B
10	19	Learning process	B
	19	Finance management	C
12	18	Training for teachers and school personnel	B
13	14	Evaluation	F
14	13	Curriculum	B
	13	Urban	A
	13	Achievement	A
	13	Access to postsecondary education	A,D
18	12	Governance	C
19	11	Lifelong education	D
20	9	Desegregation	A
21	8	Productivity	E
21	8	Technology	B
21	8	Language minorities	A

(table continued on next page)

TABLE IV. Composite Summary of Rankings, Education R & D Agencies (continued)

Rank Order	*Composite 1 Point Total*	*Goal Group*
1	*116 1/2*	*A. Access and the Underserved*
2	*111*	*B. Instruction and Educational Excellence*
3	*74 1/2*	*C. Strengthening the Educational System*
4	*56*	*D. Education Work and Life*
5	*38*	*E. Dissemination*
6	*14*	*F. Evaluation*

2. There was some surprise at the high ranking for Education and Work in the individual goal ratings, but this issue is resolved in the group rankings. In general, for this goal area, one might have expected the analysis methodology to under-rate rather than over-rate.

3. Higher rankings might have been expected for Language Minorities and Desegregation.

3. The Educational Goals—R & D Analysis

An examination of the rank order differences that appear for discrete goals between Tables 3 and 4 was made on the following basis:

If the differences in Rank Order are:	*Then it may be said that OE R & D:*
0-4	strongly matched
5-8	moderately matched
9 or more	do not match

Using this simple method of analysis, it can be noted that:

a. There is a close match in seven goal areas: Dissemination, Disadvantaged, Instruction, Management, Curriculum, Urban, and Language Minorities.

b. There is a moderate match in eight goal areas: Access to Postsecondary Education, Education and Work, Basic Skills, Lifelong Education, Government, Technology, Neglected, and Individualized Instruction.

c. OE and R & D do not match in twelve goal areas. OE is higher than R & D regarding: Evaluation, Training, Handicapped, and Compliance. R & D is higher than OE regarding: Racial/Ethnic Minorities, Women, Testing, Learning Process, Finance Management, and Achievement.

It can be seen that the one goal that is clearly a common priority for action and R & D programs is dissemination. This reflects the known priorities, but this can also be misleading. Dissemination of R & D findings and products was also an easy (if done superficially), cheap, and non-controversial "add-on" that could be included with a wide variety of R & D programs. While there were a number of serious efforts to achieve wide and good dissemination, serious questions could be posed about many of the other efforts.

In the grouped analysis, a different picture emerges than at the discrete level.

1. Dissemination no longer takes on the priority that it had.

2. As might have been expected, Access and the Underserved (or Equity) and then Instruction (or Excellence) become the primary goal areas, followed by sets of goals involved with Strengthening the Educational System and Education, Work, and Life.

In general, the grouped analysis shows a much higher level of congruence between goals and R & D than was indicated by the discrete analysis. This reflects a successful effort by a highly threatened NIE to bring rhetoric in line with goals and political realities, but abdicating its leadership responsibility as it played the political survival game, rather than acting to make its programs more relevant. If anything, the congruence at the broad brush level and its lack at the more detailed level reinforces the perception that what is being observed is a political process.

B. Law Enforcement

The term "law enforcement," while sometimes used in the United States federal establishment to refer only to police activities, may also encompass the whole justice system: criminal and civil, prevention, rehabilitation, and victims. This broader definition is the one used for this study. The activities are, for the most part, carried on by the Department of Justice but other federal units, such as the Treasury Department, the Department of Health and Welfare, and the Judiciary, are also involved. At the time that the study was going on, one of the principal programmatic arms of Justics was the Law Enforcement and Criminal Justice (NILECJ), of Juvenile Justice (NIJJ), and of Corrections (NIC), and the Federal Bureau of Investigation, the Drug Enforcement Agency, the Federal Justice Research Program. With the demise of LEAA which used to coordinate a variety of these research programs, a number of them have been brought together in the new National Institute of Justice. However, this analysis will reflect the 1979-1980 situation.

Other research functions are to be found within Treasury (Bureau of Alcohol, Tobacco and Firearms, Customs, Internal Revenue Service), HEW (as it was then—Centers for Rape Prevention, for the Study of Crime and Delinquency, National Institute of Drug Abuse) and the Judiciary (Federal Judicial Center). There is also some research done by industry (largely on equipment), by foundations and by legal associations. These will not be dealt with in this analysis summary.

1. Law Enforcement Goals

Two approaches were used to develop the prioritized goal lists for law enforcement: 1) stated goals emanating from the Attorney General, the Deputy Attorney General, and from statements at appropriation hearings; and 2) empirically estimated goals based on budgeted resources, budget increases and decreases in appropriations, and from three sets of goal rankings derived from plans (decision packages) submitted by the Department of Justice, by the Treasury, and as developed by the OMB.

a. Stated goals. The analysis of the stated goals resulted in the following ranked list: 1) white collar crime; 2) organized crime; 3) public official corruption; 4) narcotics; 5) overcrowded prisons; and 6) state and local assistance.

b. Empirically-derived goals for the Department of Justice. The final list of ranked goals produced by this process is shown in Table 5. It will be noted that the four top priority stated goals previously discussed do fall among the top half of the empirical goals. Prisons seems notably absent. Improving operations efficiency and evaluation, that do appear in the Additional Goals list of Table 5, are surprisingly absent from the first list.

Regarding federal versus state and local government law enforcement goals, an analysis was carried out on the local goals based on a resolution passed by the National Governors' Association Committee for Criminal Justice (July 9, 1979). As might have been expected, there was a considerable degree of variation between the federal and local goals. The decision was made to focus primarily on the federal level, and to use these local goals in a secondary analysis only.

TABLE V. Empirically-Derived Law Enforcement Goals

Rank	Goal	Rank	Goal
1	Organized crime	12	Explosives
2	White collar crime	13	Alcohol and tobacco
3	Customs (smuggling)	14	Land and natural resources
4	Tax fraud	15	Community treatment centers
5	Immigration	16	Firearms
6	Civil rights	17	Fugitives
7	General government crimes	18	Research
8	Protection (Secret Service)	19	Assistance to state/local
9	Counterfeit	20	Terrorism
10	Narcotics	21	Parole
11	Forgery		

Additional Goals Derived from HEW and Judiciary (unranked)
Improving efficiency
Evaluation
Classification
Sentencing
Juvenile deliquency
Rape prevention

2. Law Enforcement R & D

The R & D analysis was very difficult to do using the planned methodology. The budgets and R & D priorities of 16 research units across the Department of Justice, Treasury, HEW, and the Judiciary were assembled primarily for fiscal years 1978 and 1979. However, the enormous variation in program construction and de-

TABLE VI. Grouped Law Enforcement R & D Programs

1. Juveniles
2. Crimes (narcotics, rape, tax, customs, white collar, terror, immigration, explosives, other) *3. Effectiveness (of law enforcement, courts)*
4. Effectiveness of R & D
5. Criminals *6. Prisons*
7. Victims (restitution, etc.)

scription made a synthesis highly subjective and qualitative, despite the quantitative data available.

A ranking of R & D emphasis across the 16 federal research units based primarily on budget allocations was carried out. A matrix of the intersections between the empirical federal goals and the existence of R & D programs in the various agencies was developed. It was demonstrated that R & D on juveniles ranked first by a long way, well above the next item which focused on improving the law enforcement R & D process, especially in the area of technology transfer. This item stood well above the next two which were devoted to improving the effectiveness of the law enforcement process and somewhat lower than court operations. The next six areas were clustered together. If rape and other crimes are considered as one category then the ranking of this group would have risen to fourth place.

Clustering the R & D programs into groups produced the pattern shown in Table 6. There is, of course, considerable actual and possible overlap. The decision to keep juveniles separate from criminals is appropriate. The inclusion of the wide spectrum of activities in crimes (e.g., immigration, explosives as well as rape, white collar, etc.) could be questioned.

3. The Law Enforcement Goals—R & D Analysis

Juvenile is clearly the most active area for federal law enforcement R & D efforts even though it does not appear specifically as one of the Department of Justice program goal areas. The reason for this is structural: the National Institute of Juvenile Justice is a separate and highly-funded unit and the goal is implicit—namely, assisting through research the juvenile programs that are carried out at the state and local levels. Dealing with juveniles does appear as a priority expressed by the state governors.

The heavy R & D emphasis on improving effectiveness (or efficiency) is again not explicit in the goals but would have relevance across a wide range of programmatic areas. Even so, the concentration on process, as opposed to law enforcement topic related research, reflects a typical research-practitioner cleavage, especially considering the low priority that research seems to have on the goal rankings.

Going down the ranked list of goals, it can be seen that the top two areas, organized and white collar crime, receive very little R & D attention. There is no obvious R & D program on organized crime, although something confidential may be buried within the R & D effort in the Federal Bureau of Investigation. Alternatively, the area may not be seen as one amenable to R & D efforts, though this seems questionable. There is a modest white collar crime R & D program within NILECJ, but not commensurate with its high goal priority. Similarly, customs, tax, and immigration, which ranked 3, 4, and 5, show up as 11, 7, and 15 on the R & D list—a much lower emphasis. Civil rights receives no research support. On the other hand, community programs and, to some degree, narcotics, receive more R & D attention than would be indicated by their goal ranks.

The effect of grouping the programs puts crime R & D at a high level (but below juveniles) which is relatively congruent with the cluster of crime-related goals that occupy the majority of the top ranked Justice Department goals. The lack of congruence at the discrete level, however, makes this finding somewhat misleading.

Since a substantial portion of federal R & D effort was devoted to supporting assistance and innovation efforts at the state and local levels (reflecting the local character of much of the United States law enforcement), a specific analysis was carried out to examine the relation between federal R & D programs and state and local goals for law enforcement (based on the previously mentioned "governors' priorities") by making the comparison with the expenditures of the two largest federal research institutes most directly serving the local situation (NILECJ and NIJJ). A significant lack of congruence was observed even though all of the governors' priorities were supported—but did not fall into the top priority areas of the institutes.

In summary, the data would seem to indicate that federal law enforcement R & D only partially serves the program areas as defined by the overall priority goals, and this applies to both the national, state, and local levels. At least one explanation lies in the difference between the manner in which goals have been used here and what actually drives programs within the various and many operating and R & D units of federal government.

The analysis here looked at overall national and local goals. Law enforcement is not structured to reflect this objective system. One of the significant problems in law enforcement practice and research programs is the lack of any useful relation between the goal setting and operational processes. Therefore, the many and diffused individual units can, and do, tend to go their own ways—this is reflected in the data.

C. *Housing*

The prime federal performer of operational and R & D programs in housing is the Department of Housing and Urban Development (HUD). Federal housing support is also provided by the Economic Development Administration of the Department of Commerce. Considerable operational and R & D housing-related activity goes on in the private sector (construction, engineering, planning, materials, etc.), and some R & D in universities.

Housing is a relatively new area for federal programs in the United States. This "newness" creates both opportunities (such as the possibility of designing integrated R & D programs unfettered by entrenched commitments) and constraints (such as an inadeqaute data base and a yet unproven and low visibility R & D base).

In this analysis the focus will be primarily on HUD, with secondary attention given to private sector R & D.

1. *Housing Goals*

An analysis of HUD program documents and interviews with officials generated a list of eight general housing goals. These were prioritized through the use of two methods:

a. Identification of federal expenditures on housing by line items in yearly appropriations and from the ZBB process.

b. Comparison of goals with major housing programs, using key words to match programs and stated goals.

The result of this analysis is shown in Table 7. More recent HUD documents indicate an upward shift of the cost reduction goal (ranked 5 in Table 7) and the addition of another goal: increased energy efficiency.

TABLE VII. Federal Housing Goals

1. Revitalize distressed communities and prevent deterioration of non-distressed communities.
2. Ensure availability of decent and affordable housing for all persons.
3. Ensure freedom of opportunity in housing for all persons.
4. Help communities and neighborhoods to increase their capacity to achieve revitalization and stabilization.
5. Reduce housing costs.
6. Produce housing of sound standards of design construction livability and size.
7. Increase efficiency in residential construction and maintenance.
8. Stabilize the housing industry.

2. Housing R & D

Two approaches were used to identify housing R & D priorities. The primary data base was the actual HUD R & D programs prioritized by their 1980 estimated expenditures. This is shown in Table 8. An even more detailed but similar analysis was carried out at the project level. Each of the 365 R & D projects being conducted by the agency was examined and categorized (using a key word approach) to determine into which of the national goal categories it fell. A secondary analysis was also performed using HUD documents, congressional records and interviews to identify the stated intentions of the agency regarding R & D (i.e., their R & D goals). The comparison between HUDs stated goals and actual programs revealed only a modest level of association. This was confirmed also by a detailed review of the individual project descriptions. Based on this finding, the decision was made to use only the actual program priorities for the comparison with national housing goals.

One additional analysis was carried out on the major budgetary changes in housing R & D from 1979-1980. This showed dramatic shifts in several areas:

1. Housing economic data analysis grew by 9 percent, but on the largest R & D budget item ($13.9 to $15.1 million—representing around a quarter of the total R & D budget). All this growth was in the survey of housing ($1.64 million), a program mandated by Congress.

2. Within housing assistance research (which remained nearly constant), the area of policy research grew by 250 percent at the expense of experimental housing assistance.

*TABLE VIII. Prioritized Housing R & D Programs **

1. Housing economic data analysis ($15.1M)
2. Housing assistance research ($9.8M)
3. Community development research ($6.4M)
4. Program evaluation ($5.9M)
5. Consumer and equal opportunity research ($5.3M)
6. Community conservation research ($3.1M)
7. Housing safety and standards research ($2.9M)
8. R & D program support and utilization $2.7M)
9. Energy conservation and standards research ($1.9M)

**Figures in parentheses are 1980 estimated expenditures.*

3. Both community development and community conservation research were reduced—especially the latter—by a dramatic 73 percent.

4. Program evaluation grew by an impressive 62 percent.

5. The housing counseling and aid portion of the consumer and equal opportunity research area fell by 59 percent.

6. The energy conservation area grew by 187 percent, but on a still modest basis.

3. The Housing Goals—R & D Analysis

A detailed analysis was carried out relating R & D programs (in total and in terms of major program elements) to national housing goals. These were then related to the eight previously identified federal housing goal areas, using a key words approach drawn from the description of the program areas. Table 9 shows the various intersections between the R & D programs and the prioritized goal areas.

There is a match between the top 3 R & D programs (in terms of funding) and the top 3 national goals. Some anomalies may be seen in specific program areas, such as energy conservation research (a newly emerging area not directly related to the existing eight national goals, although it could be related to Goal 6, which calls for housing of improved construction and livability). There is also a gap in the program evaluation area which cannot be related to national goals but serves to maintain the R & D system and research support and utilization which is also used to maintain the system.

It can be seen from Table 9 that each R & D program is geared toward a certain national goal or a small subset of national goals. There is also some correlation between R & D programs which receive the large share of expenditures and the housing national

TABLE IX. Relation between Housing R & D Programs and National Goals

R & D Programs (in order of expenditures)	*National Goals Related to them*
1. Housing Economic Data Analysis	*1, 2*
2. Housing Assistance Research	*1, 2, 3, 4, 8*
3. Community Development Research	*1, 2, 3, 4, 8*
4. Program Evaluation	-------
5. Consumer and Equal Opportunity Research	*2, 3, 4*
6. Community Conservation Research	*1, 2, 3, 4*
7. Housing Safety and Standards (including Fire Research and Building Technology)	*5, 6, 7, 8*
8. R & D Program Support	-------
9. Energy Conservation and Standards Research	*6*

goals that are high on a priority list. (For example: Programs 1, 2, and 3, geared toward national goals 1, 2, and 3.)

The 1979 to 1980 observed shift, giving more emphasis to policy and data studies and less to community conservation and to counseling, is not congruent with the housing goals priorities. When added to the big increase in program evaluation observed above, this shift has to be viewed as part of a strategy of building up the R & D capacity of HUD. The relative newness of the federal housing R & D structure gives some justification to such a strategy. This could help build-up the needed base for solid future programs, even though (in a period of fixed or, as was the case, reduced budgets) this forces the agency to deemphasize programs directly supportive of high-priority national housing goals. The shift could be viewed as a maturing response of housing R & D away from reactive and short-term "problem-solving" activities that have neglected more fundamental R & D functions, toward a more basic and research infrastructure-building strategy.

Also, it should be noted that the cost reduction goal which was ranked fifth (and recently gaining in emphasis) in the national goals was not reflected to a significant degree in the R & D program. However, the new national energy conservation goal was predicted (or perhaps stimulated) by the appropriate R & D program.

Comment on private sector R & D. The variety of firms involved in the industry is enormous—from relatively specialized industries that manufacture components or deliver services necessary for the construction and the maintenance of buildings and dwellings, to industries ranging from manufacturers of building materials (steel, cement, composites), to paints and welding (to cite a few), and also to such services as engineering and architecture. The complexity and variety of specialized products and services of this "industry" makes a comprehensive analysis of its R & D very difficult.

It is worth noting that there is no coordination between government R & D in housing and research in the private industry. However, despite this, a certain degree of complementarity exists. The technically-oriented research in government is mainly standards-oriented, as well as research-concentrated on long-range, fundamental exploration of phenomena (i.e., fire research). It appears that there is no visible duplication of effort between R & D in government and in the private sector.

D. Civil Aeronautics

Aeronautics can be divided into civilian and military. Until a few years ago, there was a relatively close relationship between the two, especially in R & D, but by now this has diverged to a major extent. This analysis will be focused on civilian aeronautics.

Civil aeronautics production is carried on in the United States in the private sector by such firms as Boeing, Douglas, General Electric, and Pratt and Whitney. R & D is carried on in the federal sector primarily by the National Aeronautics and Space Administration (NASA). The Department of Transportation (DOT), the Civil Aeronautics Board (CAB), and the Federal Aviation Administration (FAA) play roles that have more to do with administrative and regulatory aspects rather than hardware development. R & D is also carried on by industry and by universities. For all practical purposes it is NASA that is responsible for the federal role in Civil Aeronautics R & D (CARD). Their projects are carried out at their own R & D centers and through contracts with industry and universities.

NASA also does R & D with military implications and or applications. The fundamental work which it does creates a knowledge base with both military and civilian implications. Because of the noted divergence in directions and goals between civil and military applications, the overlap in applied research and developmental projects is now quite small. NASA has become explicit in statements to Congress about projects that have military application (making them easier to factor out), something they never needed to do in the past. The Department of Defense has the priamry responsibility for military R & D, although some of that work has civilian relevance.

1. Civil Aeronautics Goals

The federal government does not have an operational function in civil aeronautics (or producing or even directly improving airplanes or flight systems), unlike that which it has in space (with NASA), or in education, or in housing. Therefore, its mission is focused on R & D programs that support operations carried out by industry. Therefore, federal civil aeronautics goals are goals intended to guide NASAs R & D programs.

These aeronautics goals for NASA were identified using a content analysis of hearings held before House and Senate committees in which NASA appropriations were discussed and from reviews of various documents. Since the hearings contain statements by top NASA officials, scientists, and other experts, as well as the committee members, they provide a broad data base from which to extract the goals. This documentary analysis was supplemented by interviews with NASA personnel.

The NASA appropriation hearings, for all years from 1970 to 1981, were analyzed using a key word methodology. Goals were identified in each year as follows:

1. Goal words (such as safety, economy/efficiency, environmental acceptability) mentioned in the context of national priorities, urgency, needs, etc., were noted.

2. Each identified goal was assigned a priority according to its frequency of mention, the emphasis of the statement in which it occurred, the rank of the person making the statement, and the extent of discussion the statement evoked.

Over the extended period covered by the analysis certain changes in goals and priorities were observed. Some current R & D programs were launched by goals of several years ago that have since lost priority. To take into account such changes, a scoring method was used that gave the 1970-1974 period goals a weight of *1*, those from 1975-1979 a weight of *2*, and those from 1980-1981 a weight of *3*. The resulting scores were further modified by giving goals a small additional weighting if they also appeared is several other key documents that were also analyzed. The final ranking of the derived goals is shown in Table 10.

TABLE X. National Civil Aeronautics Goals

Goal	Code
Noise reduction	*NOISE*
Improved competitiveness of U.S. aeronatucis industry	*COMP*
Improved and strengthened technological base and capabilities	*TECH*
Energy efficiency and conservation	*ENERGY*
Economic efficiency and cost reduction	*EFFICIENCY*
Improved speed and performance	*PERF.*
Environmental acceptability	*ENVIRON.*
Improved air systems	*AIR SYS.*
Support for military activities in aeronautics	*MILITARY*
Safety of passengers, crew, etc.	*SAFETY*

2. Civil Aeronautics R & D

Prioritizing R & D goals, as reflected in the budgetary expenditures of NASA, were carried out definitively using two methods of ranking. In the first method, use was made of the Program and Specific Objectives documents of NASA which detail the various program components of NASA activities down to the Research and Technology Operating Plan (RTOP). NASA R & D programs are developed on a multi-level program structure for two program areas: 1) Research and Technology Base, and 2) Systems Technology. At each level, specific objectives and targets are described. For this analysis, use was made of the objectives described for the next level (programs-disciplines). This is the same level at which budget items are detailed in the NASA budget statement, hence making comparisons possible.

In a first analysis, a set of key words and phrases was identified based on the goal words previously discussed. An analysis was done of each program objective in terms of the different key words and phrases and, hence, goal areas to which explicit reference was made. A matrix of goal areas versus programs was developed so as to indicate which programs related to which goals. The simple sum of the programs related to each goal was used to rank-order the R & D goals. A second analysis involved the dollar amounts for each program—using fiscal year 1981, Revised Estimates from NASA Budget Statement 1982. For each goal, the total amount of funds, for all the programs identified as related to that goal, was computed. This was used as a basis for a second ranking.

The result of these analyses are shown (as well as an average ranking) in the prioritized lists of the R & D goals in Table 11. The key word and budget rankings were quite close to each other. By carrying out this double analysis, the possibility that some programs may be inherently less expensive than others, but still relate to several goals, was minimized, since such differences would be reflected in differences in the two rankings. Programs such as the High-Speed, Low-Speed, and Advanced Propulsion Technology programs under Systems Technology are substantially more costly than General Aviation in the same category. A reference to a particular goal in the program objective statement of High-Speed Aircraft Systems Technology is not, therefore, equivalent to a reference in the program objective statement of General Aviation to that same goal, if dollar amounts are taken into account. On the other hand, the simple "checking" techniques did provide a means of assessing the pervasiveness of goals across programs.

From the matrix analysis it was found that with one exception (multidisciplinarity), each of the R & D goals areas was covered by a variety of program areas and each program area related to at least one R & D goal. Several R & D programs, however (aerodynamics in the R & D base, and propulsion and avionics in the systems technology programs) were related to only one or two generally minor R & D goals. However, the two goal areas to which the large aerodynamics R & D program did relate directly are amongst the highest ranked and largest of the agency R & D goals (noise

TABLE XI. Civil Aeronautics R & D Program Goals

Rank	*Key Word Analysis*	*Budget Analysis*	*Average Ranking*
1	*Safety*	= *Safety*	*Safety*
2	*Performance*	= *Performance*	*Performance*
3	*Noise*	= *Noise*	*Noise*
4	*Competitiveness*	= *Competitiveness*	*Competitiveness*
5	= *Energy*	= *Energy*	= *Energy*
6	= *Efficiency*	= *Efficiency*	= *Efficiency*
7	= *Technology*	= *Military*	*Military*
8	= *Military*	*Environmental*	*Technology*
9	*Air Systems*	*Technology*	*Environmental*
10	*Environmental*	*Air Systems*	*Air Systems*

and performance). The three low related and unrelated areas can be viewed as part of NASAs efforts to strengthen its R & D capacity.

The general high level of goal and R & D program intersection is not just an example of close coordination. It also reflects a conscious effort on the part of NASA personnel to ensure justification of their programs through the use of appropriate descriptors when requesting funds.

3. The Civil Aeronatucis Goals—R & D Analysis

Table 12 shows the rankings of NASA R & D goals as derived from the Congressional hearings compared to the rankings of the R & D programs derived from the actual program descriptions and budgets.

It can be seen that there is, in general, a very close relation with an overall average discrepancy of only one-and-one-half ranks. In fact, it is only energy and environment that create most of what little discrepancy there is; and it should be noted that these are new priorities that are gradually becoming national priorities in launching new NASA R & D programs. As yet, they have reached only fifth place for energy and an even lower rank for environment. If these two areas are removed from the table, then five of the next six top Congressional goals are also top NASA program goals.

The explanation for the discrepancy with military may be due, as mentioned before, to the fact that in the past, military and civil aeronautics R & D had much in common. As there were considerable complementarities, it was not necessary to state explicitly that military support was a part of NASA's objectives and concerns, or of its civil aeronautics R & D. This need emerged only relatively recently, and as not too great a concern, which explains why military support has a low rank in overall goals. However, within NASA, first due to the long-standing mutuality of civil and military aeronautics R & D, and secondly because of the added emphasis of recent years, the rank is still at a somewhat higher level than was warranted by the goal prior-

TABLE XII. Congressional Goals and NASA Programs

Rank	Congressional, NASA Goals		NASA R & D Programs	Ranking Discrepancy
1	Energy		Safety	-4½
2	Safety		Performance	+1
3	Performance	=	Noise	+1
4	Noise		Competitiveness	+1½
5	Competitiveness	=	Energy	+1½
6	Environmental		Efficiency	-3
7	Efficiency		Military	+1½
8	Technology		Technology	0
9	Military		Environmental	+2
10	Air Systems		Air Systems	0
			Average Discrepancy	+1½

note: ½ shown to take into account equal rankings.

ities (but still in the lower part of the priority list).

The low ranking for Air Systems may be explainable by the fact that the definition of improving air transportation systems has not been clearly articulated. In general, much of NASAs work is directly or indirectly related to improvement of air systems. On the other hand, explicit concern with improving air systems is more the mandate of the CAB, the FAA and the DOT.

In general, the close fit for the two rankings leads to two conclusions:

1. Since overall goals for civil aeronautics are fairly well specified and tangible, they are relatively easy to translate into concrete and proportionately prioritized R & D programs. The "hardware" nature of the activity enhances this possibility.

2. The time dimension is important in understanding the match between the actual activities and the overall expressed goals. Long lead times are sometimes involved in CARD projects, and the achievement of civil aeronautics goals similarly envisage long and sustained efforts. A "point in time" analysis will lose this dimension of the process.

V. COMPARATIVE ANALYSIS

Examination of the patterns across the four fields examined in the ways the analysis had to be done, reveals some interesting similarities and differences. These have been summarized in Table 13.

It can be seen that education and law enforcement, two primarily social science-based fields, have relatively similar patterns with respect to national goals and R & D program characteristics. These patterns are very different from those observed in the largely physical science-based field of civil aeronautics.

TABLE XIII. Comparison of Findings Across Fields

	Education	Law Enforcement	Housing	Civil Aeronautics
1. GOALS				
a. Multiplicity and Diffusion	Very High	Very High	Some	Low
b. Precision/Independence	Very Low	Low	Modest	Very Hgih
c. Relation between stated and budgeted goals	Very Low	Very Low	Some	Very High
d. Clarity of changes	Not Obvious	Not Obvious	Modest	High
2. R & D PROGRAMS				
a. Specifity versus Diffusion	Very Diffused	Very Diffused	Modest	Very High
b. Ability to define programs	Very Low	Very Low	Modest	Very High
c. Relation between stated and budgeted programs	Very Low	Low	Modest	Very High
d. Sense of portfolio	None	None	Some	Very High
e. System building	Some	Some	High	Some
3. GOALS—R & D RELATION				
a. Congruence	Very Low	Low	Fair	Very High
b. Role of rhetoric	Very High	Very High	Some	Some
c. Responsiveness over time	Not Clear	Not Clear	Significant	Significant

Housing patterns (which are mostly social science-based—but not entirely), are somewhere in between—but perhaps closer to the two former fields. A rating in terms of the degrees of goal and R & D program specificity, and the level of congruence between them, would put civil aeronautics clearly at the top, housing quite a bit lower, law enforcement somewhat lower yet, and education just a short distance behind.

The varying disciplinary bases of these four fields is one source of explanation for the observed differences. The specificity and level of development of the knowledge base do have an important impact, but this does not explain the whole observed difference. The operational programs in education and law enforcement are also less well-defined than those in housing, and far less so than those in aeronautics; at the same time they are much more value-laden and politicized. The public shows very little concern for what goes on in aeronautics; it cares very much about what goes on in education, law enforcement and, to some degree, in housing. Given the concommitant low specificity of the fields, rhetoric, and fadism take on a very large role in program descriptions and also in leader speeches—not always matched by actual program efforts.

Another significant factor is the varying maturity of the four fields.

Formal R & D programs and institutions in education, law enforcement, and housing are very new. They lack the traditions, the skills, the experience, the data bases, the linkages, and the many other attributes of an effective R & D operation that are found in aeronautics. NASA (with its predecessor NACA) has been doing R & D in aeronautics for almost 80 years. Its R & D centers are models of research establishments (in appearance, much like the best of university campuses blended with first-class industrial research laboratories); its people understand the "research game." The equivalent people at NIE, NIJ, and HUD are far less experienced. Further, these less-developed fields face the dilemma of having to prove themselves to survive to a greater degree while still building their R & D base.

Therefore, it should not be surprising that the cross-field differences were as observed. The issue now becomes one of how to use the observed findings for policy purposes.

VI. SOME CONCLUDING POLICY-RELEVANT COMMENTS

While R & D personnel frequently resist the idea, the extent, and the nature of the relation between a government agency's mission and its R & D programs is a legitimate concern of policymakers. Without sufficient and proper information on this question there is no hope that they can participate in a productive manner in the critical decisions having to do with budget sizes and allocations. They do not (as many R & D personnel sometimes, and wrongly, wish) abdicate these responsibilities to the R & D leadership. Instead, they often make very arbitrary and frequently destructive decisions to change, cut, or even increase overall and individual R & D program budgets. It is to R & Ds interest to improve the quality of the knowledge with which they work in making such decisions. This project set out to illustrate that this can be done and by doing it in several cases.

Various levels of relationship (or more accurately, for just about three of the four cases studied, the lack of much relation) were demonstrated. How much confidence should decision-makers place in the findings? It is with some regret that they must be warned to use them only with the greatest caution. Several reasons may be cited.

A. Goal Limitations

It is often assumed in this type of analysis that a meaningful set of prioritized national goals can be defined for a sector as the basis for evaluating the relevance of the R & D programs. We saw that this was not so, especially for those fields where discrepancy was likely and hence the need greatest. This should not have been surprising. Goals are political statements that are changeable, conflicting, often deliberately ambiguous, and inconsistent—especially in highly politicized and immature fields such as education and law enforcement. Different leaders and other influential persons espouse different goals at different times; the goals vary across institutions, government levels, etc. A consensus that produces a clear direction for R & D is rare. Agencies are generally poor at formulating goals and at translating them into program plans. Therefore, the following tends to abound: high-sounding, unprioritized, and meaningless generalities; skillful ex-post facto rationalizations of programs to meet vague goals; and management styles that combine very general direction with detailed interference (the worst of all worlds).

It follows that just because discrepancies are observed in the goals-R & D programs relation, the "blame" should not be laid automatically at R & Ds door. They cannot be expected to follow leadership that is not given. But should R & D wait for leadership or provide its own? What is R & Ds role and responsibility?

B. The Structure and Functioning of R & D

What is required of R & D varies greatly across fields. In a mature and highly differentiated field like aeronautics, R & D responsibility is much more narrow and defined than in education or law enforcement. Despite the many well-known problems of transition from R & D to field practice, the pull of practice needs, and the leadership push of technological opportunities, are crystal clear in aeronautics by comparison with the murky environment in which educational researchers must operate. These personnel must concern themselves with a much broader range of activities, from need identification to knowledge production to utilization. Their programs cannot be as specific. There will always be a shifting tension between R & D definition of needs, applications, and results and those of practitioners in such diffuse fields. They will always be forced into extreme responsiveness to external pressures and the political shifts in the wind.

It also follows that it is not sufficient to know the state of the relation between national goals and R & D programs. An agency can be working in a high-priority goal area, but be putting the wrong emphasis on the program, such as doing too little or too much on need identification, basic or applied research, or development, on dissemination or demonstration, etc. An excellent example was observed in education where pressures to show some practical results led to the development of a large-scale dissemination effort even though there was not that much of value to disseminate—"marshalling forces for battle with unloaded cannon!"

C. The Goals—R & D Programs Relation

There is a superficial implication that the greater the congruence between goals and R & D programs the better. Is this so? No, or little relation would obviously be troubling, although conditions could exist where this might be appropriate. (For example, when trying to go a new way, or when practice programs were not thought to need research, i.e., for prisons—some would claim to just build more while others would, and should, challenge such claims.) But too close a synchronization could also be troubling. R & D may have ceded its proper leadership role of showing new directions and creating new opportunities. Clearly a balance is required; but what should this be?

Short- and long-term cyclical patterns are involved. A period of radical innovation growing out of basic research may require a shift in emphasis to development exploitation, elaboration, and support for the new programs. If R & D fails to do this, it is subverting its responsibility; if it becomes completely committed to such activity, plus being overly-responsive to the shifting and often fleeting pressures from funders and users, it abdicates its mission of enlarging the knowledge base and of safeguarding the future. This had occurred, to a major degree, in education and law enforcement.

There is also a problem in taking a program-by-program approach which fails to consider the implications of portfolio balance. Even though the individual programs do seem to be the "right" set, they may not interrelate to give the cumulative and coherent thrust and synergy that is necessary for a viable R & D effort. Related is the question of continuity. R & D programs cannot easily be turned on and off to meet changing goal patterns. Programs and the needed skill groups must be phased in and out. This was observable in civil aeronautics in their energy and environment programs.

D. Data Base Inadequacies

The tortuous process by which the goals and programs and priorities were reconstructed in this study clearly illustrate the problem. The data to do the analyses are simply inadequate or unavailable, yet such studies need to be done. If policy-makers want to use them, then provisions must be made to develop the needed data bases.

In summary, then, this exercise has been helpful in giving an insight into the goals-R & D programs relation to federal agencies. It has also demonstrated the problems and difficulties inherent in carrying out such studies—and by implication, the dangers of policy-makers misusing the findings of the analyses.

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