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FINDINGS,
POLICY ISSUES,
AND OPTIONS

A Study of the
Transfer of Agricultural
and Food-Related
Technologies

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Institute for Policy Research and Evaluation
The Pennsylvania State University
University Park, Pennsylvania 16802

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EXECUTIVE SUMMARY

I. Introduction

The American system of public and private development and transfer of agricultural and food technologies is complex, varied, and changing. To assist public decision makers to adequately understand and assess the agricultural technology delivery system, the U.S. Department of Agriculture-Science and Education prepared a prospectus in 1981 for a study of "The Transfer of Agricultural, Food, and Related Technologies." After a competitive award process, the Institute for Policy Research and Evaluation, The Pennsylvania State University, was selected to conduct the study.[1] An Advisory Panel composed of representatives from public sector and private sector research and technology transfer organizations provided technical assistance and an on-going critique during the course of the study. (The members of the Advisory Panel are listed in Appendix A.)

This executive summary presents the principal findings of the Institute's study.[2] The study addressed the following objectives:

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[1]The senior members of the study group were Dr. Irwin Feller (Principal Investigator), Professor of Economics and Director, Institute for Policy Research and Evaluation; Dr. J. Patrick Madden, Professor of Agricultural Economics; Dr. Dan E. Moore, Associate Professor of Rural Sociology Extension; Dr. Laura S. Sims, Associate Professor of Nutrition in Public Health; and D. Lynne Kaltreider, Research Assistant, Institute for Policy Research and Evaluation.

[2]The full study report is presented in five volumes: Volume 1, A Document-Based Review of Organizations and Their Linkages; Volume 2,

(Footnote Continued)

1. Examine public and private sector influence on and support of technology development and diffusion in agriculture, food, and related areas where the private sector and the consumer are the primary users of the new technology.

2. Delineate the roles, responsibilities, activities, and relationships among the variety of organizations--public and private, federal and state, research and extension--involved in the development and diffusion of food, agricultural, and related technologies.

3. Analyze how this complex operates in relation to current theoretical understandings of technological innovation and diffusion and the ways in which governments can facilitate technology transfer.

4. Examine the mechanisms that technology development and diffusion organizations employ to: (1) avoid, detect, and minimize negative consequences of technologies, and (2) detect and capitalize on positive consequences.

5. Provide a foundation for guiding food and agricultural technology policies, including intergovernmental policy.

The study's principal subjects are public sector organizations--the Agricultural Research Service (ARS), the Cooperative State Research Service (CSRS), and the Extension Service (ES) within USDA, and the state agricultural experiment stations (SAES) and the Cooperative Extension Services (CES) at 1862 and 1890 land-grant universities. It also describes developments in other federal agencies, in state-supported

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(Footnote Continued)
Surveys of Organizations and Their Linkages; and Research and Extension in Human Nutrition, Food Science, and Home Economics; Volume 3, Review of Previous Case Studies; Volume 4, Case Studies of Organizational Linkages and Technology Transfer; Volume 5, Overall Study Report: Findings and Recommendations. This executive summary draws principally from Volume 5.

The materials reported on in each study segment underwent extensive review. The commodity and process research subsystem chapters (Volume 1) were sent to knowledgeable individuals within each field, and the chapters reporting on interviews in the survey states and in federal organizations (Volume 2) were sent to a number of interviewees from each site to check the accuracy of the factual components of the chapters.

universities and colleges, and in the private sector. It discusses the myriad ways in which the activities of these organizations interact with those of the USDA/land-grant sector.

The report emphasizes two aspects of the long-term contribution that public sector organizations have made to agricultural productivity and other societal goals: (1) their ability to comprise an articulated technology delivery system, linking research with technology transfer; and (2) their ability to adapt their activities to changing external environments.

II. Methodology

The study employed four mutually supportive approaches to identify and describe the organizations, programs, processes, and factors that link developers, diffusers, and users of agricultural and food technologies with those that support technology development and transfer. These four approaches were:

1. A document-based review of organizations and their linkages.
2. Surveys of organizations and their linkages.
3. A review of previous case studies of the development and transfer of technologies.
4. New case studies of organizational linkages in technology development and transfer.[3]

The relationships among the study segments are illustrated in Figure 1.

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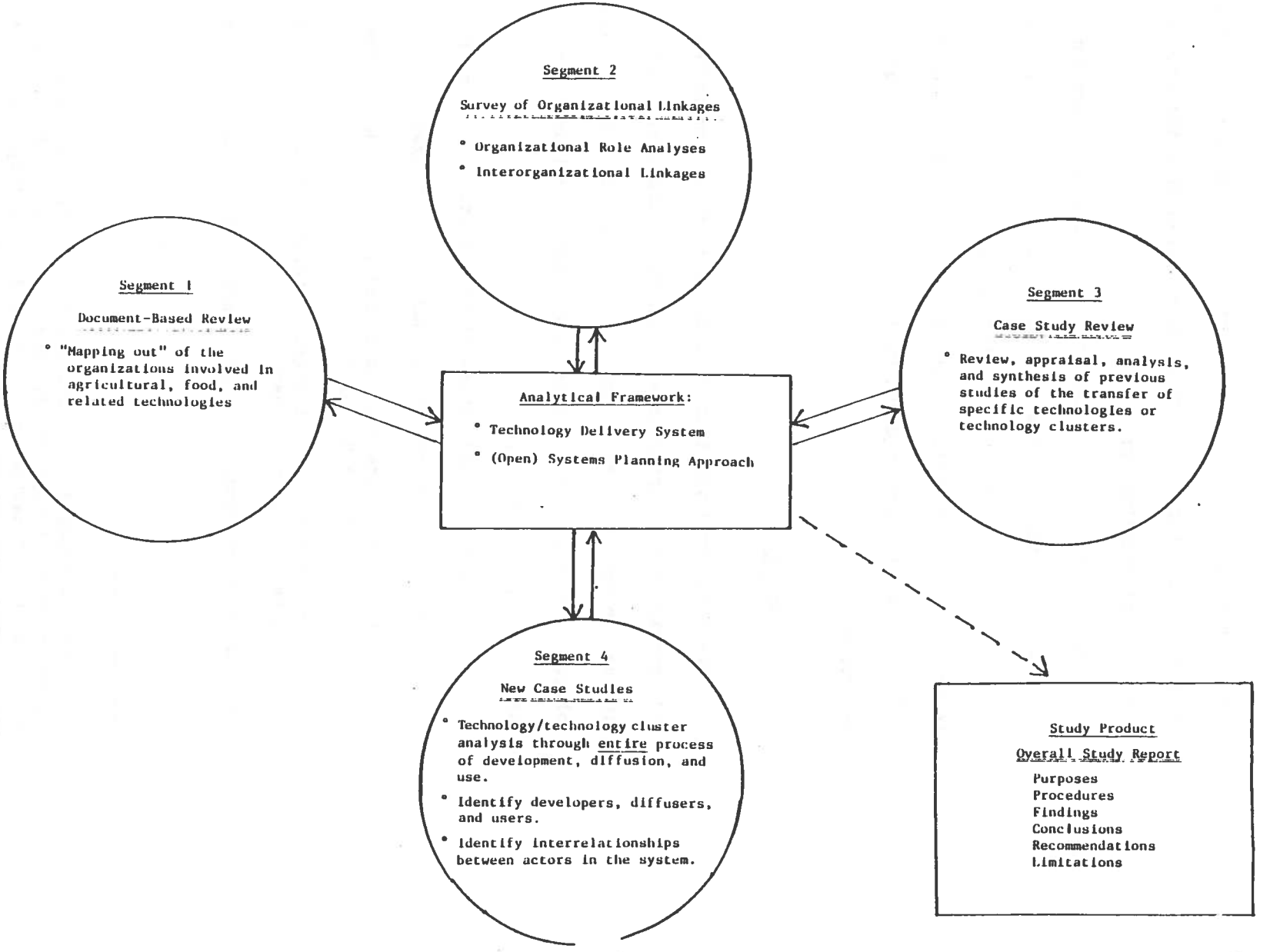
[3]The technologies selected for the six new case studies are: (1) center pivot irrigation systems, (2) large round hay balers, (3) the mechanical tomato harvester, (4) hybrid grain sorghum, (5) artificial insemination, and (6) conservation tillage.

FIGURE 1

Interrelation of Study Segments and Study Products



The study included site interviews with federal officials, with representatives of university systems in nine states, and with other public institutions. At the federal level, interviews were conducted with the officials and program leaders responsible for administering research and cooperative extension programs within USDA and with program officials in other federal agencies. The nine states (Alabama, California, Michigan, Nebraska, New York, Texas, South Carolina, Utah, and Vermont) were selected in consultation with the Advisory Panel to give coverage by census regions, by organizational characteristics of land-grant university programs in research and extension, and by several economic criteria. In each state, interviews were conducted with "decision makers" within the research and extension organizations of 1862 and 1890 land-grant colleges of agriculture, and with a varying number of researchers, extension specialists, and county agents. Two hundred and eighty-five of these interviews were conducted. During the state site visits, additional interviews also were conducted with ARS researchers located at or nearby the land-grant campuses. In addition, a telephone survey was conducted with persons involved in human nutrition, home economics, and food science in the nine survey states.

Officials of firms involved in agricultural research and product development were also interviewed. Firms were selected using two overlapping criteria: (1) their involvement in the development of one or more of the new case study technologies (e.g., the large round hay baler--Deere, Sperry-New Holland, Vermeer; hybrid grain sorghum--DeKalb, Pioneer Hi-Bred), and (2) their combined visibility both in agricultural research and in representing the views of the private sector at the national level concerning the future course of agricultural science and

technology policies (e.g., Pioneer Hi-Bred, Monsanto, DuPont). This approach led to a concentration on those firms typically regarded as the "leaders" in their respective product lines, and those with larger internal R&D programs than other firms within their respective industries. Additional interviews were conducted with farm equipment distributors.

III. Limitations of the Study

The study's scope and methodology give it a wide coverage of the agricultural technology delivery system. Still, the study has built-in limitations. Its coverage is less global than indicated by the title of the USDA study prospectus, as it covers essentially research and technology transfer oriented to agricultural production and human nutrition. Its attention to research and technology transfer is not intended to establish these activities as the only or necessarily most important components of national or state policies concerning the food supply or the economic and social well-being of American farmers and a world of consumers. Important matters such as agricultural marketing and resource economics lie beyond the scope of this study.

The study's focus on the research and technology transfer activities of public sector organizations does not constitute a complete description of the missions, programs, or priorities of the organizations surveyed. The study's emphasis on the diversity and complexity of the settings within which agricultural and human nutrition research and technology transfer activities occur should serve as a built-in caution against casual transfer of its general findings to specific settings. Moreover, the breadth of the study's scope inevitably raises concern

over the "representativeness" of selected statements presented by interviewees and used in this report to describe problems, trends, or issues.[4]

IV. Conceptual Framework: Technology Delivery and Open Systems

The study advances the concept of an agricultural technology delivery system that encompasses the following activities: (1) the delineation of research priorities, (2) the performance of various types of research, (3) the conversion of research findings into economically useful production practices and technologies, (4) the development of ancillary information on the use of the practices and technologies that accord with site-specific production settings, (5) the demonstration of new research findings and new technologies to an initial set of users, (6) the subsequent spread of the new practices to a larger set of users, and (7) the iterative feedback of changes in research activities, adaptive modifications, and consequent changes in use patterns that follow from use of the new practices.

Central to the context within which the findings of this study have been analyzed is the open systems planning approach presented by Lipman-Blumen and Schram. As noted by these authors:

> A fundamental tenet of systems theory is interdependency. That is, each component of the wider system affects and is influenced by every other component. A "problem" or a dysfunction in one part is a "message" to the whole system. A systems perspective suggests that difficulty in any one component is a problem for the whole

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[4]This concern has been addressed at several places in the report, first, by indicating the nature of the disagreement among alternative perspectives; second, by recourse to other findings germane to the issue in question; and third, by making clear throughout the study the type of evidence upon which statements are based.

system. As in biological ecostructures, no unit is an "island" but rather a reflection of the whole. Sub-units within any one organization, such as Extension, CSRS, or ARS (within USDA), may interact, communicate, negotiate and establish territory. Adaptation is the evolutionary response to environmental shifts, and likewise, in systems, a redefinition may occur to meet new environmental inputs.[5]

V. Findings

The principal findings of the study, briefly stated, are as follows:

-- The American agricultural research and technology transfer system is complex and diverse.

-- Trends within ARS and the SAES system are towards a greater use of formal planning.

-- Trends within ARS and the SAES system are towards a more basic research orientation.

-- The need to maintain articulated relationships among the stages of the technology development process, and accordingly, between "research" and "extension" organizations, is accentuated by the move to a more basic research orientation.

-- Alternative performers of agricultural research and technology transfer continue to emerge in both the public and private sectors.

-- Performance and quality, perceived very differently by various audiences and decision makers, affect resource allocation decisions.

-- The political base for public sector research and technology transfer continues to change, requiring officials increasingly to "justify" as well as to "explain" the merits of the traditional system.

-- Change--in structure, leadership, and openness--permeates much of the traditional public sector.

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[5] Lipman-Blumen and Schram (1983), The Paradox of Success (USDA-Science and Education), p. v.

These findings are discussed more fully in the following sections: (1) research--planning and coordination, (2) research/technology transfer linkages, (3) human nutrition, (4) consideration of impacts, and (5) public sector/private sector relationships. Although presented in sections, the thrust of this study remains the interdependency of its findings, and of changes (and policies) among the events and organizations examined.

1. Research: Issues of Coordination and Direction

a. Complexity

For many general purposes, existing descriptions of the agricultural technology delivery system's public sector component composed of USDA (ARS, CSRS, ES) and the land-grant university system of state agricultural experiment stations and cooperative extension services provide a useful touchstone. Over time, however, these descriptions have become increasingly less accurate in describing the many direct and indirect ways in which interaction occurs among these and other components of the agricultural technology delivery system. The research system is far more open to both reinforcing and divergent pressures from commodity growers, scientific associations, and state-level influences than appears from more stylized descriptions. Similarly, the technology transfer system is quite variegated in its forms and processes, as are the ways in which research and technology transfer organizations interact with one another.

This study documents the extent of the agricultural technology delivery system's complexity and diversity. The system is complex in its patterns of organizational cooperation and involvement; it is

diverse in that those patterns vary from one setting to another. It also is complex in the number of organizations that fund and/or perform some aspect of research, development, or technology transfer. Specifically, the agricultural technology delivery system cuts across three sectors: (1) the public sector, (2) the private sector, and (3) a third sector, which includes scientific associations, nonprofit institutions, and coordinating, advisory, lobbying, and educational organizations (Figure 2). The organizational linkages among and within these sectors were found to vary by commodity subsystem, such as dairy, cotton, and vegetables.

Graphic examples of different conceptualizations of the U.S. agricultural research system are provided in Figures 3 and 4. Figure 3 suggests a co-equal rather than a hierarchial relationship between the federal and state components of the public sector, as well as other common points of interest. It includes other research organizations as well as organizations that speak on behalf of both agricultural research and the research capabilities of their respective members. Figure 4 provides a somewhat different conceptualization of the system. Figure 4 is included to illustrate that (1) the system can be viewed from more than one perspective, and (2) an entirely different perspective (in this case, a commodity orientation) produces a conceptualization equally as complex as that in Figure 3.

b. Planning and Basic Research

The fuller accounting of interorganizational complexity and interaction used in this study suggests that discussions of the need for

FIGURE 2

A General Guide to the Sectors and Types of Organizations Involved in the Agricultural Research and Technology Transfer System (Linkages Among Sectors and Organizations Not Shown)

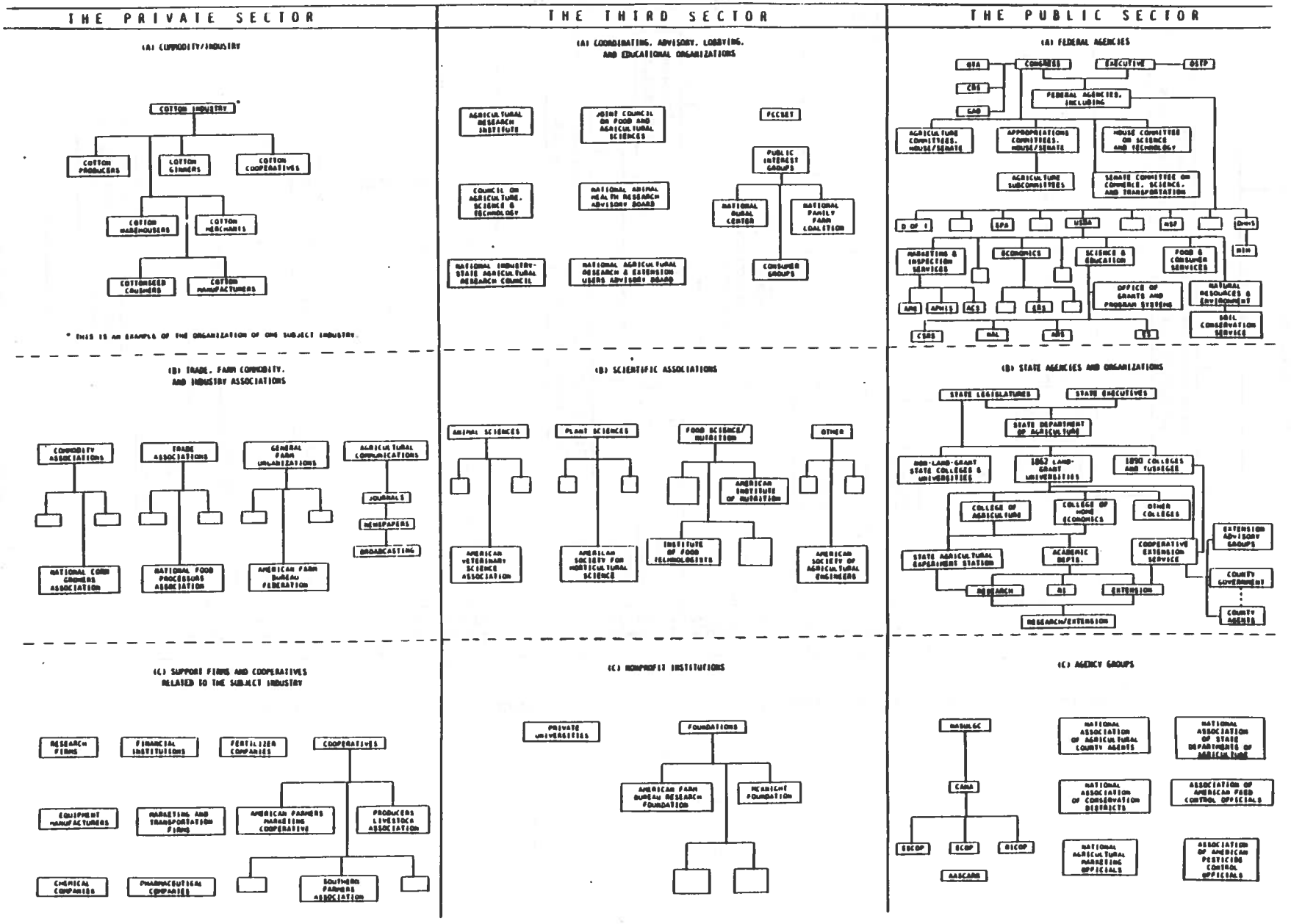


FIGURE 3

Schematic of Agricultural Research System Including Key Constituent Organizations

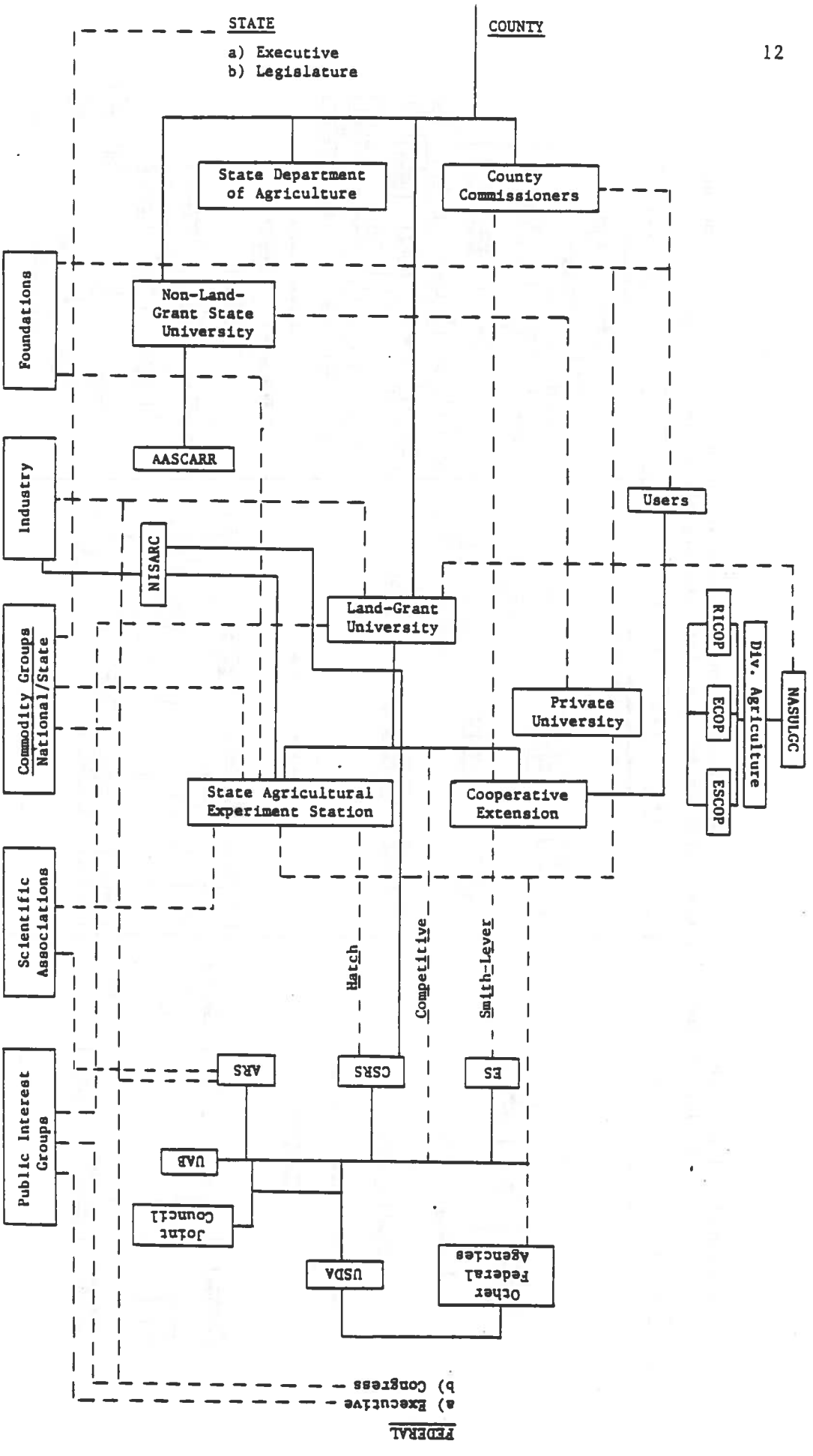
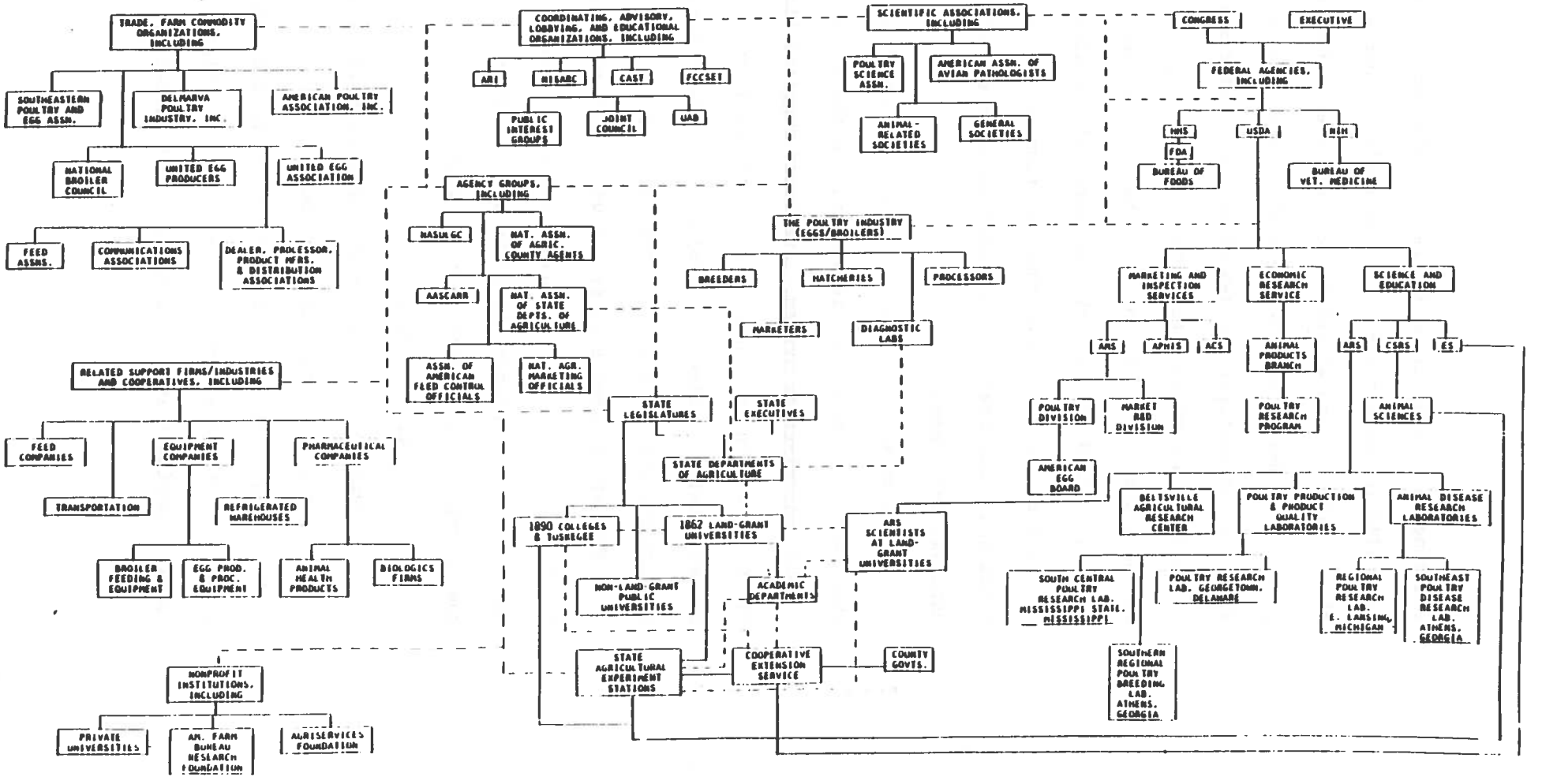


FIGURE 4

Organizations Relevant to Research in the Poultry Commodity Subsystems



planning and coordination in the establishment of research priorities are valid in the sense that the multiple influences on the system and the multiple points at which decisions are made have the potential to produce fragmented behavior. On the other hand, by not adequately considering the multiple sources of influence on research priorities, such discussions are unrealistic concerning the degree of coordination that can be exercised by USDA or any other federal agency. Earlier treatments also tend to overlook the degree of coordination already generated by the direct and indirect communication among the constituent organizations and their iterative accommodations to one another and to common external influences.

The complexity of the agricultural research system also raises questions concerning the operational content of USDA's leadership role in the federal-state system. The study suggests limitationss in USDA-S&E's ability to lead or to coordinate the activities of the state system outside of direct control over its own laboratories and personnel and control over federal pass-through funds.

This study reports on trends within ARS and the SAES system towards a more basic research orientation and greater use of formal planning. This is clearly apparent in ARS's Six-Year Plan, but also is found in the movement towards more formal planning in several of the state agricultural research systems surveyed.

The commitment towards planning and towards a basic research orientation by the land-grant universities reflects influences quite independent of considerations at the federal level and those voiced in General Accounting Office and related reports. It reflects the views of research administrators and faculty in colleges of agriculture that

scientific advances have opened new possibilities of generating basic knowledge relevant to agriculture and that land-grant university personnel must be included in such research, both to maintain standing among their disciplinary peers or institutional rivals and to serve the needs of the producers in their state. The move towards planning also reflects the infusion of new leaders, recruited both from within and without the experiment station and cooperative extension system, some of whom have had prior experience with planning. More generally, the commitment towards this activity reflects the fact that planning has permeated administrative circles in a wide variety of public and not-for-profit organizations.

The independent adoption of more formal planning procedures in both ARS and the SAES system suggests that coordination and planning between USDA and the SAES system are less critical issues today than in the past. The system is "linked together" in the openness and the frequency of interaction between the federal and state organizations and in the openness of the various state systems to multiple but common influences. The study also suggests that planning is not a frictionless activity, but one that at times creates new difficulties within ARS and the SAES system, between them, and between the experiment stations and the private sector.

In spite of the recent thrust towards more disciplinary or basic research, there remains both within ARS and the SAES system, a commitment to the concept of problem-solving or targeted research. That is, the increased commitment to basic research is justified in terms of its promise of ultimate application to improving agricultural production and human nutrition.

As a consequence of the actions taken by ARS and the SAESs, there appears a renewed credibility to the agricultural research community's contention that agricultural research is a mission-oriented undertaking, and that it is necessary to programmatically and organizationally link disciplinary or "basic" research with more applied research undertakings and with technology transfer activities.

2. Research/Technology Transfer Linkages

Maintenance of an articulated set of relationships between the research and the technology transfer-related components of the overall agricultural technology delivery system requires that organizations adjust their activities to fit (1) changes in their respective external environments (e.g., clientele demands, scientific advances), and (2) changes in the activities of other organizations in the overall system.

In particular, the futures of public sector research and extension organizations are interconnected. Unless changes are made to maintain strong links between research and technology transfer components, it is likely that both segments (and associated organizations) will suffer. Public sector research organizations will suffer, for example, if basic research activities are emphasized to the detriment of the more client-oriented applied research needed to justify continuing levels of public and political support. The debates of the 1960s and early 1970s concerning the public return from its investment in R&D clearly demonstrate that mission-oriented research must be linked to research utilization/technology transfer programs to maintain continuing public support. Although public funding to support basic research in agricultural

biotechnology can at present be justified in terms of "science" alone, past experience suggests that potential "pay-off" is never absent from the executive or congressional bottom-line. For its part, without links to new research, the technology transfer component will suffer because of accelerated obsolescence, which erodes the productivity of the information and technical assistance it offers.

The increasingly basic research orientation of public sector organizations is a new pull on the maintenance of articulated links among the stages (and organizations) in the agricultural technology delivery process. Although the study's description of recent changes in the research orientation of ARS and the SAES system highlights the need to maintain articulation among components of the system, it notes that it is not the surge of interest in basic research alone that creates this situation. Agricultural researchers, extension administrators and personnel, private industry representatives, and observers of the evolution of agricultural research and extension organizations have identified many factors that have served to blur traditional roles and relationships. These factors include: (1) the increased technical complexity of agricultural production, (2) the increased importance of large-scale farms operated by technically-trained managers, and (3) the increased number of private sector suppliers of technical information.

Interactions among the changing characteristics of producers, the technical orientation of research and extension personnel, the nature of the technologies being developed, and the R&D intensity of agriculture in a particular region are too numerous to prescriptively identify and assign responsibilities to in this changing situation. The study reveals very dissimilar services being performed by agricultural county

agents, specialists, and researchers across the country, with each reported as suitably serving the needs of producers in a particular region.

Interviews with persons both within and outside the land-grant universities do suggest, however, that farmers and other clients are turning increasingly to extension specialists and researchers at the land-grant university instead of to county agents for answers to agriculture technology problems because of the increasing complexity of agriculture. In virtually every state, there was concern about the mechanisms that draw research and extension together.

The keystone to this concern appeared to be the role of the extension specialist. In those land-grant systems that pride themselves on basic research, we observed that the extension specialists were more likely to find themselves in the role of applied researchers. The specialists were heavily influenced by academic standards including publication of research results in refereed journals. The specialists and their administrators viewed such publications as important for promotion and tenure decisions. In other states, extension specialists served essentially as technical consultants to both agents and producers, heavily taking on service roles, e.g., drafting drawings of irrigation systems. They transmitted already known state-of-the-art knowledge; they were only marginally involved either in their own research problems or in disseminating emerging findings.

These and other changes in the underlying knowledge basis for agricultural production also are affecting the roles of county agricultural agents. Many of the functions traditionally associated with the county agent are performed by producers themselves (or by staff within

corporate farms) as the producers' own educational level enables them to search out information from multiple sources including the university, trade associations, commercial vendors, and other components of the private sector. At the same time that the county agricultural agent is under pressure to remain technologically sophisticated, a variety of other pressures exist concerning the agent's roles that derive from clientele and extension missions that may lie outside the agent's traditional agricultural technology transfer role.

Our surveys served largely to confirm traditional verities concerning the functions of county agents: agents transferring and interpreting to growers the most recent findings from their experiment stations; agents passing on to researchers questions arising from producers concerning whether local veterinarians are following the most modern procedures; agents helping to organize trips to farms in neighboring states where practices dismissed as impractical by experiment station researchers in their own states are in productive employment; agents assisting researchers to obtain the cooperation of producers in field tests; agents organizing field days at which specialists and researchers present or demonstrate their latest findings; and agents undertaking their own research projects in order, among many reasons, to adapt more general findings to local needs or to address problems not being addressed by researchers elsewhere.

Also identified were several less visible roles for county agents--serving as an informal technology transfer link between growers and ARS researchers at field laboratories; serving as a link between commodity marketing order boards and university researchers in defining projects that combine scientific interest and commodity-specific relevance; and

serving as an "objective" reference when producers seek confirmation of information provided to them by salespeople or private consultants. Aggregated, these activities highlight how extension has contributed to increases in agricultural productivity.

Researchers, extension specialists, and county agents continue to perform at times in quite traditional ways. But relationships among the actors also have changed in many different ways in response to changes in the characteristics of agricultural production technologies and in the structure of agriculture. In some states these changes involve a repositioning of the functional activities of each of the actors. In these states, as researchers have moved towards a more basic research orientation, extension specialists and county agents have moved into de facto problem-focused research.

Other arrangements used in various states to achieve articulation between researchers and extension activities include joint research/extension appointments and organizational strategies such as regional centers housing research and extension personnel. In such regional centers, the extension specialist has access to ongoing research, while the researcher is kept aware of multiple growing conditions for which specific research findings may be needed; the system can then communicate these findings to county agents. The intent is to link research and technology transfer activities in reaching producers and to remove administrative barriers that segment research and extension activities.

Clearly there are many combinations within these archetypes. Again, given the diversity of agriculture across the country and the many different historical patterns concerning roles and relationships, it is not possible to say where individual systems will locate

themselves on any sort of continuum or where a total system positions itself. Nor is it apparent that an organizational strategy that has evolved successfully in one state's cultural, political, and natural environment would succeed in other states.

3. Human Nutrition Research and Technology Transfer

Several organizational patterns, some reported on in earlier studies, some identified in this study, hamper linkages between research and technology transfer in the field of human nutrition. Moreover, recent changes in the research orientation of ARS, while planned responses to influential criticisms, may have the effect of further attenuating ties between the priorities of human nutrition researchers and those involved in developing programs based on new research findings or in educating consumers and households about human nutrition. Finally, the combination of pre-existing patterns of relative federal agency roles in the support of human nutrition research, the organizational difficulties of linking research and technology transfer across several units, and the recurrent if muted issue of the priorities attached to human nutrition research within the SAES system point to the formidable task facing USDA if it seeks to establish itself as a more important, and indeed, the lead federal agency in the field of human nutrition.

Earlier studies contain convergent findings concerning the fragmentation of support for human nutrition research among and within federal agencies. In general, allowing for reservations concerning the comparability of data across agencies, the Department of Health and Human Services, through the National Institutes of Health, supports approximately 3½ times as much research on human nutrition as does USDA.

Within USDA, the responsibility for research, extension, and information on human nutrition is widely distributed. Intra- and inter-agency coordinating committees exist, but their influence on programmatic priorities is unclear. More pointedly, based on interviews with participants in other parts of the system, it is not apparent that existing mechanisms would be sufficiently effective to support a larger (and more assertive) USDA role in human nutrition. During the course of this study, efforts were underway within USDA both to increase the importance attached to human nutrition research, and to redirect this research towards more basic research questions.

This study finds serious gaps in the chain connecting researchers, extension specialists, and county agents in the field of human nutrition. Part of this lack of connectedness relates to the heterogeneity in the field of human nutrition itself (e.g., food science, human nutrition, home economics), which is compounded by variegated responsibilities and arrangements for organizing human nutrition research, technology transfer, and educational programs in the land-grant universities. Further serving to loosen ties among the components are the limited funds, as perceived by researchers in human nutrition, available to them through the state experiment stations or through USDA, which leads them to seek support from other federal agencies. The lower ratio of nutrition specialists to county agents relative to agriculture is perceived to limit the two-way communication of research findings and research needs between extension specialists and county agents.

These existing difficulties are likely to be compounded by recent changes in the research orientation of ARS and the SAES. Changes in the research priorities of ARS and the SAES system may be appropriate both

in terms of the long-term potential benefits of the scientific findings they produce and as useful responses to external critics concerning the character of the research performed by the traditional public sector organizations. They may, however, in the short run at least, aggravate the difficulties that applied researchers, specialists, and county agents have in responding to the programmatic needs of their clients.

This prospect clearly is not what is sought by ARS, which has assigned high priority to human nutrition research in its new plan. Recognition of this potential problem is apparent in a series of studies recently funded by ARS and CES concerning the flow of information between researchers and extension personnel. Over time, however, it is likely that a more effective integration of research findings into the programmatic activities of cooperative extension will require changes in the organization of human nutrition/home economics/food science programs on university campuses.

4. Incorporation of the Assessment of Impacts into Agricultural Research and Technology Transfer

The study included interviews with representatives of various public interest groups, who, in some instances, have widely different perspectives and assessments of the system from those articulated by participants in the agricultural R&D system. Not all of the representatives of public interest groups interviewed were critical of the system, but the vast majority were. Common themes recurred. Many view the primary clientele of the system as wealthy farmers, agribusiness chemical and machinery corporations, and other nonfarm interests, who, according to this group of critics, are able to exert strong leverage on the mission and priorities of the system. Furthermore, it is alleged that

researchers develop a vested interest in ignoring the ecological impacts of toxic chemicals, and that no incentive exists within the system for researchers to find economically and environmentally sound methods of conserving and enhancing the productivity of the nation's natural and human resources.

According to some public interest groups, cooperative extension, and the land-grant system in general, have led farmers into a highly energy-intensive technology, encouraging gross overproduction of certain crops, leading to regional specialization and regional dependency. Perhaps the most severe criticism encountered was that extension pretends to be the friend of all the farmers, but in reality it is contributing to the demise of many: by enhancing the competitive position of larger farms, it undermines the smaller ones; by encouraging all to use highly capital-intensive methods, extension becomes an advocate of technology that is inappropriate and financially ruinous for many of the smaller farms.

The problem of reconciling differences among diverse groups of persons with diametrically opposite positions on policy issues is extremely complex, involving clusters of beliefs, priorities, and goals.

Mechanisms used to reconcile conflicts regarding agricultural research and extension priorities and methods include lawsuits, publications by critics, the political process, recruitment policies, public policy education, and advocacy by professionals within the system.

Interviews with research administrators, researchers, and extension personnel suggest that priorities and programs are being changed. The interviews suggest a recent increase in attention to production techniques that promote a more sustainable agriculture and reduce

environmental damage. This trend is most clearly seen in the growing research interest in conservation tillage and integrated pest management. Again, chains of influence are difficult to detect. Enhancement of research interest in these techniques is as readily explainable in terms of desire for more profitable farming methods (in view of rising energy prices and declining effectiveness of pesticides) as in concern over, or submission to, the agendas of public interest groups.

The traditional pattern of interaction between county agents and clients also may serve to heighten interest within extension (and thus, indirectly, within the research community) toward a broadening set of impacts. It has been suggested that the questions asked by "back-to-the-land" small farmers and home gardeners differ from those asked by extension's more commercially oriented clientele, and that these questions have induced extension personnel to seek out information compatible with the "regenerative agricultural perspectives" of these clients, and to publish this information in popular publications that cater to this audience.

Some observers also see the new emphasis on accountability and evaluation within ES and CES as serving to lead it toward giving increased consideration to the social consequences of its work.

5. Relationships Between the Public and Private Sectors in Agricultural Research and Technology Transfer

Relationships between the public and private sectors in agricultural research and technology transfer are changing. Two obvious recent changes in public sector/private sector relations have been in the funding of research and in the character of the incentives for private sector research. The trend has been towards an increase in the relative

role of the private sector, which is variously estimated to account for about 65 percent of all agricultural research. Changes in property rights also have affected public sector/private sector relationships. The Plant Variety Protection Act of 1970 and the 1980 Supreme Court decision in Diamond v. Chakrabarty on the patentability of micro-organisms have expanded the domains of knowledge over which property rights can be established.

The patterns of relationships between the public sector and the private sector are varied and intricate, a product of the evolution of relationships between organizations and individuals that reflect legal, political, economic, and personal ties. This complex pattern is interwoven by the range of specific technologies--seeds, fertilizers, harvesting equipment--as well as "farm practices," "know-how," or "agronomic information" included within the broad concept of agricultural production techniques. There is a paucity of analytical treatments as to what these patterns include except for generalizations on roles in research fields. There are few studies that describe the institutional character of the relationships between the public/private sectors.

Existing paradigms of the respective roles of the two sectors, while valid under certain prespecified conditions, do not capture the changing relationships between the sectors. For example, our case studies illustrate that vast changes in roles occur during the technological and economic life cycle of specific technologies. Changes in the commitments of private industry to research and technology transfer are likely now to move what are already blurred boundary markers concerning relative roles.

Industry has increased its total commitment to agricultural research, and in the case of some large firms has demonstrated its willingness to invest in basic research activities of a type and scale that formerly were undertaken only by the public sector. Firms also appear to be increasing the scale of their technology transfer activities. In particular, firms that have invested in basic research in seeking to fully develop the markets for their activities will engage in technology transfer activities commonly associated with the activities of the public sector. New firms specializing in agricultural information services also are appearing.

It is unclear at present which sector has the better mix of incentives or organizational characteristics for performing either in the aggregate or for various fields, be these broad classifications such as animal or plant agriculture, commodities, or even different product lines. Lacking any certainty as to the roles of the public and private sectors, it is difficult to track through their future relationships. Multiple points of connection seem probable, some reflecting delineation of activities according to property rights or market size, others relating to the differential competencies of organizations, and yet others relating to political or idiosyncratic factors.

Interviews with private firms and at land-grant universities point to considerable differences in the views held by each sector concerning which is the organizationally superior performer of basic research in biotechnology. Again drawing mainly on interviews with the larger, R&D-intensive firms, industry believes it is better situated to support and maintain long-term basic research programs because (1) it is better able to pull together the interdisciplinary teams needed to develop an

integrated research and technology delivery activity, and (2) it is able to have a longer term perspective, not being constrained by the need that university researchers have for publishable short-term results to satisfy promotion and tenure committees.

Based on interviews with those land-grant institutions that have already established a biotechnology capability, universities see themselves as having this long-term research capability. They are aware of industry's current commitments and of the statements of industrial leaders concerning their basic research capabilities, but they remain skeptical as to whether the 8- to 10-year commitments can, in fact, be maintained within the private sector before bottom line, short-term, market-driven imperatives take over. Interviews with industry trade association representatives provide some support for this skepticism, suggesting that some major firms are already beginning to comprehend the level of effort needed to surmount basic research questions, and accordingly, are pulling back somewhat on their support of basic research or are quickly channeling their research efforts to a smaller number of commercially promising lines of inquiry.

The anomaly at present is that amidst this uncertainty concerning relative roles, one can point to certain problems generic to the activities of both sectors. Neither sector seems to have fully worked through the question of the product development/technology transfer aspects of biotechnology research. In the private sector, the emphasis on basic research appears so strong and the findings to this point so few that considerations of product development and commercialization are premature. In the land-grant sector, the division between research activities and extension appears as an organizational convenience for

not anticipating the changes in the roles of researcher, specialist, or county agent that may be required to use biotechnological innovations commercially.

At the federal level a similar question exists. ARS is simultaneously trying to strengthen its basic research capability and beginning to consider an expanded technology transfer role, in part in response to the provisions of the Stevenson-Wydler Act and in part in response to recurrent congressional pressures on ARS to demonstrate the transferability and applicability of its research findings.

Most analytical and policy discussions concerning the relative roles of the public and private sectors in the agricultural technology delivery system relate to research. But the more significant changes in relative sector roles may be occurring at the technology transfer/information dissemination stages. The role of the intermediaries between the manufacturer and the farmer is perhaps the least frequently examined of all the relationships in the agricultural research/technology transfer system. The emergence of feed, seed, fertilizer, and machinery salesmen or representatives as suppliers of technical information to farmers, as alternatives to cooperative extension, has already been noted. The study suggests that the private sector supply of technical information is becoming more prevalent, but it is not possible from this study alone to test its relative importance.

This lack of a "baseline" prevents highly precise statements concerning the rate or magnitude of change. It seems apparent, however, both from industries' descriptions of their activities and from accounts of what they are beginning to do, that industry is more actively involved in communicating directly with producers concerning the

characteristics of their products, not simply in promotional material that emphasizes static performance specifications, but also the outcomes that can be expected from use of their product under alternative production conditions. It appears that those firms that emphasize the innovative, or R&D-intensive, characteristics of their products are "coupling" or "bundling" a product package in which they sell both the core technologies, e.g., the seed or the herbicide, and information concerning the best uses of the product. From the manufacturer's perspective, provision of technical information is a necessary complement to selling the new technology. The success of such products in the market suggests that a market for information exists and that once suppliers have organized the market, buyers are willing to pay the requisite price. In this respect, the information that industry is offering begins to resemble that traditionally supplied through the SAES-CES system. It represents a situation in which there has been a privatization of what formerly was publicly supplied knowledge.

VI. Policy Options for USDA-Science and Education

The study outlines three broad approaches to the future activities of USDA-Science and Education. These options are presented as a framework within which the long-term programmatic effectiveness and political viability of current incremental changes by separate agencies can be considered. Presentation of these options reflects our view that continuing systemic changes exist within which public sector agricultural research and technology transfer organizations function, and that these changes--principally the concentration of production in fewer and larger units, the increased level of technical sophistication on the part of

producers, the increased level of private sector activity in both research and technology transfer, and the emergence of alternative public sector performers of agricultural research--cannot be satisfactorily responded to by incremental responses to specific criticisms or challenges alone.

For simplicity we have labeled these approaches: maintenance, incremental change, and fundamental change. Option 1, Maintenance, implies no major change in the trends observed in the level and type of activity performed by the agencies in the public sector of the agricultural technology delivery system. Where recent trends have occurred, Option 1 assummes these trends will continue. Option 2, Incremental Change, implies a modest increase in the public sector's level of activity, and moderate changes in the organizational linkages and mandates of the various agencies. For example, we assume under Option 2 that existing public organizations will continue to exist. Option 3, which we call Fundamental Change, describes major departures from the current system. The implications of each of these options for each of the research and extension agencies within USDA-S&E, i.e., ARS, CSRS, and ES, are discussed in Volume 5.

Permeating our discussion of the three options is the theme of an integrated technology delivery system in which specific organizations perform separate but linked roles. Paramount to any consideration of the feasibility or desirability of these options is an organizationally effective means of analyzing these options and presenting the case for specific recommendations. Probably the single most important organizational issue within the study is the need for an integrative perspective and voice within USDA, first, to organize its own activities, and then

to work with other organizations, starting with the land-grant university system and other federal agencies, in identifying how changes in each sector impact upon one another.

Another underlying theme of this study is the need for a restatement of the social benefits of the activities performed by publicly-supported agricultural research and technology transfer organizations. While deriving from past performance, this restatement must be rooted in the fundamental concepts of the unique role of public sector organizations; the necessity for maintaining high degrees of programmatic articulation among basic research, applied research, adaptive or developmental research, demonstration and dissemination; and the relative efficiencies of specific public sector organizations. It must be grounded in an analysis of public sector/private sector relationships that considers the two as joint actors, each having specific characteristics and specific domains, but as shown in the case studies, with high degrees of complementarity between their activities.

APPENDIX A

Advisory Panel

Dr. Nancy Belck	Dean of Home Economics, University of Tennessee
Dr. David Dyer	U. S. Senate Committee on Agriculture, Nutrition and Forestry
Dr. Gary Evans	Coordinator, Natural Resources and Forestry, Cooperative State Research Service
Dr. J. D. Eveland	Innovation Processes Research, National Science Foundation
Dr. C. Dennis Ignasias	Assistant Dean, School of Agriculture Sciences, University of Maryland-Eastern Shore
Dr. Patrick Jordan	Administrator, Cooperative State Research Service
Dr. Leo Lucas	Director of Cooperative Extension, University of Nebraska at Lincoln
Dr. Lynn Maish	Program Analyst, Office of Budget and Program Analysis, U. S. Department of Agriculture
Dr. Arland W. Pauli	Product and Market Planning, Deere & Company
Dr. William Presnal	Vice Chancellor for State Affairs, The Texas A&M University System
Dr. Paul Putnam	Area Director, Central Plains Area, National Animal Disease Center, Ames, Iowa
Dr. Thomas N. Shiflet	Director of Ecological Sciences, Soil Conservation Service
Janet E. Tenney	Coordinator of Nutrition Programs, Giant Foods, Inc.

Project Monitor

Dr. Claude Bennett	Evaluation Specialist, Extension Service

Observers

Dr. John Bottum	Deputy Administrator, Extension Service
Dr. Barbara Fontana	National Governors' Association
Dr. Denzil Clegg	Associate Administrator, Extension Service
Dr. Mitchell Geasler	Director of Cooperative Extension Service, Virginia Polytechnic Institute and State University
Dr. James Halpin	Director-at-Large, Southern Region, Experiment Station Committee on Organization and Policy
Dr. James Hall	Technology Transfer Staff, Agricultural Research Service
John Victor	Budget Division, Agricultural Research Service
Dr. Gerald Welsh	Research Coordinator, Soil Conservation Service