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MANAGEMENT OF FEDERAL R&D FOR COMMERCIALIZATION

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EXECUTIVE SUMMARY

MANAGEMENT OF FEDERAL R&D FOR NONFEDERAL APPLICATIONS

This document is the Executive Summary of an empirical investigation of federal civilian R&D management practices conducted by SRI International for the Experimental Technology Incentives Program (ETIP), National Bureau of Standards.* The summary and the final report are addressed to federal civilian policymakers and R&D managers responsible for planning, developing, and implementing R&D programs whose results are intended for commercial production and application in the nonfederal sector.

ETIP was initiated in 1972 to conduct a series of background studies and experiments to find ways by which the federal government could effectively alter the rate and diffusion of civilian technological change. Previously, relatively little effort had been made to understand how federally funded civilian R&D can most effectively be conducted in order to improve the application of R&D results. Unlike defense and space R&D agencies, applied civilian R&D agencies do not control the production or purchase of the product resulting from their R&D. Thus, the management of federal R&D intended for commercialization must address issues of commercial acceptability as well as technical success.

ETIP engaged SRI International (then Stanford Research Institute) in 1975 to address these management issues. Specifically, the purposes of the present study are to:

(1) Describe current policies and practices of federal agencies regarding the management of federally funded R&D intended for nonfederal application.

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*ETIP is now part of the Center for Field Methods of the National Bureau of Standards.

(2) Develop a set of empirically grounded recommendations for policies and practices that would improve the commercialization of federally funded R&D results.

Thus, the study is not intended to address the appropriate scope, priorities, or level of federal R&D. Rather, the guidelines developed here are intended to assist R&D managers--once these decisions have been made--to achieve the transfer of federal R&D to the marketplace, which is a necessary step to achieving social benefits. The recommendations have been developed by analyzing the relationships between the management actions and characteristics of a set of R&D projects and the degree of commercial application of their results.

Our findings indicate that the most important recommendations for improving the management of federal R&D fall into two major areas: (1) Market Planning and Analysis, and (2) Market Intelligence and Communications Techniques. The first emphasizes the importance of orienting federal R&D agencies to the marketplace and of designing projects to meet producer and user requirements rather than promoting a technology per se. The second stresses the importance of communications and cooperation among the various parties--federal R&D funding agency, R&D performer, potential producers, potential users, and other governmental and nongovernmental bodies--whose actions affect the transition of R&D to the marketplace. Both sets of activities embody a philosophy of market responsiveness that current federal practices make difficult to realize.

Methodology

The sample of projects examined consists of 46 projects in various programs of 11 federal agencies. These projects were randomly selected from two groups, one group consisting of projects that had been commercialized and one of projects that had not; all projects in both groups were technical successes. Based on a conceptual model of the delivery system for federally sponsored civilian technology, a set of factors is hypothesized to affect commercial application of federal R&D. These factors are organized into five functional areas of responsibility for R&D management, and are listed below in the approximate temporal order in which they are undertaken:

- Project Planning and Project Initiation, such as establishment of commercialization objectives, importance of external influences, characteristics of products and markets, and levels of technical advancement and overall commercial risk for the R&D.
- Project Selection, such as market studies, feasibility analyses, and project selection methods.
- Project Deployment Planning, such as the sufficiency of information for commercialization decision, development of a deployment strategy, analysis of barriers, and involvement of manufacturers and users.
- Project Implementation and Administration, such as choice of the R&D performer, contracting procedures, time and financial resource sufficiency, and stability of agency goals and personnel.
- Project Review and Evaluation, such as project and contract monitoring, evaluation during and after project completion, and project termination.

Data were obtained on each factor included in these five areas and on the extent of commercialization of project results. Commercialization was measured by the extent to which the R&D results have been marketed in products (from "marketing never planned" through "marketing has been started and has proved to be profitable") and by whether R&D expenditures have been continued in the private sector. Data were collected by interviews with the agency program director, the agency project manager, the project manager of the R&D performing organization, and other knowledgeable individuals in nonagency organizations such as potential manufacturers.

These data were then analyzed statistically for correlations of management actions taken and exogenous factors influencing the projects with the commercial outcomes of the projects. Several project characteristics and early R&D management decisions listed later in this summary were also investigated for their effect on making the associations stronger or weaker. Details of the correlational analyses are presented in Chapter III of the final report. Guidelines for improving the commercialization of federal civilian R&D management were then developed from the correlational findings concerning the factors in the five functional areas above that actually predicted commmercialization in our sample of projects. These guidelines are applicable to agency program- and project-level management. The

analysis indicates that the factors hypothesized as determining the commercial outcome of projects actually accounted for over 80% of the total variation in these outcomes. This represents a high level of explanation compared with studies having a similar structure in other fields of social science.

The interpretation of correlations as guidelines for action requires a causal interpretation of our findings. This causal rationale in our study is provided by the conceptual model--whereby management actions are assumed to affect commercial outcomes--that was used to formulate our hypotheses. This basis for our research questions, and the relatively strong explanatory power of the factors thus identified, lead us to believe that following the management guidelines is likely to improve the commercial success of federal civilian R&D projects. Nonetheless, a number of limitations to the methodology of this study should be recognized in assessing and applying our results. First, the project selection process was designed to obtain a set of projects that were approximately balanced between marketing successes and failures, both overall and within a number of federal agencies, rather than being necessarily representative of the universe of federal R&D projects intended for commercialization. Second, the retrospective interview methodology meant that faulty respondent recall generated "noise" in our data, which reduced the number of significant factors (respondent perceptions) affecting project outcomes that we could detect. Furthermore, though the model of the R&D process from which we generated our research questions made causality intuitively plausible, it is not possible to rule out other factors as creating the associations we observed between management actions and project outcomes. For example, what results when an agency is held to a guideline by Executive or Congressional oversight might be very different from what occurs when the agency personnel are taking actions of their own choosing. (The nature of the studies needed to overcome these problems is discussed in the concluding paragraphs of this summary.)

Guidelines Summary

Thirty-six explicit operational guidelines for federal agency R&D management are provided for the five identified R&D management functions described above:

- Program Planning and Project Initiation
- Project Selection
- Project Development Planning
- Project Implementation and Administration
- Project Review and Evaluation.

To better enable the R&D manager and policymaker to see the coherence among such a large number of guidelines, they have been organized into three thematic groupings:

- Market Planning and Analysis--understanding and analysis of the market during the planning phases of R&D.
- Market Intelligence and Communication Techniques--effective communication among and information gathering from participants in the R&D delivery system.
- Selection and Management of R&D Performers--execution of R&D projects, particularly the choice of and relationships with the R&D performer.

The guidelines in these three groups are listed in Tables S-1, S-2, and S-3, followed by a summary table in matrix form. (Some R&D management functions do not have a guideline in a given thematic group, e.g., there is no Project Implementation and Administration guideline under Market Planning and Analysis.) The summary table, Table S-4, indicates that Market Planning and Analysis has the greatest array of activities recommended to be undertaken in Program Planning and Project Initiation. Market Intelligence and Communications Techniques and Market Planning and Analysis have nearly an equal number of guidelines in Project Selection and Project Deployment Planning. In terms of predictive importance for commercialization, on the other hand, our statistical findings indicate that the market-oriented guidelines in the first three functional areas of R&D management, especially the guidelines for Program Planning and Project Initiation, account for most of the explanatory power of all 36 explicit guidelines. (Chapter III of the final report contains a more complete discussion.) Therefore, planning and early project decisions

Table S-I

COMMERCIALIZATION GUIDELINES FOR MARKET PLANNING AND ANALYSIS

Program Planning and Project Initiation

- Assess organizational structure and adequacy of resources devoted to planning functions.
- Make commercialization an explicit agency program objective.
- Seek projects in response to perceived market opportunities.
- Seek projects serving stable, regulated markets that have high buyer awareness of the product.
- Select projects with the following product characteristics: low commercial, social, and environmental uncertainty; low cost and high performance; large state-of-the-art advance; and meeting or exceeding regulatory requirements.
- Avoid interference of federal policies (e.g., Congressional, patent) with commercialization prospects.

Project Selection

- Conduct agency market demand studies before contract awards.
- Obtain comparative feasibility studies.
- Fund basic research and commercial-scale demonstration, especially under certain conditions (see final report).

Project Deployment Planning

- Produce sufficient information for private commercialization decisions.
- Develop a deployment strategy.
- Analyze barriers to deployment, such as regulations, costs, delivery system, and federal incentives.
- Use selected federal incentives when justified.

Project Review and Evaluation

- Reassess commercial prospects during project life and terminate if appropriate.

Table S-2

COMMERCIALIZATION GUIDELINES FOR MARKET INTELLIGENCE AND COMMUNICATION TECHNIQUES

Program Planning and Project Initiation

- Involve manufacturers, other agencies, and buyers throughout R&D process.
- Find a powerful product champion before starting a project.
- Seek support from the Assistant Secretary for Administration or equivalent in the agency.

Project Selection

- Involve industry groups in project selection.
- Use R&D performers and manufacturers for feasibility studies.
- Use quantitative techniques in project selection.

Project Deployment Planning

- Use R&D performers and manufacturers in deployment planning.
- Obtain participation in deployment planning and execution through agency consultation with trade associations, producers, and users; industry advisory committees; and producer workshops.
- Assure effective relations among the agency, users, and manufacturers, and between R&D performers and buyers during deployment.

Project Implementation and Administration

- Seek advice from R&D performers and manufacturers on time and funds necessary to complete the project.
- Maintain effective working relationships with R&D performers (and with other agencies if relevant).

Table S-3

COMMERCIALIZATION GUIDELINES FOR SELECTION AND MANAGEMENT OF R&D PERFORMERS

Program Planning and Project Initiation

- Use flexible and adaptive procurement/contracting procedures, except on long-duration projects (5 years or longer).

Project Implementation and Administration

- Prefer federal in-house labs or federal contract research centers as R&D performers (while obtaining market and production information from industry sources).
- In selecting manufacturers as R&D performers, choose those with demonstrated effective internal working relationships.
- When cost sharing is required as part of the funding of a project, grant the performer technical latitude. When cost sharing is not required, take a more active role in deployment and in contract monitoring.
- In selecting R&D performers, prefer organizations that are small, that have project leaders with project-related expertise, and whose motivation is not primarily technical.
- Keep nonsponsor agencies out of technical roles in project management.
- Provide sufficient time and resources to complete projects.
- Minimize changes in agency goals and in project personnel.

Project Review and Evaluation

- Monitor projects closely during implementation.
- Evaluate results on project completion.
- Carefully review projects receiving OMB attention.

Table 5-4

COMMERCIALIZATION GUIDELINES FOR FEDERAL R&D MANAGEMENT BY AGENCIES

R&D Management Function	Market Planning and Analysis	Market Intelligence and Communication Techniques	Selection and Management of R&D Performers
Program Planning and Project Initiation	• Assess organizational structure and adequacy of resources devoted to planning functions. • Make commercialization an explicit agency program objective. • Seek projects in response to perceived market opportunities. • Seek projects serving stable, regulated markets that have high buyer awareness of the product. • Select projects with the following product characteristics: low commercial, social, and environmental uncertainty; low cost and high performance; large state-of-the-art advance; meeting regulatory requirements. • Avoid interference of federal policies (e.g., Congressional, patent) with commercialization prospects.	• Involve manufacturers, other agencies, and buyers throughout R&D process. • Find a powerful product champion before starting a project. • Seek support from the Assistant Secretary for Administration or equivalent in the agency.	• Use flexible and adaptive procurement/contracting procedures except on long-duration projects (5 years or longer).
Project Selection	• Conduct agency market demand studies before contract awards. • Obtain comparative feasibility studies. • Fund basic research and commercial-scale demonstration especially under certain conditions (see final report).	• Involve industry groups in project selection. • Use R&D performers and manufacturers for feasibility studies. • Use quantitative techniques in project selection.	
Project Deployment Planning	• Produce sufficient information for private commercialization decisions. • Develop and deployment strategy. • Analyze barriers to deployment such as regulations, costs, delivery system, and federal incentives. • Use selected federal incentives when justified.	• Use R&D performers and manufacturers in deployment planning. • Obtain participation in deployment planning and execution through agency consultation with trade association, producers, and users; industry advisory committees; and producer workshops. • Assure effective relations among the agency, users, and manufacturers, and between R&D performers and buyers during deployment.	
Project Implementation and Administration		• Seek advice from R&D performers and manufacturers on time and funds needed to complete the project. • Maintain effective working relationships with R&D performers (and with other agencies if relevant).	• Prefer federal in-house labs or federal contract research centers as R&D performers (while obtaining market and production information from industry sources). • In selecting manufacturers as R&D performers, choose those with demonstrated effective internal working relationships. • When cost sharing is required as part of the funding of a project, grant the performer technical latitude. When cost sharing is not required, take a more active role in deployment and in contract monitoring. • In selecting R&D performers, prefer organizations that are small, that have project leaders with project-related expertise, and whose motivation is not primarily technical. • Avoid micromanaging decision making of technical roles in project management. • Provide sufficient time and resources for a pilot project. • Minimize changes in project goals and in project personnel.
Project Review and Termination	• Reassess commercial prospects during project life and terminate if appropriate.		• Monitor projects closely during implementation. • Terminate contracts on project completion. • Carefully review projects receiving OMB attention.

in relation to the intended market strongly affect the eventual commercial application of projects and consequently should receive particular attention.

The study also included an investigation of seven conditions involving project characteristics and early R&D management decisions that were selected by the Review Panel of this study as particularly important for policy decisions. The conditions investigated were:

- Whether commercialization was an explicit program objective (e.g., specified in writing).
- The perceived level of uncertainty in the overall commercial risk of producing and marketing the resulting product.
- The perceived degree of advancement in the state of the art of the technology that was represented by the project.
- Whether an in-house market study was conducted prior to contract award (in-house meaning by the agency rather than an external contractor).
- The duration of the project in years.
- Whether the R&D performer was a manufacturer as contrasted with a purely research-oriented organization such as a federal contract research lab, a university, or a private research organization.
- Whether cost sharing was required of the R&D performer.

The findings indicated that agency R&D managers should pay particular attention to certain guidelines, depending on the conditions that describe their projects (e.g., whether the R&D performer is a manufacturer, or whether cost sharing is required of the performer). Only one guideline--on flexibility of contracting procedures--was reversed by a change in condition (namely, from short- to long-duration projects). All other guidelines varied only in relative importance with condition. Once agency R&D managers characterize their projects in terms of these seven conditions, our findings (summarized in Annex Table 1 of the final report) will enable them to further concentrate their attention on the most important management practices for commercialization of each project.

Finally, we wished to assess how often federal R&D management actions in our sample of projects were consistent with our guidelines, as the best indication available to us of the profile of federal R&D management

performance. To carry out this assessment, we analyzed the relative frequency with which the management actions in our sample of 46 projects were consistent with ("followed") our guidelines. The results are displayed in Table S-5, which divides the guidelines into three sets: those followed in under 25% of the projects ("seldom followed"), in 25% to 75% of the projects ("occasionally to frequently followed"), and in over 75% of the projects ("usually followed"). Because the sample is divided about equally between marketed and nonmarketed projects, guidelines classified as "seldom followed" were observed in less than half of even the more successfully commercialized projects. Average agency performance in the sample in terms of these guidelines could have been significantly improved, even in the more successful projects. On the other hand, guidelines classified as "usually followed" were observed in more than half of even the less successfully commercialized projects. Agency performance in the sample in terms of these guidelines was relatively good, but in those instances where they were not followed, a strongly negative impact on commercialization resulted. Emphasis could thus have been placed on identifying those instances and correcting them.

Seven guidelines were found to be "seldom followed" in our sample; four of these seven are in Market Planning and Analysis, constituting a significant fraction (27%) of the total of 15 guidelines in this group. The management activities highlighted by this group of guidelines appear to warrant substantially greater attention by federal agencies. Nineteen guidelines, more than half the total number of 36, were found to be "occasionally to frequently followed"; this includes nearly three-quarters of the guidelines in Market Intelligence and Communication Techniques, which are often quite important to commercialization. Evidently, there is considerable room for improvement in management performance on these activities in our sample. Finally, 10 guidelines were found to be "usually followed"; these fall principally into Selection and Management of R&D Performers (5 guidelines) and Market Planning and Analysis (4 guidelines). Not following the guidelines in the former group--concerning performer selection, contracting, monitoring, and evaluation--and especially one guideline in the latter group--concerning sufficiency of

CURRENT USE OF GUIDELINES

Management Function	Seldom Followed (Fewer than 25% of projects)	Occasionally to Frequently Followed (25% to 75% of projects)	Usually Followed (more than 75% of projects)
Market Planning and Analysis			
Program Planning and Project Initiation	• Seek projects in response to perceived market opportunities. • Select projects with low initial uncertainty in commercial risk for the resulting product.	• Seek projects serving markets that are stable, regulated, and have high buyer awareness of the product. • Select projects with the following product characteristics: low initial uncertainty in social and environmental effects; lower cost and higher performance than competing products; meeting or exceeding regulatory requirements.	• Select projects with large state-of-the-art advancements in the resulting product. • Make commercialization an explicit agency R&D program objective.* • Avoid interference or seek support of federal policies (e.g., congressional, patent) for commercialization.
Project Selection		• Conduct agency market demand studies before issuing RFPs or making contract awards. • Obtain comparative feasibility studies. • Fund basic research and commercial-scale demonstration, especially under certain conditions.	
Project Deployment Planning	• Analyze barriers to deployment, such as regulations, costs, delivery system, and federal incentives. • Use selected federal incentives when justified.	• Develop a deployment strategy.	• Produce sufficient information for private commercialization decisions.*
Project Review and Evaluation		• Reassess commercial prospects during project life and terminate if appropriate.	
Market Intelligence and Communication Techniques			
Program Planning and Project Initiation	• Seek support from the Assistant Secretary for Administration or equivalent in the agency.	• Involve manufacturers, other agencies, and buyers throughout R&D process. • Find a powerful product champion before starting a project.	
Project Selection		• Involve industry groups in project selection. • Use R&D performers and manufacturers for feasibility studies. • Use quantitative techniques in project selection.	
Project Deployment Planning	• Obtain participation in deployment planning and execution through agency consultation with trade associations, producers, and users; industry advisory committees; and producer workshops.	• Use R&D performers and manufacturers in deployment planning and assign responsibility for deployment to the R&D performers. • Assure effective working relationships among the agency, users, and manufacturers, and between R&D performers and potential buyers during deployment.	
Project Implementation and Administration		• Seek advice from R&D performers and manufacturers on time and funds necessary to complete the project, and give such advice considerable weight.	• Maintain effective working relationships with R&D performers (and with other agencies if relevant).
Selection and Management of R&D Performers			
Program Planning and Project Initiation			• Maintain procurement and contracting procedures that permit R&D performers to respond to changing technical and market information while keeping the project on course.
Project Implementation and Administration	• In selecting principal R&D performers, consider giving preference to federal in-house labs or federal contract research centers as R&D performers (while obtaining market and production information from industry sources).	• In selecting R&D performers, prefer organizations that are small, that have project leaders with project-related expertise, and whose motivation is not primarily technical. • Provide sufficient time and resources to complete project. • Minimize changes in agency goals and in project personnel.	• Keep nonsponsor agencies out of technical roles in project management. • In selecting manufacturers as R&D performers, choose those with demonstrated effective internal working relationships.
Project Review and Evaluation		• Carefully review projects receiving OMB attention.	• Monitor projects closely.* • Evaluate results on project completion.*

*Not followed in 4 or 9 of the 46 projects.

information for a commercialization decision--appeared to exert a particularly strong negative influence on commercialization. Overall, this assessment indicates that, in our sample of projects, civilian agencies with R&D programs destined for the commercial sector have not been following R&D management practices that, if followed, would lead to greater commercialization results.

Conclusions and Recommendations for R&D Managers

It is clear from this examination of past projects that there are a number of R&D management practices that federal civilian agencies with R&D programs intended for nonfederal application should follow to achieve greater commercialization of their results, and that in many projects these practices have not been followed. Projecting from our results, there appears to be ample reason for R&D directors, managers, and agency heads to use these guidelines in undertaking an initial audit of R&D management practices to determine how many the agency or program follows, and how frequently. The evidence of this study indicates that those practices not in conformity with the guidelines presented here can be changed to improve the prospects for private-sector assumption of further development and ultimate application of the R&D outputs of that agency. Ongoing assessment and feedback of management and outcome information to policymakers should then be used to provide the decision-relevant data base for continued improvement of federal R&D programs.

The importance of guidelines concerning Program Planning and Project Initiation should be of particular concern for agencies where R&D and commercialization functions are separated. The results of this study indicate that it is rarely possible for R&D programs and projects that are poorly planned and launched toward commercial application to be salvaged later. Consequently, the commercialization considerations presented in these guidelines must be introduced when first designing an R&D program, not after its technical results are available for application. When technological research and commercial application responsibilities are separated in a government agency, the organizational structure and resources devoted to R&D planning functions must be designed to achieve the integration

called for in our guidelines and to continually monitor the effectiveness of that integration. This becomes a principal management responsibility of the top administrative personnel of the agency.

Recommendations for Future Research

It is clear from the earlier discussion of the limitations of this study that further research is needed to firmly validate the guidelines developed in this study. The problem of respondent recall and the objective determination of events can only be dealt with by real-time longitudinal analysis of ongoing R&D projects. More importantly for policy, however, the establishment of causality and the understanding of behavioral and institutional problems of implementation can only be addressed by undertaking experimental trials in federal R&D agencies of the R&D management policy changes recommended in this study. Naturalistic observation--whether retrospective like the present study or in real time--is not adequate to provide the significant further understanding likely to result from a program of real-time explicit policy experimentation in agency settings, with careful assessment and feedback to R&D policymakers.