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The Defense Department's Support of Industry's Independent Research and Development (IR&D)

Analyses and Evaluation

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PREFACE

In 1986, Congress requested an independent evaluation of Department of Defense (DoD) policies toward independent research and development (IR&D). The Under Secretary of Defense for Research and Engineering[1] then asked RAND to undertake a study that would (1) clarify the goals of IR&D (explain how DoD support of IR&D can serve the national interest); (2) assess whether certain DoD administrative and financial arrangements promote or thwart the goals of IR&D; and (3) evaluate the IR&D process overall, determining to what extent it contributes distinctively to U.S. national defense.

The Office of the Under Secretary of Defense for Acquisition supported this work through the National Defense Research Institute, the DoD-sponsored Federally Funded Research and Development Center at RAND.

[1]In the reorganization of DoD, this position was replaced by that of the Under Secretary of Defense for Acquisition

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This report examines the benefits and costs of DoD support of IR&D, how to administer such a program and recommendations. Topics include: Cost recovery allocations; Accountability for public funds; Incentives. Keywords: Research management. (edc)

SUMMARY

In 1986, the House Appropriations Committee directed the Department of Defense (DoD) to "arrange for the preparations of an independent assessment of the justification, tangible benefits, specific costs, management and administrative structure of IR&D/B&P [Independent Research and Development/Bid and Proposal]."[1]

IR&D is research and development initiated and conducted by contractors. It is not specified under any contract or grant. It is funded and managed at the contractor's discretion from contractor controlled resources, with a portion of the costs later recovered in the overhead portion of DoD contracts.

Administration of the IR&D/B&P cost recovery process is centered in the office of the Under Secretary of Defense for Acquisition. An office for research and technology develops policy for the technological aspects of the process, including the technical review of company project descriptions; a procurement office develops policy for all business aspects of IR&D/B&P. The military services actually implement the negotiation of cost recovery rates and the technical evaluations of IR&D projects.

JUSTIFICATION

From a review of scores of official and unofficial statements on the purposes of IR&D by program officials, independent analysts, and critics, we found that past justifications were plausible but not definitive: None showed how IR&D directly contributes to national security.

In terms of its most direct and fundamental contributions to national interest the goals of IR&D are:

- Encouraging greater contributions to technology related to future defense systems;
- Hedging against the uncertainties, inflexibilities, and short time horizons of defense planning and systems development;
- Promoting the movement of new ideas and technologies into enhanced defense capabilities.

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[1]U.S. House of Representatives, Committee on Appropriations, *Department of Defense Appropriations Bill, 1986*, 99th Cong., 1st Sess., Report 99-332, October 24, 1985, p. 284-285.

If the goal of encouraging more defense technology is to be met, larger defense-oriented contractor R&D programs are needed than would exist without DoD support for IR&D. Broader, more diverse R&D programs are needed if the goal of hedging is to be met. Also for that goal, R&D programs must involve many autonomous decisionmakers free to investigate different problems and to use methods different from those chosen by the planners responsible for DoD's weapon design and procurement. To ensure that the application of research results to defense capabilities is met, the results should be understood and, most important, used by the organizations responsible for military systems development and production.

If DoD's IR&D process has these effects, it deserves to be counted a success. Evaluation of the process, therefore, requires measurement or assessment of the following:

- The incentives of government IR&D support for contractor-initiated R&D;
- The response of contractors to these incentives;
- The range of technical problems investigated;
- The number and dispersion of IR&D decisionmakers, the locus of project planning, and the flexibility of R&D decisionmaking;
- The directness of the linkage between IR&D and the creation of defense-relevant products.

We were able to assess most of these outcomes. We studied the contractors' internal R&D decisionmaking to learn whether contractors take account of DoD's support of IR&D as they plan and manage their independent technical efforts. This would tell us whether DoD policies encourage greater IR&D effort, more hedging, and technology transfer; but it could not tell us precisely how strong the contractors' responses were.

We also analyzed quantitative records to estimate the strength of contractors' responses to DoD inducements. This would help us estimate the net effects of DoD efforts and, in particular, by what amounts the total volume of IR&D performed with DoD encouragement was greater than the amount that would have been undertaken without the DoD contribution.

BENEFITS

Evidence from our industry case studies and statistical analysis indicates that companies perform more defense-related R&D than they would in the absence of government support of their IR&D costs.

Companies plan their IR&D investments in anticipation of cost recovery, the amount of which depends on how much IR&D the companies decide to perform. This cost sharing by government, in essence, reduces the price of R&D to industry, thereby leading to higher levels of IR&D spending. We conclude that the IR&D process does encourage a larger technology base effort than firms would conduct without government support.

Our quantitative analysis of contractors' cost recovery and spending is consistent with this view of internal company processes. In general, the more IR&D a company performs, the more it recovers from the DoD. For recent years, if an average firm sustains an increase in its total spending on IR&D of $1 it can successfully negotiate an increase in its overhead cost recovery of $0.30–$0.40.

We tried to estimate the effects of increased cost recovery on contractors' IR&D effort. Our results indicate that contractors' IR&D effort rises as government support increases. For the typical firm in our sample, we estimate that a $1 increase in DoD share is associated with an increase of about $0.60 in total IR&D spending in the first year the increase is realized, rising to a total of about $2 over the next several years.[2] Thus, in the long run, the typical firm spends an additional dollar of its own funds for IR&D in response to a dollar of increased government support.

Our analysis of corporate R&D planning, based on interviews and a review of the literature, provides some evidence that a firm's IR&D portfolios are more diverse, less conservative, and further from a company's main lines of business than they would be if the companies had to pay the full cost of their R&D. However, data limits did not allow us to make a conclusive test of these arguments.

The IR&D process also promotes the movement of technologies into new defense capabilities. The defense contractors that conduct the lion's share of IR&D are vertically integrated, to ensure that new ideas do not languish as scientific curiosities, but are used. The same organizations have strong commercial incentives to keep abreast of emerging national security requirements and stay in close touch with the military services that ultimately purchase their products. The services make serious efforts to inform contractors about emerging needs so that contractors can know how new discoveries might be applied.

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[2]More definitive models of firms' behavior and better estimates of their response to cost recovery are possible and may illuminate the issue in the future. See Frank Camm, *How DoD Policy Affects Private Expenditure on Independent Research and Development: A Comparison of Empirical Studies*, The RAND Corporation, N-2384-OSD, 1989 (forthcoming).

COSTS

Besides the cost to the government of $3.5 billion in IR&D and B&P payments to contractors during their overhead charges in 1986, the DoD review and accountability processes impose additional costs on the government and firms. This costs the government approximately $10–12 million per year and contractors $92–115 million per year.

GOVERNMENT ADMINISTRATION

The negotiation process limits government costs and ensures that expenditures can be adjusted in light of contractor performance. However, recent efforts to limit government obligations have weakened the links between firms' IR&D effort and technical performance on one hand, and cost recovery on the other.

The technical review provides some accountability for public funds, but administration of the annual ceilings imposed by Congress on the aggregate size of the IR&D effort and other service-level policies have reduced the influence of technical review scores on contractors' cost recovery. Strong arguments can be made that forcing all contractors to pay some IR&D costs (limiting cost recovery to less than 100 percent of IR&D expenditures) would reduce the need for technical review by creating incentives for strong technical management by the firms themselves.

Service-level negotiators and reviewers respond closely to service-level concerns that may be at variance with the national goals of IR&D. For instance, the services have put pressure on corporate decisionmakers to develop portfolios that directly parallel or complement current service R&D priorities. This runs counter to a hedging strategy that requires distributed decisionmaking.

RECOMMENDATIONS

IR&D serves important national purposes. Funding it through overhead cost recovery increases the technology base effort while preserving the contractors' ability to make independent technical decisions, thus promoting the hedging goal. The current IR&D process may not be the only way to promote hedging, but it is workable. We recommend marginal improvements in the IR&D process: strengthening the linkage between contractors' IR&D effort and their ultimate cost recovery, simplified technical review procedures coupled with increased incentives the firm level for accountability of funds, and consolidated organization of the government portion of the IR&D process to ensure that the basic goals of IR&D are consistently pursued.

ACKNOWLEDGMENTS

This report has benefited from the generous cooperation of government and industry people. The experience and candor of Defense Department personnel gave us an understanding of the process that was unavailable from the stack of reports generated on this subject. Industry executives not only provided their opinions and varied experiences, but showed us at first hand actual IR&D projects in industrial laboratories and company R&D centers. Moreover, requests for permission to use proprietary information elicited a 100 percent response and approval from the more than 100 companies—an unheard-of response rate in research studies.

This work has also benefited from inputs by several RAND colleagues who participated in various phases of the study. Substantial portions of an unpublished interim report by Paul Hill and Susan Bodilly were incorporated into this report. Todd Porter, a RAND Summer Intern, contributed to the data development, statistical analyses, and theory formulation. Michael Rothman was responsible for the management and merging of several data bases. Jack Stockfisch and Kevin Terpstra contributed theoretical analyses and research support in the early phases of the study when our concepts were first forming. Gene Fisher, Glenn Kent, James Hosek, Frank Camm, and Thomas Glennan reviewed earlier drafts and made valuable suggestions to clarify our arguments. Stanley Besen and Milton Margolis provided detailed critiques of the analysis.

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I. INTRODUCTION

ORIGIN OF THE STUDY

The House Appropriations Committee report on the 1986 DoD appropriations bill directed the Department to "arrange for the preparation of an independent assessment of the justification, tangible benefits, specific costs, management and administrative structure of IR&D/B&P [Independent Research and Development/Bid and Proposal]."[1] The Undersecretary of Defense for Research and Engineering asked RAND to undertake this assessment.

IR&D/B&P has been of special concern to Congress since the late 1940s because it is managed through a relationship between the DoD and its contractors that is considerably more complex in its goals and procedures than is usually the case. This complexity has led to confusion over the goals, their justification, and the methods developed to administer the process. Congress has therefore periodically called for hearings and studies into these matters and has several times rewritten the law governing the subject.

The central policy issue related to IR&D and B&P arises from the fact that a negotiated amount of these expenditures may be included as indirect costs on government contracts. The government thus supports or underwrites a portion of industry's IR&D and B&P.

The present study is not the first on this subject. Indeed, we have built on and made use of a voluminous literature.[2] However, this

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[1]U.S. House of Representatives, Committee on Appropriations, *Department of Defense Appropriations Bill, 1986*, 99th Cong., 1st Sess., Report 99-332, October 24, 1985, pp. 284–285.

[2]In particular, the following items provide a detailed history and description of IR&D/B&P: U.S. Department of Defense, Office of the Director of Defense Research and Engineering, *The Independent Research and Development Program: A Review of IR&D*, as reported to The IR&D Policy Council by the DoD Working Group on the Nature, Objectives, and Effects of the IR&D Program, June 1974, National Technical Information Service (NTIS) AD/A-004 610.

U.S. Congress, Joint Economic Committee, Subcommittee on Priorities and Economy in Government, and Senate Committee on Armed Services, Subcommittee on Research and Development, *Hearings on Independent Research and Development*, 94th Cong., 1st Sess., September 1975, Washington, D.C., 1976.

U.S. National Research Council, *The DoD-NASA Independent Research and Development Program: Issues and Methodology for an In-Depth Study*, NTIS PB82-192741, 1981.

Joan Dopico Winston, Congressional Research Service, Library of Congress, *Defense Related Independent Research and Development in Industry*, Report No. 85-205 S, October 1985.

Mention should also be made of an internal DoD history that has formed the basis of literature is largely descriptive and assertive, with little attempt to investigate actual behavior in a framework of incentives and organizational processes. We have considered the motives that influence government and industry and analyzed actual government and industry behavior.

ORGANIZATION OF THE REPORT

This report is structured to respond to the four congressional issues:

- Justification
- Benefits
- Costs
- Management and Administration

After describing IR&D and B&P and the process by which the DoD supports these industry efforts, we develop a set of goals that would justify DoD support. Evaluation of the tangible benefits is based on determining whether the actual process furthers the goals identified. We then consider aspects of management, administration, and cost—again evaluating these activities in light of the goals put forward as justification for government support of IR&D and B&P. The final section of the report makes policy recommendations. The appendixes contain statistical details and analyses to support and enlarge upon points raised in the main part of the report. They also consider questions and issues raised outside of the congressional language that stimulated this research.

SOURCES OF INFORMATION AND METHODS

This report is based on several sources of information and analysis. We reviewed the shelf-full of previous studies, hearings, statements, and articles dealing with IR&D. We conducted interviews and detailed reviews of company processes covering 12 contractors and more than a score of their operating divisions, selected to obtain a range of size, structure, and specialty—including aerospace, electronics, shipbuilding, and computer software. In these company reviews, we were particularly interested in internal corporate IR&D planning and financing, and in the IR&D projects and results.

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many of the above-cited references: C. E. Deardorff, *Historical Evolution of Independent Research and Development*, Office of the Undersecretary of Defense for Research and Engineering, 21 January 1981.

We interviewed more than 50 DoD officials and former officials, including top officials of Defense Research and Engineering, the services IR&D coordinators, Defense Advanced Research and Projects Agency (DARPA), and service laboratory managers and scientists.

With the use of several data bases, we performed statistical analyses of IR&D behavior of industry and government, covering about one hundred companies over a 17-year period. In addition, we reviewed published studies on R&D to check the consistency with our own findings and to seek answers to questions that our data bases could not answer.

The legislation, regulations, administrative case law, and customs governing the administration of the IR&D/B&P process have developed into a tight and complex web of interpretations and procedures. Our consideration of the basic rationales and goals for IR&D/B&P were not necessarily limited by such laws, regulations, etc. Instead, we have attempted to recast the goals, justifications, and rationales by asking, "What are the benefits, advantages, and costs to the nation as a whole and to its security?" In doing this, we have had to back away from accounting conventions, customary usages, and habitual modes of thinking about the subject.

DEFINITIONS

According to the Federal Acquisition Regulations (FAR), "a contractor's independent research and development (IR&D) effort is that technical effort which is not sponsored by, or required in performance of, a contract or grant and that consists of projects falling within the four following areas: (1) basic research, (2) applied research, (3) development, and (4) systems and other concept formulation studies."[3] In nonlegal terms, IR&D is research and development initiated and conducted by contractors; it is not specified under any contract or grant. It is funded and managed at the contractor's discretion from contractor-controlled resources, with a portion of the costs later recovered in the overhead portion of DoD contracts.

Bid and proposal costs are defined in the same regulation as those costs "incurred in preparing, submitting, and supporting bids and proposals (whether or not solicited) on potential Government or non-Government contracts." The term does not include the costs of effort sponsored by a grant or cooperative agreement or required in contract

[3]FAR 31.205-18 (a).

performance.[4] B&P efforts can include technical background work needed to enable a contractor to submit a proposal. There may therefore be considerable overlap in the kinds of activities included in the IR&D and B&P accounts. Although B&P is closely related to a company's marketing activities and usually is planned with a shorter time horizon than R&D, many B&P activities are often functionally indistinguishable from IR&D; the cost recovery process is also similar, and the two accounts are permitted by regulation to be fungible. For simplicity, in much of this report we will treat IR&D and B&P together under the IR&D designation, unless the two categories are explicitly dealt with individually.

Since 1970, for IR&D and B&P costs to be considered as an allowable cost for recovery purposes, they had to have "a potential relationship to a military function or operation," specified as PMR (potential military relationship).[5]

IR&D can be distinguished from other research and development conducted by a company. Since IR&D is unsponsored R&D, a contrasting category includes contract or grant R&D, directly sponsored and paid for by another party: government, commercial, nonprofit foundation, etc. Companies may also conduct other company-funded R&D that does not fall into the IR&D category for any of several reasons: (1) it may not meet the IR&D definitions—for example, manufacturing process R&D falls outside the IR&D definitions; (2) it may be performed in operating divisions that do not conduct business with the DoD; and (3) the company may withhold it from consideration for proprietary reasons or for other business strategy purposes. IR&D's roles and functions in the overall defense R&D framework are shown in Table 1.

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[4]A rich administrative case law and legal history developed over the meaning of such terms in the regulations as "sponsored" and "required in performance of."

[5]Public Law No. 91-441, Sec. 203 (a) (1970).

Table 1

THE DISTRIBUTION OF R&D FUNCTIONS AND RESOURCES BETWEEN THE DEFENSE DEPARTMENT AND INDUSTRY

R&D Functions	DoD In-house R&D	DoD Contract R&D	IR&D/ B&P	Other Industry-sponsored R&D[a]
Plan	DoD	DoD	Industry	Industry
Finance	DoD	DoD	DoD/Industry	Industry
Perform	DoD	Industry	Industry	Industry
Amount ($ billion 1985)	$7.0	$22.0	$5.0/2.0	$8.0-16.0

SOURCES: DoD in-house R&D and contract R&D: Defense Department, *The FY 1987 DoD Program for R&D, Statement by the Undersecretary of Defense, Research and Engineering*, 99th Cong., 2d Sess., 1986, p. A-6.

IR&D/B&P: Defense Contract Audit Agency, *Independent Research and Development and Bid and Proposal Cost Incurred by Major Defense Contracts*, 1986.

Other Company R&D: Securities and Exchange Commission, 10K financial reports.

[a]Other industry-sponsored R&D is that performed by companies negotiating IR&D agreements in 1985; it includes the total amount of reported R&D minus IR&D. The smaller figure omits IBM, GM, and AT&T, whose efforts were primarily in nondefense areas.

II. HISTORY OF IR&D

EARLY HISTORY

The present process started with the 1934 Vinson-Trammell Act, which limited the profits on naval vessels and aircraft to 10 percent of the total contract price.[1] This restriction on profits, defined as a percentage of costs, demanded a definition of acceptable costs. Treasury Decision (T.D.) 5000 identified certain indirect R&D cost items that would be recognized by the government, including a reasonable portion of "general experimental and development expenses which may be charged off currently";[2] indirect engineering expenses;[3] and "bidding and general selling expenses."[4]

The requirement to define acceptable costs that followed from the profit restrictions of the Vinson-Trammell Act was continued by the subsequent "excess-profits" tax and the pricing of contracts during World War II. This cost-based approach to contract pricing has dominated defense procurement up to the present time.[5] As one company financial vice-president told us, "If we don't get it in the cost structure, we don't get it in price, revenues, or profits."[6]

Following World War II, the contract cost regulations were rewritten as part of the new Armed Services Procurement Regulation (ASPR). In 1949, R&D was considered an allowable cost only if specifically related to the items covered by the contract; general research expenses (roughly equivalent to IR&D) were unallowed unless specifically provided for in the contract.[7] However, many defense contractors insisted on the inclusion of such IR&D-like costs as a condition of doing

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[1]48 Stat. 505; 34 U.S.C., sec. 496.

[2]Sec. 26.9 (5) (E) (d).

[3]Sec. 26.9 (5) (E) (f).

[4]Sec. 26.9 (5) (E) (g) (2).

[5]The cost-based approach to pricing has been reinforced by the prevalence of new technologies and products in the military's market basket that have no civil analogues and few antecedents. Under these conditions, cost has become the principal determinant of price.

[6]An authoritative cost-accounting manual states: "For a government contract, the focal point of cost accumulation is the contract. . . . Government contractors find that they must negotiate a price . . . for each contract. Since the starting point for negotiations is the contractor's cost, the contractor attaches as many costs as is reasonably possible to the contract." Lane K. Anderson, *Accounting for Government Contracts: Cost Accounting Standards*, Matthew Bender, New York, 1986, pp. 9-5, 9-6.

[7]ASPR, sec. 15-204(s) and 250(j), 1947.

business with the government.[8] The Air Force reacted to these demands by requiring contractors to submit an annual IR&D plan so that the projects and costs could be reviewed and recovery amounts negotiated.

ESTABLISHING PRINCIPLES OF GOVERNMENT INVOLVEMENT

In the years after the 1949 disallowing of general research expenses, industry, Congress, and several investigating agencies criticized the policy and urged that the cost principles be rewritten.

With the intense focus on military and civil R&D following the Soviet launch of the first Sputnik in 1957, there was a general feeling that DoD support for IR&D should be given greater encouragement. If there was to be greater support, however, increased accountability would also be required. By the late 1950s, senior DoD officials believed that some constraints were necessary on IR&D cost recoveries and that better assurance was required that companies' IR&D efforts would produce useful results.[9] Proposals were made for explicit cost-sharing of IR&D and for advance agreements on recovery amounts.

In 1959, a new ASPR implicitly incorporated three principles into the determination of allowable IR&D costs.

- To control its expenditures, the government would limit the amount of IR&D it would allow in the overhead rate of procurement contracts.
- The government would reimburse only the portion of IR&D that could be expected to benefit future defense capabilities.
- Accountability of public funds would be established.

The new ASPR incorporated these principles into an IR&D process that included both a negotiation of the recovery amount and a technical review. First, the new regulation specified that a ceiling of accepted or "allowable" IR&D costs should be established through negotiations with contractors. Thus, the amount of IR&D to be recovered would not be automatically determined solely by the behavior of defense contractors, but rather negotiations would determine a "reasonable" amount stated in terms of an allowable ceiling. Second, a portion of the ceiling (a so-called "allocable share") could be charged (or "allocated") as overhead to DoD contracts. This share, which is highly

[8]Deardorff, 1981, p. 3.

[9]Ibid.

correlated with the ratio of a company's defense to total sales, attempted to relate IR&D recovery to the company's volume of defense-related IR&D. Third, contractors were required to submit technical brochures describing their IR&D projects, which were to be evaluated by technical specialists in DoD with the evaluations furnished to the DoD IR&D negotiator. This requirement established a procedure for the accountability of government funds to ensure that IR&D projects were technically reasonable and professionally managed.

Many companies had to reorganize their internal R&D management to prepare the IR&D project plan for technical evaluation and negotiation. In addition, the first several rounds of technical review produced considerable surprise to industry technical personnel as the evaluations often indicated deficiencies or lagging technical standards compared with those of other companies or government laboratories. Such reviews were especially distressing because they influenced the level of the negotiated ceiling. However, according to Charles Deardorff, an active government participant during this period, contractors reacted quickly to poor reviews, and the technical scores rapidly reached a more uniform plateau at a higher level.[10]

CURRENT STATUS

Numerous technical problems surfaced with the 1959 regulations. Additional studies were commissioned, draft regulations were issued for comment, congressional hearings were held. Public Law 91-441 was enacted in 1970, which included Sec. 203 on IR&D and B&P. This law, and the regulations that implement it, govern the present operation of the IR&D and B&P cost recovery process. The law required "advance agreements" on the allowable ceiling with penalties for contractors who failed to negotiate, technical evaluation of all IR&D projects submitted for consideration in the company's IR&D pool, and review of the potential military relationship of all IR&D projects.

Any company that currently receives $4.4 million in combined IR&D and B&P costs from DoD contracts is required to negotiate a "ceiling" of "allowable" IR&D costs that can later be recovered in overhead on government contracts. (This threshold value has been modified since the 1970 legislation to take account of inflation.) For each qualifying company, an advance agreement must be negotiated at the profit-center level (usually a company division) if the profit center contracts directly with the government and recovered $550,000 in IR&D and B&P costs from the government during the previous year.

[10]Ibid., p. 7.

As of 1988, there were over 13,000 defense contractors. In 1985. 108 companies (including 306 single companies and divisions) negotiated IR&D and B&P. Data on those companies are audited and reported by the Defense Contract Audit Agency (DCAA). Companies not meeting the negotiating criterion establish their cost recovery amounts through a formula. Approximately 97 percent of all IR&D is accounted for by the hundred or so companies that negotiate with the DoD, and only 3 percent by the other 13,000 defense contractors.[11] The remainder of this report concentrates on the IR&D process and outcomes of the hundred or so negotiating companies, which perform the overwhelming amount of IR&D.

The basic process has not changed since the 1970 passage of the legislation governing IR&D/B&P. In 1983, however, Congress required DoD to set a target for the total IR&D allowable ceiling of $5.2 billion. This target continued in effect through 1988 with annual adjustments for inflation and overall budget trends.

DoD IR&D ORGANIZATION

Administration of the IR&D/B&P cost recovery process is centered in the office of the Under Secretary of Defense for Acquisition. However, the responsibility is split into two functions: An office for research and technology develops policy for the technological aspects of the process, including the technical review of company project descriptions; and a procurement office develops policy for all business aspects of IR&D/B&P, including the negotiation of advance agreements with contractors and coordination with other government agencies on accounting and regulatory matters.[12] The research and technology office is nominally responsible for coordination of these functions, but since the two offices are at the same bureaucratic level, clear policy leadership has been difficult.

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[11]These percentages were calculated from a 1979 DCAA survey. The 13,000 contractors referred to are those supplying products and services other than subsistence products, clothing, petroleum products, and other products whose price is market determined. The survey indicated that these 13,000 contractors, on the average, spent about three-quarters of one percent of sales on IR&D. ("As you go down in volume to the smaller and smaller contractors, IR&D almost completely disappears," said James Brown, DCAA Deputy Director.) These companies received about 30 percent of total DoD procurement and R&D contracts, or about $9.5 billion; 0.75 percent of $9.5 billion is $71 million, or 3.3 percent of the reported $2.1 billion of IR&D in 1979. U.S. House of Representatives, Appropriations Committee, *Department of Defense Appropriations for 1983, Part 4*, 97th Cong., 2d Sess., pp. 703, 714.

[12]The organizational name and subordination of these two offices have changed in the past, and no doubt will do so in the future. As of 1988, the offices were under the Deputy Under Secretary for Research and Advanced Technology and the Deputy Assistant Secretary for Procurement.

The military services actually implement the negotiation of advance agreements and the technical evaluations of IR&D projects. Sited within the services acquisition commands, the two functions fall under a contracts and business office and a technical office. A contractor is assigned to the military service with which it has the greatest volume of business; however, since assignments rarely change, altered business patterns may create anomalous situations wherein companies continue to deal with a service that no longer is its chief customer.

III. THE IR&D PLANNING, PERFORMING, AND COST RECOVERY PROCESS

The IR&D process is complex, but it can be reduced to a few successive steps, some performed by contractors, some by the government, and some jointly. In sequence, (1) The firm develops an IR&D portfolio and begins work, (2) it submits descriptions of all of its current and expected IR&D projects, (3) the government performs a technical review, (4) the firm and the government IR&D/B&P negotiators settle on a value for IR&D costs to be included in DoD contract negotiations, (5) these negotiators take account of the dollar amount when negotiating the overhead rate on all contracts signed that year, and (6) the firm attempts to recover the negotiated IR&D costs in the course of performing its DoD contracts.

CORPORATE PLANNING AND PERFORMANCE OF IR&D

The IR&D process begins with a contractor's corporate strategy and related planning activities. The corporate R&D manager develops an IR&D plan as part of the firm's overall R&D plan, after reviewing the project proposals coming up from R&D personnel and the strategic, marketing, and financial guidance flowing down from corporate officers. An important element in this review is the expected amount of IR&D cost recovery. On the basis of this review the R&D managers reject marginal projects that do not meet internal corporate criteria and cannot be covered by expected funding. Following corporate approval of the plan, the firm executes its research plan. Subsequent transactions with the government—the technical evaluation and negotiations processes—may have marginal effects on the plan, but the contractors proceed without awaiting government action.

TECHNICAL REVIEW

Congress intended technical evaluations of contractors' projects to control reimbursement by making the allowable ceiling depend to some degree on the quality of IR&D, and to reduce the hazard of improper or unjustifiable expenditures. The technical evaluation also determines whether the projects meet the definitions of allowable costs and whether they have a potential military relationship.[1] In short, the technical review process was imposed to ensure accountability. Over time, another function has been added: The services use the evaluation process to stimulate communications between government scientists and specialists in the private sector.

Each contractor that negotiates an advance agreement must submit a description of its portfolio of IR&D projects for government technical review. This description includes a one-page summary and a detailed brochure of almost 30 pages for each project. Each contractor is assigned to a military service (a lead agency), which is responsible for the negotiations and for technical evaluations of the contractor's IR&D projects. The lead service's technical evaluator distributes the IR&D technical project descriptions submitted by industry for evaluation to service laboratories or to other government agencies with the necessary expertise. Figures for 1983 indicate that more than 30,000 technical evaluations were performed for some 10,000 projects.[2] The evaluators, who remain anonymous to the contractors, are government scientists and engineers with other primary responsibilities. The evaluators score each project and provide comments as warranted. Each project is scored on the specification of objectives, the technical viability of the approach chosen, whether sufficient resources are earmarked, and whether reasonable progress has been made in the past year, if it is a continuing project. The evaluators also judge whether the project has sufficient potential military relationship to justify DoD cost reimbursement.

Each project's scores are weighted by the evaluator's self-rated expertise. All of the contractor's project scores are then dollar-weighted for a final score. The individual project scores are sent to the contractor, and individual scores and contractor averages are sent to the government IR&D negotiators for consideration in the recovery negotiations.

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[1]Potential military relationship is determined by three basic considerations. (1) IR&D does not have PMR if DoD is precluded by law or policy from directly funding R&D in a given area. (2) The degree of applicability of the end product to defense needs must be considered. If the end-product has only incidental military application, the project is nonrelevant. If the project is primarily nonmilitary but concerns a "tailored military application such as high-lift wing devices for a light general aviation aircraft," then the project is relevant. If the project is primarily nonmilitary, but has a "substantial though non-tailored military application such as typewriters or beds," then one more factor must be considered. (3) Does another government agency have responsibility for such R&D? If so, then the project is not considered relevant. U.S. House of Representatives, Committee on Appropriations, *Department of Defense Appropriations for 1983,* 97th Cong., 2d Sess., pp. 734–735.

[2]U.S. House of Representatives, Committee on Appropriations, *DoD Appropriations for 1983,* 97th Cong., 2d Sess., p. 734.

The evaluation of brochures is supplemented by on-site visits to contractors on a three-year cycle. During these visits, government personnel have the opportunity for face-to-face contacts with company scientists and engineers and for more realistic project evaluations than is possible through brochures.

NEGOTIATIONS

After the entire pool of proposed projects has undergone a technical review, a complex multistage negotiations process ensues. The firm meets first with specialized IR&D/B&P negotiators and later with contracting officers on its individual contracts to:

- Set a limit on the total amount of IR&D that DoD will recognize as eligible for government cost sharing
- Estimate what share of the eligible pool will be funded by the government through overhead cost recovery.
- Set an overhead rate that, when applied to the firm's expected DoD contracts, will produce revenues equivalent to the share of the firm's IR&D expenses the government intends to pay.

In the technical terms used in this negotiation process, the first step sets the "allowable ceiling." The second step estimates an "allocated defense share," and the third step establishes the overhead rate for IR&D in the firms' current DoD contracts.

The allowable ceiling negotiations, performed by special IR&D negotiators, reduce the dollar amount of the contractor's pool of planned and ongoing IR&D projects to an acceptable level for government reimbursement.[3] All projects that do not have PMR, as determined by the technical review, or that do not meet legal criteria for IR&D are removed from consideration. The resulting dollar amount of the

[3]The basic law governing IR&D requires advance negotiated agreements on the ceilings. Regulations instruct negotiators to pay attention to trends in company business and previous IR&D expenditures, projected DoD and commercial business, and the results of the technical evaluations of IR&D projects. The negotiations are intended to control the government's cost exposure according to a determination of the "reasonableness" of IR&D costs. The notion of reasonableness is firmly entrenched in DoD regulations and administrative case law as the amount a prudent businessman would expend in conducting a competitive business. This includes consideration of whether the cost is generally recognized as ordinary and necessary and whether it is a "sound business practice." Two other considerations have entered into the determination of reasonableness: affordability and government benefit. These latter-day criteria emphasize the oversight and accountability aspects of negotiations; as such, they shift from the "just cost" point of view of the prudent business decisionmaker to a view that evaluates the costs and benefits to the nation.

proposed pool is reviewed and, usually, reduced by the government IR&D negotiator based on criteria that include: general guidelines required to keep overall DoD support for IR&D within a ceiling set by Congress, the firm's projected defense sales and other financial indicators, technical review scores, the firm's past performance on IR&D, and historical trends in the firm's level of IR&D effort and reimbursement. The resulting dollar amount is known as the "allowable ceiling" and is the maximum dollar amount that a firm could recover if DoD agreed to pay all its IR&D costs. The IR&D/B&P negotiations are essentially completed with the determination of the ceiling amount.

In subsequent contract negotiations the allowable ceiling is "allocated" to DoD contracts as the "DoD share" of allowable costs. It is treated as an element of General and Administrative (G&A) expenses[4] and allocated among contracts accordingly. The intent of this step, which is also taken on the G&A cost elements, is to limit government IR&D support to its "fair share" of the total. DoD does not want to reimburse IR&D that would have been undertaken solely or primarily for commercial purposes. A simple rule of thumb is used to reduce the allowable ceiling to an amount allocable to defense contracts, usually on the same basis used to allocate G&A: Typically, the ceiling is multiplied by the ratio of the firm's projected defense sales to total sales. The result is an estimated dollar amount of IR&D that can be allocated to defense contracts; it is known as the "DoD share of the allowable ceiling" or the "allocated share."

Contracting officers take the final step to convert the dollar DoD share into an overhead rate element that can be included in specific DoD contracts. The dollar DoD share is divided by the firm's projected defense sales for that year, resulting in a percent or rate that is incorporated into the overhead rate contracts signed that year.[5]

These same negotiations, minus consideration of technical review scores, are performed for B&P funds. Once the B&P recovery rate is established, the two categories are combined and contractors are free to cross-allocate IR&D and B&P funds.

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[4]The large defense contractors analyzed in this report are under constant scrutiny by government auditors and contract officers. Changes in a company's aggregate DoD sales, commercial sales, or IR&D expenditures from those contemplated at the time of the original overhead rate determination may be used to revise the overhead rates applicable to ongoing cost-based contracts.

[5]Negotiated IR&D and B&P ceilings of allowed costs must be accepted in subsequent negotiations. Government officials negotiating contracts may consider the reasonableness of the IR&D/B&P costs when bargaining over a company's total overhead rate or other cost elements. The negotiations also establish "forward pricing rates" applied in multiyear fixed-price contracts.

The firm performs its contracts, and payments from the government include overhead recovery based in part on the rate negotiated for IR&D. The firm maintains its own internal accounting system and pays the costs of its IR&D projects from the funds on hand. The amount that the firm actually spends on IR&D is called "incurred IR&D." Whether the firm recovers the full amount negotiated for IR&D depends on the price it negotiates on DoD contracts, whether the incurred amount is as high as originally estimated, and whether the firm's sales and costs are as high as expected.[6]

This process is summarized in Fig. 1, which shows several feedback loops that lie at the heart of IR&D process and policy. Government negotiators use the expected level of a company's IR&D spending in conjunction with its defense business to form a notion of the reasonableness of a company's IR&D plan, which enters into the formation of the negotiated ceiling. The ratio of DoD sales to total sales is used to calculate the DoD share, given the ceiling. And—most important—the expected level of DoD share is a central determinant of industry's IR&D spending plans.

Annual statistics on IR&D and B&P are shown in App. A.

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[6]The total recovery of IR&D and B&P costs is currently formally limited by the total amount of IR&D having a potentially military relationship. If actual sales and incurred costs turn out as originally estimated, the firm will receive its "DoD share." Otherwise the amount with PMR serves as an upper limit.

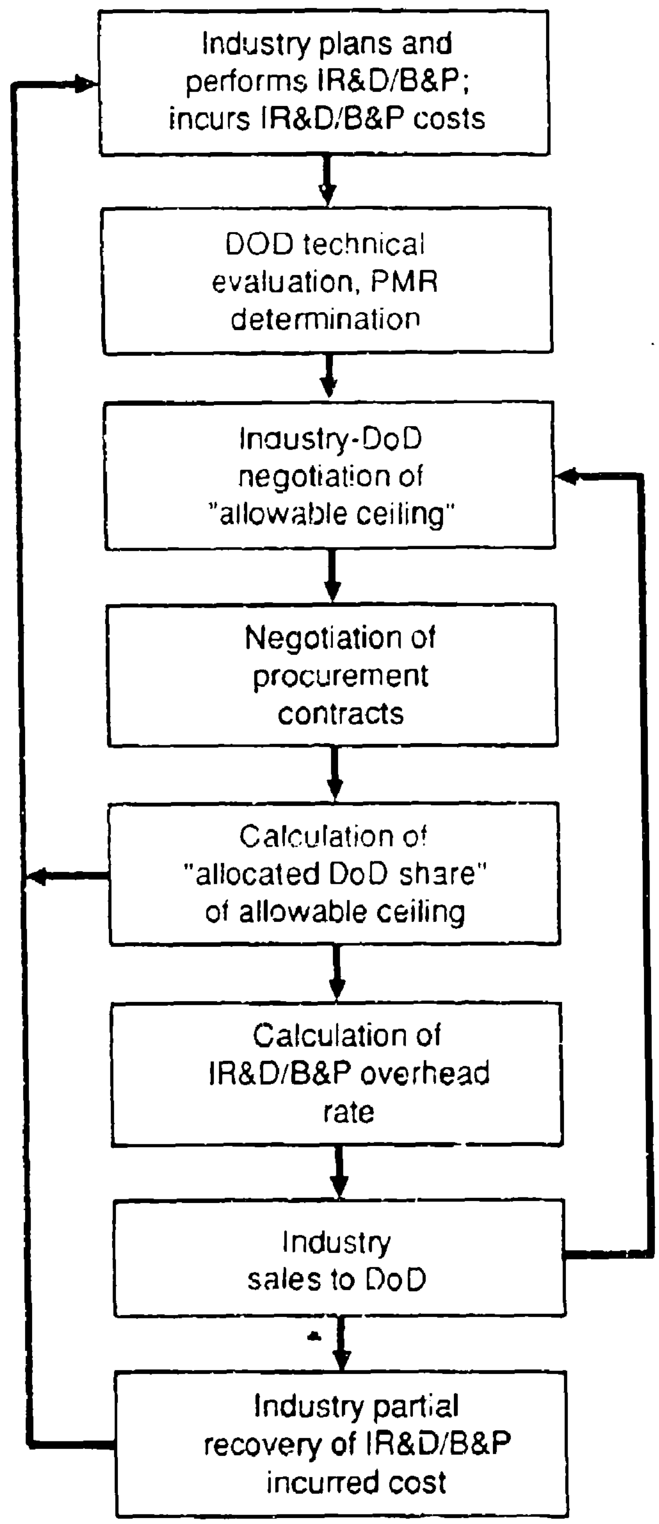

Fig. 1—The IR&D/B&P cost recovery process

IV. GOALS OF IR&D

PREVIOUSLY STATED IR&D GOALS

We reviewed the relevant statutes, regulations, official statements, congressional hearings, and comments of people in government, industry, and the academic world for their statements about the rationales or goals of government support of IR&D. We then combined the various statements and rationales into the following representative list of the purposes for both government support of IR&D and the process by which that support is provided. Government support of IR&D has been said to be justified because:

- It is a necessary cost of doing business.
- It encourages R&D of innovative concepts for DoD systems.
- It fosters competition by promoting technical competence in several companies.
- It contributes to economic stability of the defense industry.
- It stimulates the creation of innovative products and capabilities.
- It ensures the military relevancy of defense industry research.
- It promotes information exchange between DoD and industry scientists and engineers.
- It creates DoD leverage for influencing industry's choice of R&D projects.
- It enhances the international competitiveness of U.S. industry.

All of these rationales have been put forward through the 50-year history of IR&D support, but the emphasis has changed over time. Before and shortly after World War II, justifications for IR&D support emphasized the necessity of industrial R&D for defense; IR&D support by the government was seen to be in the national interest because it gave firms an incentive to develop products for the military market and to generate production capacity and experience.

From the 1950s into the 1970s, the policy emphasized the defense technical base; government support was desired to encourage firms to allocate their best scientific and technical talent to create defense-related technology. In the mid-1970s, when critics of government policy questioned the value of IR&D support, the IR&D process was pictured as a source of leverage and quality control to ensure that DoD would receive good value in areas that were deemed desirable in exchange for DoD contributions to IR&D efforts.

In the 1980s a new purpose was added, especially by industry representatives, as the United States encountered a seriously deteriorating trade position. IR&D was seen as enhancing the American competitive position in world markets.

These statements represent plausible rationales for government support of IR&D, but none is definitive. None shows how IR&D directly contributes to national security. Moreover, they manifest some tensions among themselves--for example, promoting stability could reduce competition. Some statements—for example, encouraging defense-industry stability—concern problems that are less severe in some periods than they were when the goals were first formulated. Other statements—for example, reimbursing contractors for reasonable expenses—represent intermediate goals and do not specify how the national interest is ultimately to be served. In 1940, when military R&D was only 3.2 percent of procurement, government's acceptance of industry's military-related R&D as a cost element of procurement contracts was perhaps more clearly "necessary for the performance of the contract" than it is in the 1980s when R&D is 40-45 percent of the military procurement budget.[1] To answer the questions posed by Congress, we must identify how government support of IR&D makes direct and specific contributions to national security.

NEW FORMULATION OF GOALS

We tried to create new statements that were consistent with the goals historically attributed to government support of IR&D and abstracted their underlying attributes but were formulated in terms of a broader national interest. We believe that a plausible justification for IR&D support can be made in terms of three important goals (whether the existing IR&D process is a particularly effective way of meeting them or not):

- Encouraging greater contributions to technology related to future defense systems;
- Hedging against the uncertainties, inflexibilities, and short time horizons of defense planning and systems development;

[1]In 1940, military procurement was $2.1 billion and R&D was $67 million. The corresponding figures for 1985 were $70.4 billion and $27.1 billion. Sources: 1940 R&D, Vannevar Bush, *Science, the Endless Frontier*, NSF Report 1980, Table 1, p. 86; 1940 procurement, R. Elberton Smith, *The Army and Economic Mobilization*, Washington, D.C., 1959, pp. 6-7; 1985 R&D and procurement, U.S. Department of Commerce, *Statistical Abstract of the United States, 1988*, Table 509, p. 314.

- Promoting the movement of new ideas and technologies into enhanced defense capabilities.

These three goals together reflect the contribution that DoD's financial support of IR&D may make to the national defense effort. They do not appear in any previous documents on IR&D; we distilled them from the body of work previously devoted to the subject.

Identifying national goals that government support of IR&D may serve, however, does not in itself demonstrate that DoD efforts to promote them are effective. Rather, we can restate the justification in the following terms: To the degree that these goals are accepted as valid rationales of government policy, they can be used as a framework for the evaluation of current program activities.

WHY ARE THESE GOALS IMPORTANT AND DO THEY MERIT DoD SUPPORT?

Goals as a Rationale for IR&D Support

The three goals reinforce each other and should be considered as a package. Although none is unique to IR&D, no other program simultaneously promotes growth in the technology base, hedging, and application of new ideas and technologies.

Although hundreds of DoD offices and agencies plan, conduct, or contract for defense R&D, most of their attention and resources are devoted to supporting current systems development projects. Moreover, their internal planning and allocation methods are inherently conservative and often difficult to change in the short run in response to new information flowing from current R&D results or to new intelligence information on changes in potential threats.[2] A more decentralized system is therefore needed to hedge against these systemic deficiencies.

IR&D's uniqueness in fostering growth of the defense technology base arises from its loose coupling to the internal DoD resource allocation and priority-setting process. The decentralized structure of industry raises the likelihood that R&D decisions are made independently by knowledgeable parties who are outside the DoD, responding to different information, expertise, and incentives. To the degree that the IR&D cost-recovery process promotes more R&D, it enlarges the technology

[2]We do not mean to criticize the defense R&D process but rather to recognize that the incentives and structures established to serve one set of goals may produce systemic shortfalls in attaining other goals.

base per se and by doing that improves the chances of hedging against the shortfalls of the internal DoD process.

The IR&D process potentially accomplishes all three of the goals listed above: Cost recovery is likely to stimulate more R&D by defense contractors who propose and conduct the work; hedging is promoted by the fact that the decisions and work are performed in more than 100 companies, 300 organizations, and 10,000 projects. Because the research performers are also the probable system developers and producers, efficient use of R&D results is likely.

Impediments to Private R&D

Although defense contractors have strong incentives to support R&D on their own, and they would do so whether the government encouraged them or not, there is reason to question whether industry, in pursuing its own profit goals, would perform a sufficient amount of research when valued from a national perspective.

Various possible "market failures" prevent private profit-seeking firms from conducting the optimal amount of R&D from a broad social perspective. Two features of R&D in particular can reduce the amount that firms are willing to finance on their own: inability to appropriate and uncertainty. Once knowledge is created in an R&D project, it may be difficult for a firm to capture all of the benefits from that knowledge. New knowledge may be transferred at low cost to buyers or competitors, thereby reducing its value to the creator. Also, R&D results may be difficult to turn to a profit when a firm is unlikely to have a product line that could incorporate the results.

Uncertainty reduces the amount of R&D investments when managers shy away from risk-taking—when possible winning projects are overpowered in the manager's calculations by the negative effects on career and short-term profits of big losers.

Both the inability to appropriate and uncertainty can retard R&D investment such that insufficient amounts are invested from a broader social perspective. Numerous studies of industrial R&D conclude that this is the case, despite the use of different methods and data samples: The social returns of industrial R&D far outweigh the private returns and the returns to other uses of capital.[3] The issue therefore comes down to the question of whether defense industry, investing according to its own private incentives, would generate a sufficient amount of independently chosen R&D when valued from the perspective of national defense priorities and available resources. If privat

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[3]Much of this evidence is summarized in Martin Neil Bailey and Robert Z. Lawrence, *Tax Policies for Innovation and Competitiveness*, Council on Research and Technology, Washington, D.C., April 1987.

incentives were inadequate to promote the desired level of R&D, a program of industrial defense R&D would presumably require additional encouragement and support to stimulate the socially desired investments.[4]

Hedging Against the Formalized Decision Structure

A landmark RAND report of 1958 summarized a multiyear research program on weapons acquisition and recommended a policy to promote independent, military-related R&D outside the framework of final system development.[5] The authors concluded that "weapon system development is most efficient when technological problems are tackled first, because the new knowledge gained from solving them is essential to proper guidance of the later and more expensive stages of program."[6] Case studies of successful and unsuccessful developments had indicated that when the necessary technical knowledge was well in hand, development itself could become faster and less costly.

Furthermore, the report observed that "present policies do not emphasize sufficiently the importance of advancing technology outside the context of weapon-system development."[7] Bureaucratic and budgetary forces raised the demands of system development to such high priority that they dominated the allocation of the R&D budget and determined the pattern of R&D administration as a whole.[8] The authors recommended the devotion of more R&D funds to a "vigorous independent program to advance technology apart from particular system projects."[9] They urged that money for the purpose should be taken out of system projects.

The passing years have witnessed the creation of the Defense Advanced Research Projects Agency (DARPA) to foster pre-systems R&D, and new offices have been created under the Office of Secretary of Defense (OSD) and the services to promote these same aims. But

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[4]This is not to say that we (or anyone else) knows exactly what is the socially optimal quantity of defense R&D, but that the amount provided solely by private industry is likely to be below the optimum.

[5]B. H. Klein, W. H. Meckling, E. G. Mesthene, *Military Research and Development Policies*, R-333, The RAND Corporation, 1958.

[6]Ibid., p. 23.

[7]Ibid., p. 25.

[8]Ibid., p. 26.

[9]Ibid., p. 24.

these organizations must still respond to current DoD priorities and take account of defense requirements.[10]

Although DoD and the services try in their formal planning process to take account of emerging needs and technical opportunities, they inevitably make "bets" on the future by setting priorities and concentrating resources. But even when this is done as well as humanly possible, the results can prove wrong. Changes in the threat, in knowledge, or in technology can devalue the worth of a previously wrought plan.

If DoD R&D planning and acquisition fail to provide a needed capability, U.S. national security would depend on the quality of work that had been done outside the DoD's directly funded R&D processes. If the technologies must be developed from scratch, there is no alternative to a risky, time-consuming crash program. The costs of failing to hedge are likely to be high: Capabilities produced under time pressure usually cost more, take longer to develop, and perform less well than do systems assembled from available technologies that may have been created through an independent, nonsystems-driven R&D process.[11]

Applying R&D Results

Ensuring efficient and effective movement of new concepts into defense capabilities is a natural concomitant to any policy that promotes defense technology. Defense-relevant R&D that does not flow into enhanced capabilities is simply a waste of resources. If this element of R&D policy is left to chance, good and potentially valuable research results often lie unexamined and unused. We have therefore included a goal of effective technology movement to assure that the loop is closed, that R&D results lead to capabilities.

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[10] In 1982, the Deputy Under Secretary of Defense for Research and Advanced Technology stated in support of IR&D, "It is difficult to stimulate innovation within the DoD's own research and development sphere since DoD is performing its R&D for specified projects." Investigative Staff Report, House Appropriations Committee, March 2, 1982. (Reported in U.S. Congress, Department of Defense Appropriations for 1983, *Hearings before Committee on Appropriations*, 97th Cong., 1st Sess., Part 4, p. 655.)

[11] Klein, Meckling, and Mesthene, 1958, p. 24.

V. ASSESSING GOVERNMENT SUPPORT OF IR&D

ASSESSMENT STRATEGY: MEETING THE GOALS

If the goal of encouraging more defense technology is to be met, larger, defense-oriented contractor R&D programs are needed than would exist without DoD support. Broader, more diverse R&D programs are needed to meet the hedging goal. Also, R&D programs must involve many autonomous decisionmakers free to investigate different problems and to use methods different from those chosen by DoD planners. To ensure that the goal of application of research results to defense capabilities is met, the results should be known to, available, and used by the organizations responsible for military systems development and production.

If DoD's IR&D process has these effects, it deserves to be counted a success. Evaluation of the process, therefore, requires measurement or assessment of the following:

- The incentives of government IR&D support for contractor-initiated IR&D;
- The response of contractors to these incentives;
- The range of technical problems investigated;
- The number and dispersion of IR&D decisionmakers, the locus of project planning, and the flexibility of R&D decisionmaking;
- The directness of the linkage between IR&D and the creation of defense-relevant products.

This general framework should guide any assessment of the value of DoD policy toward IR&D. We were able to assess some of these outcomes. We studied the contractors' internal R&D decisionmaking to learn whether contractors take account of DoD's support of IR&D as they plan and manage their independent technical efforts. This would tell us whether DoD policies encourage greater IR&D effort, more hedging, and technology transfer, but it could not tell us precisely how strong the contractors' responses were.

We also analyzed quantitative records to estimate the strength of contractors' responses to DoD inducements. This would help us estimate the net effects of DoD efforts, in particular, the difference between the total volume of IR&D performed with DoD encouragement and the amount that would have been undertaken without the DoD contribution.

Does the IR&D Process Encourage More Defense R&D?

Does IR&D cost recovery increase the amount of IR&D spending by industry and does industry undertake a net increase in its total R&D, or does it simply substitute government funds for its own funds? In general, we found strong positive support for concluding that DoD support does increase contractors' defense-related R&D expenditures.

Level of Effort. Our case-study interviews show how DoD policies toward IR&D affect contractors' decisionmaking. The key actor in the relationship between a contractor and DoD is the contractor's R&D manager. This official's title and rank vary from one firm to another, but his function is the same—to initiate and manage a program of R&D projects that will serve current corporate strategy and create technical opportunities for future business. The R&D manager serves corporate goals, but he must compete with other corporate interests for resources.

Corporate R&D managers claim that DoD's encouragement and financial support for IR&D give them an advantage in the internal competition for resources. They can argue that the DoD's willingness to share costs justifies a larger R&D effort than the corporation could support on its own and that DoD's obvious interest in the results of IR&D makes it a highly promising endeavor. Corporate R&D managers are convinced that their firm's R&D efforts are larger and better funded as a result. Corporate financial officers and others who must compete with the R&D manager for resources also believe that to be the case.

Our quantitative analysis of contractors' cost recovery and spending is consistent with this view of internal company processes, and with a general belief among defense contractors that IR&D policy effectively allows DoD to share the costs of performing IR&D. Estimation of IR&D stimulation and cost recovery is difficult, given the complexity of the recovery processes and of firms' business calculations. We made our best estimates in light of our understanding of the firms' apparent procedures and incentives. More definitive models of firms' behavior in the future may allow better estimates of their response to cost recovery and further illuminate the issue[1].

In general, the more IR&D a company performs, the more DoD's negotiated IR&D share increases. In recent years, industry has recovered in the aggregate 40–50 percent of its incurred IR&D and B&P through the DoD share (30–40 percent IR&D and 50–60 percent

[1]Frank Camm, *How DoD Policy Affects Private Expenditure on Independent Research and Development: A Comparison of Empirical Studies*, The RAND Corporation, N-2834-OSD, 1989 (forthcoming).

for B&P). On the basis of these estimates, a marginal increment of IR&D costs industry only 60 to 70 cents.[2] This expected recovery reduces the cost of IR&D to the firm and may act as a positive incentive for the firm to spend more on IR&D.

We tried to estimate the effects of increased DoD support on contractors' IR&D effort. Our results indicate that contractors' IR&D effort rises as government support increases.[3] For the typical firm in our sample, we estimate that a $1 increase in DoD share is associated with an increase of about 60 cents in total IR&D spending in the first year the increase is negotiated, rising to a total of about $2 over a five-year period. In the long run the typical firm spends an additional dollar of its own funds for IR&D in response to an increase of $1 in government support.[4]

These estimates are consistent with research findings on the effects of the R&D tax incentive in effect from 1981 to 1985. One study, for example, found that the elasticity of industry R&D with respect to foregone government revenues was close to 1.0, and that about $2 of additional industry R&D was performed for every dollar of tax revenues lost to the federal government.[5]

Is IR&D Substituted for Other Corporate R&D? The positive response of industry's IR&D effort to the DoD share does not necessarily mean that total company R&D rises. It is possible, as some critics of government support of IR&D contend, that companies shift some of their R&D from other corporate divisions to the defense-oriented divisions in order to take advantage of the IR&D support. The increase in IR&D may be offset by reductions in other company R&D with no increase taking place at the aggregate company level. Our findings are not consistent with this view. Indeed, other corporate R&D appeared to increase in response to increased IR&D at the marginal rate of about $0.50 to an extra $1.00 of IR&D. However, a reverse effect was not observed in the data: Changes in the amount of other company R&D do not seem to influence the amount of IR&D performed.

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[2]For a full treatment of the statistical estimates, see App. C.

[3]The long-run elasticity of industry's IR&D expenditures with respect to the DoD share is for the most part somewhat less than 1.0; the best supported estimates span a range of about 0.80 to 1.10.

[4]The estimated industry response to a marginal dollar of DoD share varies from $1.60 to $2.40, depending on sample, time period, and estimating method.

[5]Bailey and Lawrence, 1987, pp. 19–20. The R&D tax credit allowed a 25 percent credit for R&D expenditures in excess of the average amount spent during the three previous taxable years. In 1986, the credit was extended (with modifications) to the end of 1988.

The analysis to date, then, is consistent with the supposition that the DoD share has a double effect on private industrial R&D: Increments to the DoD share stimulate IR&D and do not reduce other company R&D.[6]

Does the IR&D Process Promote Hedging?

Does government support of IR&D result in more varied and riskier IR&D portfolios, and are independence and flexibility encouraged? Subjective evidence and the assertions of industry R&D managers are consistent with the aims of hedging, but we were unable to perform quantitative analyses that could further illuminate the issues.

More Varied and Riskier R&D Agendas. Compared with the fairly centralized management of DoD-directed research, IR&D projects flow from 100 high technology companies, 300 profit centers, and 10,000 individual R&D projects. Because the firm pays less for IR&D and therefore can afford to do more, the corporate IR&D portfolio can include some projects that would not otherwise meet the firm's criteria for return on investment. Some projects can therefore be riskier than would be possible without DoD encouragement. These observations suggest that IR&D policy may promote hedging; however, we cannot say whether the research program is in fact more varied and diverse than we would find without government support or with a contractual system substituted for the present process.

Other research has shown a direct relationship between an industry's level of R&D and the probability of its diversifying into other R&D-intensive industries, and also of the industry itself being entered by R&D-intensive firms.

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[6]The stimulative effect of the R&D subsidy inherent in the DoD share can be compared to the effects of contract R&D. Studies on government R&D contracts and grants note that many companies respond by seeking government support for their best projects. The net result is that government funds substitute for company-financed R&D. R&D grant and contract programs, therefore, often do not add dollar-for-dollar to the amount of R&D actually carried out, but can displace private spending. Frank R. Lichtenberg, "The Relationship Between Federal Contract R&D and Company R&D," *American Economic Review*, May 1984, Table 3, p. 77, found that an increase in government R&D contracts led to a strong negative change in company-sponsored R&D, so that total R&D rose by only an estimated $0.50-$0.85 for a marginal dollar of R&D contracts. A second study by Lichtenberg suggests that federal R&D contracts stimulate only six cents of company-sponsored R&D for every dollar of contract R&D. Frank R. Lichtenberg, "The Effect of Government Funding on Private Industrial Research and Development: A Re-assessment," *The Journal of Industrial Economics*, Vol. 36, No. 1, September 1987, Table 1 (Eq. 4), p. 102.

> Intensive research and development activity in a firm's primary activity increases the extent of diversification by the firm, but also channels the diversification toward other R&D intensive industries and away from industries with little orientation toward R&D.[7]

This effect provides a channel through which a program that enhances the level of R&D also encourages hedging.

Is There More Basic Research? Basic research is one of the important sources of new concepts and technologies, of diversity. The hedging goal would be served, therefore, if the IR&D cost-recovery process promoted more basic research. Reducing the IR&D risks to companies through government cost-sharing does not necessarily imply that companies will perform more basic research as a result. Basic research is generally considered to involve greater risks—to produce less predictable results for a private firm than applied research or product-related development. Whether a lower cost of R&D produced by the DoD share will induce greater amounts of basic research depends on the specific relationships between additional R&D investment and the rate of return from that investment. Statistical analysis (App. C) suggests that if government cost-sharing of IR&D reduces the required rate of return from R&D investments, the stimulus generates only a small additional amount of basic research, whereas company-sponsored development shows a much larger response—in both absolute and percentage terms. These relationships are shown in Fig. 2, which is roughly consistent with the statistical findings. A shift in the required rate of return from A to B, brought about, for example, from government's cost-sharing of IR&D, will generate only a small increase in basic research. According to our estimates, an additional million dollars of DoD share for an average company would stimulate 27 man-years of greater development effort, eight man-years of applied research, three man-years of system studies, and only about 0.6 man-years of basic research.[8]

The available data do not allow us to look closely at each project or to identify the marginal projects induced by government funding support. Therefore we do not know what is encompassed in the categories of development, applied research, systems studies, and basic research. These categories might encompass hedging, if development activities investigate alternative system concepts or test out new technologies and components in prototype designs. We could not, however, make such judgments.

[7]James M. MacDonald, "R&D and the Directions of Diversification," *The Review of Economics and Statistics*, Vol. 67, No. 4, November 1985, p. 588.

[8]The elasticities, or percentage responses, of these categories to an increase in DoD share are 0.91, 0.58, 0.46, and 0.23 for development, applied research, systems studies, and basic research, respectively.

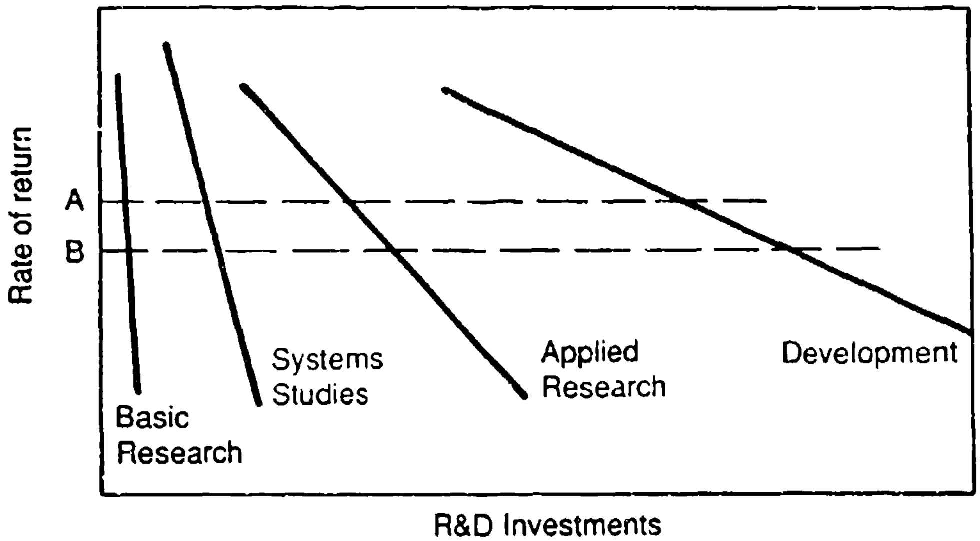

Fig. 2—Hypothesized rates of return to R&D investments, by type of R&D

Independence and Flexibility. The IR&D process allows contractor discretion in the choice of IR&D projects. Contractor R&D organizations are free to reallocate their staff and equipment so that projects can be started and stopped as new opportunities arise. Compared with contract research for the Defense Department, company officials claim that this flexibility pays off in more projects for a fixed amount of funds, in fewer deadwood projects, and in more timely response to new information.

Contractors can use this flexibility to sponsor research that has been overlooked or assigned low priority in the DoD R&D planning process. Some important new defense capabilities may be developed as a result.[9]

[9]A good example is the development of single-crystal turbine blades for jet aircraft engines. This technology was developed under IR&D by General Electric and Pratt & Whitney at a time when DoD had directed its R&D contracts toward the development of composite materials. Single-crystal technology proved superior to composites and is now used in the most advanced engines. This example demonstrates the value of hedging and

Funding through a flexible, indirect method (such as overhead-cost recovery) is a key to IR&D's value as a source of hedging. Contractual funding methods or a system of grants could expose contractor R&D programs to stricter oversight and accountability and sharply reduce flexibility and independence.

Does the IR&D Process Promote Creation and Application of Technology?

Studies of technology transfer show that the most efficient and effective transfer mechanism is of individuals applying personally embodied knowledge to new uses.[10] Although always a difficult endeavor to manage, movement of technology through people is most easily accomplished within a single organization. Since the companies among the present group of defense contractors are the most likely developers and producers of new weapons and military systems, their research will be more easily, effectively, and efficiently transformed into actual defense equipment if the research were done by one party and the development and production by another. R&D performed by other parties—other companies, universities, government laboratories—would have to overcome difficult organizational boundaries to be incorporated in fielded systems.

ASSESSING SPECIFIC BENEFITS AND COSTS

Congress asked for an analysis of the costs and benefits of the IR&D process. We have described some of the potential benefits above: increased technology base, hedging, and smooth technology transition to developed weapon systems. We now deal with more specific costs and benefits.

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shows how IR&D facilitates it. It does not prove that IR&D is always more productive than DoD-planned and contractor R&D; rather, it exemplifies the value of independent decisionmaking in R&D.

[10]For example, a study of technology transfer in three countries noted: "First of all, there is the usual discovery that nearly all of the information is obtained through direct personal contact." The authors concluded: "The overwhelming dominance of personal contact in technology transfer has been replicated in study after study, yet it is consistently ignored by policy makers." Thomas J. Allen, Diane B. Hyman, and David L. Pinckney, "Transferring Technology to the Small Manufacturing Firm: A Study of Technology Transfer in Three Countries," *Research Policy*, Vol. 12, 1983, pp. 202, 208.

Assessing Specific Benefits or Outputs

The discussion up to this point has focused on dollars and IR&D investment—on inputs. We have spoken only tangentially about the value of these investments in generating an understanding of technology, in reducing uncertainty, and in hedging. We have not discussed the key question of the military value of the additional IR&D spending stimulated by the government support. The data available for this study do not permit us to address it.

We reviewed the R&D portfolios of many firms, interviewed project leaders, and looked at the laboratories and experiments in several facilities, but it was not analytically possible to determine the marginal projects or the R&D results that would not have been conducted without government support. Over the years, IR&D has produced an impressive array of results that have gone into U.S. military products. Industry has compiled these results.[11] The identification and evaluation of specific marginal projects, however, remains a problematic endeavor.

From a private, profit-valued perspective, we know in advance that the additional IR&D performed by industry as a result of the stimulus of government cost-sharing must be less valuable to the company than the IR&D companies would do without government support. If the marginal IR&D were as valuable, the companies would have invested in it without special inducements. The reason for government involvement is the presumption that companies would not perform as much long-term or high-risk R&D on their own as the national interest requires.

Statistical analyses of the effect of IR&D on future company profits show that IR&D has a lower return (ratio of profits to total assets) on the margin than other company R&D.[12] This result is just what we would expect if the policy is effective: The cost-sharing nature of DoD support encourages companies to invest more in projects with lower private rates of return. Whether this research has sufficient public value to warrant government support is a subject left unanswered.

Assessing Specific Costs

One of the congressional requests was for an assessment of the specific costs (other than the estimated $3.5 billion now recovered from the government for IR&D and B&P) of both government and industry

[11] Numerous examples of IR&D results can be found in Tri-Association Ad Hoc Committee on IR&D/B&P, *Technical Papers on Independent Research and Development and Bid and Proposal Efforts*, AIA/EIA/NSIA, March 1974.

[12] See App. C.

in managing IR&D. Although the estimates that follow are not precise, they do give a rough notion of costs.

We first consider the government's costs and start with the technical evaluations, which absorb the most manpower of all the government IR&D functions. Congressional hearings in 1982 produced evidence that there were seven full-time civilian employees involved in managing technical review.[13] To that figure must be added the effort involved in the reviews themselves, an estimated 30,000 such reviews in 1982. We estimated that this review process absorbs about 67 man-years, or some 4.5 hours per review.[14]

In the military services, 12 full-time civilians perform the negotiations. The DoD spent an additional $1 million in 1982 on travel and related expenses for on-site technical reviews at contractors' facilities. The addition of audit efforts by DCAA and miscellaneous administrative costs produces a total DoD effort of more than 100 man-years.[15] Converting these costs to a dollar amount yields an estimate of about $10–12 million for DoD.[16]

Turning to industry, again we find that producing technical project descriptions requires the bulk of the effort. Interviews with industry people responsible for report preparation indicated that perhaps four weeks of writing and other activities was a typical effort for developing the 30-page brochures, usually by senior research staff. For 10,000 projects, this adds up to about 800 man-years.[17] In addition, each of the 300 negotiating contractors assigns at least one individual to manage the flow of the technical reports, their presentation to DoD, on-site evaluations, and preparations for annual negotiations. Assuming that these people spend an average of three months per year in IR&D administration capacities, an additional 75 man-years is required.

[13]U.S. House of Representatives, Committee on Appropriations, *Department of Defense Appropriations for 1983, Part 4*, p. 733.

[14]In 1975, the Air Force manager of technical evaluations judged that 11,000 evaluations required 24.5 man-years. We applied these figures to the 30,000 evaluations in 1982 to obtain the 67 man-years reported above. See U.S. Congress, Joint Economic Committee, *Hearings on Independent Research and Development*, 1985, p. 41.

[15]The Grace Commission estimated DoD efforts for managing IR&D at 86 man-years. However, their report allocated only 18 man-years to technical evaluations, rather than our 67 man-year figure. See *The President's Private Sector Survey on Cost Control*, "Task Force Report on the Office of the Secretary of Defense," 1983, p. 163.

[16]Our estimate of total man-year cost is $100,000–$125,000 for senior civil servants and scientists when fringe benefits and overhead costs are added to basic salaries.

[17]The Grace Commission figure for report preparation was 1,450 man-years, or seven weeks per project description. A consortium of industry associations (the Multi-Association, which comprises the AIA, EIA, and NSIA) estimated a total industry cost of 6 percent of IR&D, or $300 million in 1985. This is equivalent to $30,000 per project, or one-quarter of a man-year at our projected man-year costs. See The Grace Commission Report, 1983, pp. 156–164.

Costs of printing, distribution, and other miscellaneous activities add another $500 per project, or $5 million for all projects. Using the same man-year costs as for the government yields a gross industry cost figure of $92 to $115 million.

Some contractors claim that the DoD process is superimposed on the company's existing internal R&D management process, so that the additional costs are deadweight burden. Others, however, have built their own internal procedures around the DoD evaluation process, so that the net costs imposed by DoD are small. We cannot calculate the exact net cost, but it is clearly substantially less than the gross amount of about $100 million.

In terms of the $3.5 billion of industry's total cost recovery of IR&D and B&P in 1986, gross industry costs amount to about 3 percent; government's costs are one-third of 1 percent.[18] Although small in percentage terms, the absolute value of costs, especially in industry, are sizable; more important, because they produce only small results, they are reducible.

ASSESSING ADMINISTRATION

Negotiation

Negotiation of advance agreements was intended by law to establish ceilings bounded by standards of cost allowability. Two standards were recognized: potential military relationship and reasonableness. Compared with after-the-fact determinations, both government and contractors benefit from advance agreements because they reduce uncertainty over cost recoveries. Projects that may not meet IR&D definitions can be identified and discussed in advance of their implementation in order to resolve their questionable status. Contractors can also manage their IR&D portfolios with greater confidence in their ultimate level of cost recovery.

Our interviews revealed that the negotiations over "reasonableness" can create uncertainties weakening two linkages that are crucial to the attainment of the goals of IR&D. The first linkage is between a firm's level of IR&D effort and its ultimate level of cost recovery. If a firm is unable to see a connection between the size of its IR&D effort and its ultimate cost recovery, its incentive to expand its IR&D portfolio is dampened. In recent years negotiators have used the previous year's

[18]These percentages would be higher if B&P were removed from the base, which could be rationalized on the grounds that B&P projects do not require descriptions and evaluations.

ceiling as a starting point: Firms whose DoD business or IR&D effort changed markedly were unable to predict and plan for the resulting changes in their ceilings. Negotiators' need to hold total commitments within an annual ceiling capped by Congress on the size of the total IR&D effort further weakened this linkage.

The second crucial linkage is between the quality of a firm's technical performance and its cost recovery. Contractors and government negotiators agree that negotiation was once used to reward superior technical performance as revealed by project evaluations, but it no longer serves that purpose.[19] The effort to hold down total government commitments so dominates the negotiations that technical scores have no apparent influence on the outcome for most firms. Negotiators can still respond to dramatic rises and falls in technical scores, but the marginal changes that occur in most contractors' already-high scores have no effect.

Overall, we observed that the negotiations process was often influenced by objectives other than the central goals of the IR&D program. Some of the tensions in the negotiation process arise from the separation of responsibility among OSD offices with different concerns: The office for research and advanced technology is concerned with the promotion of technology and the encouragement of industry R&D; the procurement office pursues lower costs for weapon systems; they oppose IR&D increments to overhead accounts that drive up total contract costs. Similarly, the services have different objectives depending on whether they are trying to maximize this year's buy of ships or tanks or are looking forward to tomorrow's systems. Also, many apparent DoD and service-level policies went beyond the goals we proposed for IR&D and beyond declared government policies. For example, some service representatives stated that the negotiations were used to influence firms' decisions about choices of projects. Furthermore, some services in some periods have attempted to impose their own priorities over procurement and R&D that deviated from those of OSD.

The different objectives across OSD offices and the military services, the growth of accountability concerns, the imposition of the aggregate congressional ceiling and its method of implementation, and the reduced importance of technical review are perceived by contractors as weakening the links between the amount of IR&D a contractor performs and the amount it recovers from DoD. A reduction in DoD's responsiveness to industry's expenditures could act against the broader goals of IR&D. As the connection between contractors' IR&D effort

[19]We base this statement on the participants' testimony; our data did not permit an independent statistical test.

and cost recovery becomes less direct and harder to perceive, firms' incentives to mount larger and more ambitious IR&D programs are weakened.

Technical Review

The technical review and scoring process was introduced originally for accountability purposes to ensure that IR&D projects supported financially by the government were of potential usefulness to the funding organization. Acceptability was based on subject matter, technical feasibility, management, quality of research approach, and reasonableness of scale of effort. As the technical review process matured, the services (who perform the review) used the visibility into industry's R&D programs for the purposes of technical communication and internal R&D planning, in addition to the original purpose of accountability.

Some tensions have developed among the goals of IR&D support, accountability, and technical communications and planning. On the positive side, technical review can encourage contractors to plan impressive research programs and to present them clearly. To the extent that the technical review process has these effects, it promotes the goal of building the defense technology base. It also creates opportunities for communication between government and contractor scientists.

The visibility of contractors' technical programs and the scoring that goes along with it generates a semblance of accountability; it is intended to provide some assurance that government funds are being devoted to purposes that the government and nation would find useful. The process may prevent abuse of the system by screening the bogus projects from the IR&D pool; it could also deter companies from including projects with clearly no military relationship. To the degree that this screening takes place, the accountability sought by Congress would be attained.

On the negative side, technical review can create an opportunity for the military services to press contractors to support their current program priorities. The hedging goal requires that contractors be free to pursue problems and approaches other than those emphasized by government planners. The contractors need information about the services' current and future needs, but the technical review process could work against the goals of IR&D if it became an occasion for strong pressure for particular technical priorities.

Our interviews show mixed results. On the one hand, the government's review process is sometimes technically weak and does little to guide contractors toward improvements in their R&D programs. On the other hand, the very existence of an external review process strengthens the hands of corporate R&D managers, who can argue that ratings (and ultimately cost recovery) will fall if IR&D plans are not ambitious and carefully prepared. The process also encourages contractors to identify and maintain communications with those laboratory scientists who have technical interests complementary to their own.

PMR assessment is loosely managed and sometimes inconsistent. Laboratory scientists who recommend PMR ratings to the service manager often lack a knowledge of the services' future needs and strategies, and they can assign ratings without explicit justification. Moreover, the PMR of truly advanced R&D concepts is difficult to judge; industry laboratory directors claim that the PMR assessment may therefore discourage the riskier projects IR&D is intended to promote. According to a report of the DoD's Inspector General, PMR review eliminated only 140 projects from 10,743 projects submitted in fiscal years 1984 and 1985.[20]

Technical reviews are sometimes performed by government scientists who rate their own qualifications for reviewing a particular project as only "fair." As is often the case for any peer-review evaluation process, for the most original and technically ambitious IR&D projects, evaluating scientists may be less technically qualified than the senior contractor personnel who supervise the work. Despite these flaws in the process, contractors try to obtain high technical ratings for their IR&D plans so as to strengthen their positions in the ceiling negotiations. Often, though, this takes the form of brochuremanship, including the hiring of specialized companies who assist contractors in writing their brochures so as to improve their scores. All in all, we see little evidence that technical review contributes to fine-tuning the establishment of negotiated ceilings. However, we reiterate a point made earlier that our evaluation of the technical review process did not use a broad data base, but depended on interviews and an attempt to understand the processes, procedures, and motivations governing the effort.

A more technically sophisticated evaluation process may work no better. The independence of IR&D (and thus its ability to serve the hedging goal) requires decentralized decisionmaking. If the government's review were more stringent, it could also discourage firms from undertaking the risky independent projects that could lower their technical review scores and thus their cost recovery.

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[20]DoD, *Audit Report, DoD Administration of the Independent Research and Development Program*, Office of the Inspector General, No. 88-025, October 13, 1987, p. 15.

An incentive for R&D managers to encourage high scores on individual projects was that the scores were used in the negotiation process. Higher scores could result in greater reimbursements. In recent years, however, both government and industry people assert that the connection between technical ratings and cost recovery has weakened. As discussed above, review scores appear to have little effect on ceiling negotiations now.[21] As that becomes more evident to contractors, the leverage exerted through the review process may diminish further.

The accountability function of technical review was intended to ensure that the government was getting value for its investment by tying cost recovery to the contributions that a company's IR&D could be expected to make to national security. The accountability purpose of technical review can be met, though, in ways other than the present method. For instance, from our industry interviews and from a review of the literature on strategic planning and the planning of R&D it was clear that a company's R&D investment is at the very core of its future and the center of its business strategy. Consequently, most companies manage this activity with a great deal of care and attention. Because the companies' futures depend on developing and producing items that the DoD will desire in an increasingly competitive environment, internal company control of R&D quality and relevance is a matter of vital concern to all levels of company management. Accountability, therefore, may be achieved by contractors' own internal processes—not because they are altruistic or motivated by patriotism, but because it is in their own best, profit-seeking interest.

This internal company accountability function can be strengthened. When a firm finances IR&D at least in part from its own sources, it will probably manage its efforts more effectively than if its IR&D expenditures were totally recovered from the government—it is in its own best interests to steward its own money to get the most benefits. Some firms that sell only to DoD now recover 100 percent of their IR&D costs. Reducing government support to less than 100 percent of incurred expenditures would require firms to invest some of their own funds into IR&D. This should provide an automatic incentive for firms to adequately manage their IR&D resources.

This is not an argument for eliminating government oversight. Abuse of the system may still be countered by the standard techniques of auditing and spot checks; technical reviews that look in detail at only a selected subsample of projects, rather than the cursory review of every project attempted in the present process, could also serve the accountability function.

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[21]This could have resulted from a greater uniformity of scores produced by the review process itself or from a reduced effect of scores on ceiling negotiations.

VI. CONCLUSIONS AND RECOMMENDATIONS

We evaluated the justification, benefits, costs, and administration of the current IR&D process using qualitative and quantitative analyses. Our review of IR&D enabled us to formulate a set of goals that potentially could be met by the current process: encouraging an increased defense technology base; hedging against future uncertainties and against the centralized planning of DoD; and encouraging a smooth transition of innovation into weapon systems. To be counted a success the current IR&D process would have to show that the DoD encouragement led to the accomplishment of these goals.

Case study evidence, economic analysis, and the statistical results indicate that companies perform more defense-related R&D than they would in the absence of government support of their IR&D costs. The reason for the stimulating effect of the government support is that companies appear to plan their IR&D investments in anticipation of cost recovery, the amount of which depends on how much IR&D the companies decide to perform. This apparent cost sharing by government, in essence, reduces the price of R&D to industry, thereby leading to higher levels of IR&D spending.[1] On the average, our data analysis indicates that industry responds to an additional $1 of cost recovery by spending about $2 additional on IR&D and $1 on other corporate R&D.

Our analysis of corporate R&D planning, based on interviews and a review of the literature, supported the contention that DoD encouragement of IR&D leads to portfolios of IR&D projects that are more diverse, less conservative, and further from a company's main lines of business than they would be if the companies had to pay the full cost of their R&D. These judgments are supported by the logic and structure of the IR&D process, but data limitations did not allow us to make definitive quantitative tests.

If hedging does, in fact, take place, then efforts to increase government control may undermine it. Processes that forged a more direct link between project approval and funding (for example, contracts or grants for R&D) would be more cumbersome and would obligate the

[1]For policy purposes, it is important to interpret these figures carefully. Small or marginal changes of the DoD share around present values are predicted to generate the estimated response. Given the range of variation in the data, the predictions are more likely to be valid in the range of ± 25 percent around present positions than in more radical departures from the status quo.

government to supervise the technical work more closely; thus they would inevitably create pressure for projects that supported DoD priorities. Such pressures would reduce the independence of IR&D. Moreover, administration of a process of contracts and grants would require greater government management and more technical personnel and would cost more than the present system, which to a great extent the companies self-administer.

As a general observation, we found that the negotiation process weakens the link between corporate IR&D effort and ultimate cost recovery, which lowers firms' incentives to undertake more IR&D than they otherwise would.

We found that the DoD technical review process could be technically weak and inconsistent in some cases. However, the need to prepare for external review often encourages contractors to assess the quality of their own work and to maintain professional communications with government laboratory scientists. The effects of technical evaluation have been weakened by the ceiling negotiations, which in recent years have apparently assigned less value to assessment of quality, originality, or technical inventiveness. Moreover, we are doubtful that better, more competent technical reviews would be forthcoming without considerably greater dedication of capable reviewers at much higher cost than the present process; and if such an improved review process were tied more tightly to the negotiation of ceilings, the goal of hedging on DoD choices and priorities could be compromised.

BASE GOVERNMENT SUPPORT ON IR&D EXPENDITURES

The current system appears to produce its stimulus through its reduction of the marginal cost of IR&D to a company. This effect works only if government support is on a true cost-sharing basis, varying in relation to changes in a company's IR&D. If the links between IR&D expenditures and cost recovery are broken, much of the stimulus effect vanishes. Policies that dilute or weaken these links dampen industry investments. We therefore recommend the following:

- If government support is desired to promote more industry IR&D, policy and procedures should clearly link government support to company IR&D spending. Anything that weakens or diffuses these links reduces the stimulating effect of government support by adversely affecting the cost-sharing anticipated by company planners. Looser ties between government support and industry spending would therefore produce less IR&D for a given level of government costs.

- Over the years, several proposals have been put forward to simplify the IR&D cost recovery process. One recurring suggestion is to eliminate the entire process and substitute a simple increment to defense contractors' markups or profit rates. Such a policy could drastically reduce industry's IR&D investments because it would totally sever the link between IR&D expenditures and cost recovery from government. We do not recommend policies of this type.

QUALITY CONTROL AND TECHNICAL REVIEW

Technical review by government experts was originally intended to ensure the quality of research and the orientation of these efforts to defense needs. Another goal was added over the years: to stimulate and increase the flow of information between industry and government scientists and engineers.

According to the anecdotal evidence, the influence of the technical review process on the level of negotiated ceilings has diminished over time. The costs to industry of this review are substantial.

- We recommend that technical reviews be reduced and simplified. Firms should submit one-pagers, which should be randomly checked. Further random, spot-check technical audits of projects should provide sufficient information and incentives to meet the policy goals. In addition, the one-page project descriptions could provide the overall view of company R&D without the present cumbersome technical review process. Continued on-site visits would provide the best means for clear understanding and assessment of firms' IR&D programs. Poor programs should receive penalties in the form of reduced reimbursement.
- The above recommendation must be accompanied by clear incentives for firms to develop and maintain internal accountability functions. Such quality control may be obtained through reliance on the incentives of companies to manage their own core activities. To ensure that the incentives are actually present, we also recommend that IR&D cost recovery be limited to some level below 100 percent to guarantee that the companies put their own funds at risk.

CONSOLIDATION OF DoD POLICY AND MANAGEMENT

The present administration of the IR&D cost recovery process is spread among two offices in the Office of the Secretary of Defense (OSD) and the three military services. One of the OSD offices is a proponent for new technology, greater levels of IR&D, and more government support, but the other attempts to minimize costs and maximize the volume of procurement items per dollar, causing a conflict of goals. The services also differ in the emphases they place on weapon procurements today versus better weapons tomorrow. Because the services conduct the actual negotiations, the possibility arises of inconsistencies across services, companies, divisions, and products.

- Our principal recommendation is to consolidate policy and oversight at a level high enough in OSD—perhaps directly under the Under Secretary for Acquisition—to assure a single policy and unified voice to the rest of OSD, the services, Congress, and industry. Moreover, if this office is to be effective, it must have authority to enforce its guidance and cannot be placed in an organization that is not a major player in technology and procurement matters. Whether technical review (in present or modified form) and negotiations should also be consolidated remains an open question.

HOW MUCH IR&D IS ENOUGH?

A persistent set of questions has repeatedly confronted the country's political representatives and government policymakers: How much IR&D is enough and how much should government support industry's efforts? Control mechanisms over total IR&D recoveries have varied from none from the 1930s to 1949, control over the "acceptability" and "reasonableness" of individual company plans since 1949, and proposals in 1969 followed by implementation in 1983 of aggregate ceilings. The issues of controls and ceilings have generated controversy over whether external considerations should influence the reasonableness of company plans, whether there should be an aggregate ceiling, and if there is a ceiling how high it should be. Our study results themselves cannot resolve these perplexing questions, but we may be able to illuminate them by placing them in a broader perspective and by asking some narrower questions.

Two general propositions are relevant:

- IR&D involves the allocation of government resources. Even though private parties control the expenditure of IR&D funds, the costs recovered by contractors are ultimately paid by taxpayers.
- IR&D overhead rates represent a deduction from the budget of each DoD procurement program. Costs paid for IR&D directly reduce the level of effort on current production programs and other acquisitions.

IR&D is not a private entitlement program. We see no reason why it should be exempt from normal public-sector decisionmaking practices. We realize that long-term R&D is a fragile objective that can be neglected when short-term budgetary pressures are strong. But we cannot find any argument in favor of letting IR&D cost recoveries be set entirely by private action—a course of behavior implied by the original rationale for cost recovery as a "necessary cost of doing business."

On the question of the size of the IR&D effort we suggest some criteria that may be useful in determining how much IR&D is enough. Government support of IR&D may be considered a reduction in government procurement that is reallocated to encourage R&D and diversity. How much reduction of present procurement are we willing to trade for future capabilities and a broader technology decision base? What is the balance between today and tomorrow? Where should the line be drawn between controlled and directed R&D and independently chosen, autonomous industry R&D? Information to help answer these questions can be found in evaluating industry and DoD capabilities in weapon developments, especially in the front end or early stages. Are technologies, components, materials, designs, and concepts available? Is knowledge about them well enough in hand at the beginning of system developments to permit decisionmaking on projects that can cost many billions of dollars to carry through to completion? If technology is unready and designs premature, we suggest that more front-end R&D is required and that not enough IR&D had been performed. If a sufficient number of ideas and matured technology is available, but on the wrong subjects, then more control and direction may be needed, either through IR&D or through directed contracts and in-house R&D. Does the readiness of industry to participate in system development vary across products, technologies, industries? If so, then IR&D policy should concentrate on the deficient areas.

How much reduction in current procurement can we afford, and what are the gains from increased industry defense R&D and diversity? The DoD and Congress must ultimately address these questions in arriving at IR&D policy and in deciding how much IR&D is enough.

Appendix A

IR&D AND B&P DATA

Table A.1

ANNUAL AGGREGATE DATA ON IR&D AND B&P
(Million $)

			IR&D			B&P		
Year	Number Companies[a]	Number Negotiating Organizations[a]	Incurred by Industry	Accepted Ceiling	DoD Share	Incurred by Industry	Accepted Ceiling	DoD Share
1969	98	182	777.5	627.3	410.5	439.8	421.5	289.6
1970	84	171	715.3	556.9	359.0	413.5	398.4	278.3
1971	77	167	663.5	539.6	337.1	427.6	389.9	265.1
1972	82	184	937.9	726.5	392.8	472.3	435.8	309.3
1973	91	231	1159.9	892.6	438.2	551.7	514.2	360.0
1974	98	258	1171.0	917.0	465.1	548.7	504.3	355.5
1975	99	256	1234.8	1015.3	501.1	602.8	538.4	381.0
1976	91	231	1377.2	1052.2	538.8	676.3	575.5	406.3
1977	90	221	1569.0	1199.5	598.5	737.8	606.5	440.8
1978	93	226	1788.0	1364.9	642.6	779.6	662.2	469.2
1979	95	240	2132.0	1528.6	714.9	846.2	729.4	517.2
1980	99	251	2373.3	1727.6	812.2	1011.4	872.4	594.1
1981	99	264	2796.0	2039.0	1055.9	1157.0	1007.3	688.5
1982	99	264	3654.5	2821.4	1338.2	1348.7	1136.5	813.2
1983	99	275	4008.5	2961.3	1600.9	1569.5	1271.3	966.3
1984	103	294	5172.6	3897.1	1884.4	1965.4	1475.7	1130.8
1985	108	326	5048.4	3509.4	2103.9	2174.3	1711.7	1292.2

SOURCE: DCAA, *IR&D and B&P Cost Incurred by Major Defense Contractors, 1969–1985.*

[a]Number of companies and negotiating organizations (companies and divisions) comprise those with nonzero values of sales, IR&D, or B&P.

Table A.2

AVERAGE IR&D AND B&P BY NEGOTIATING ORGANIZATION[a]
(Million $)

	IR&D						B&P					
	Incurred by Industry		Accepted Ceiling		DoD Share		Incurred by Industry		Accepted Ceiling		DoD Share	
Year	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median
1969	4.7	1.7	3.4	1.0	2.5	1.1	2.6	1.1	2.3	.9	1.7	.7
1970	4.7	1.8	3.3	1.1	2.4	1.0	2.5	1.3	2.3	1.2	1.7	.9
1971	4.5	1.6	3.2	1.2	2.3	1.0	2.7	1.3	2.3	1.2	1.6	.9
1972	6.0	1.8	3.9	1.2	2.5	1.1	2.7	1.4	2.4	1.2	1.8	.9
1973	5.8	1.6	3.8	1.0	2.2	.8	2.5	1.1	2.2	.9	1.7	.8
1974	5.4	1.3	3.5	.9	2.1	.8	2.3	.9	1.9	.7	1.5	.6
1975	5.7	1.6	4.0	1.0	2.3	.9	2.5	1.1	2.1	.8	1.6	.6
1976	6.8	1.8	4.5	1.2	2.7	1.0	3.0	1.3	2.5	1.0	1.8	.8
1977	8.0	2.1	5.1	1.4	3.1	1.3	3.4	1.5	2.6	1.0	2.1	.9
1978	9.0	2.6	5.7	1.5	3.3	1.4	3.6	1.6	2.8	1.2	2.2	1.0
1979	10.2	2.7	6.2	1.6	3.4	1.4	3.6	1.7	2.9	1.3	2.2	1.0
1980	10.9	3.0	6.7	1.9	3.8	1.6	4.1	1.7	3.4	1.4	2.5	1.0
1981	12.3	3.1	7.4	2.0	4.7	1.8	4.5	1.9	3.6	1.4	2.7	1.1
1982	15.6	3.9	10.2	2.5	5.9	2.2	5.1	2.3	4.1	1.8	3.1	1.2
1983	16.3	4.4	10.3	3.0	6.6	2.6	5.7	2.4	4.4	1.9	3.6	1.4
1984	19.2	4.8	12.7	3.1	7.2	2.7	6.7	2.8	4.8	2.0	4.0	1.7
1985	16.9	4.6	10.3	3.0	7.2	2.5	6.7	2.9	5.0	1.9	4.1	1.6

[a]Means and medians calculated for observations with nonzero values of variables.

Table A.3

DEFENSE AND TOTAL SALES OF ORGANIZATIONS NEGOTIATING IR&D AND B&P[a]
(Million $)

	Defense Sales			Total Sales			Ratio: Defense/Total		
Year	Total	Mean	Median	Total	Mean	Median	Total	Mean	Median
1969	23,000	127.1	62.5	36,308	199.5	93.8	.64	.73	.83
1970	21,400	125.9	59.5	32,518	190.2	92.8	.64	.74	.82
1971	19,646	118.4	59.1	32,064	192.0	83.7	.63	.71	.79
1972	19,605	107.7	56.2	31,002	168.5	76.8	.65	.72	.79
1973	21,459	93.7	43.8	37,970	164.4	60.0	.55	.70	.79
1974	22,542	88.7	38.2	43,441	168.4	59.6	.53	.67	.75
1975	25,283	100.7	39.9	46,713	182.5	67.9	.53	.66	.73
1976	26,800	117.5	49.2	47,349	205.0	76.1	.57	.67	.75
1977	29,930	137.3	56.3	52,443	237.3	85.1	.58	.66	.77
1978	31,894	143.0	62.0	62,078	274.7	93.8	.52	.67	.76
1979	35,503	150.4	63.5	73,373	305.7	97.8	.49	.66	.73
1980	43,311	174.6	69.3	84,434	336.4	113.2	.51	.66	.71
1981	53,597	206.9	72.0	95,716	362.6	113.0	.56	.66	.73
1982	63,813	243.6	86.5	105,574	400.0	137.0	.60	.67	.74
1983	77,152	282.6	104.0	119,051	432.9	149.0	.65	.71	.78
1984	89,714	312.6	116.0	136,891	465.6	158.5	.66	.71	.79
1985	103,288	323.8	114.0	154,250	473.2	153.0	.67	.71	.79

[a]Means and medians calculated for observations with nonzero values of variables. "Total" ratio is the ratio of aggregate values of the variables.

Table A.4

IR&D RATIOS[a]

	Ceiling/Incurred			DoD Share/Ceiling			DoD Share/Incurred		
Year	Total	Mean	Median	Total	Mean	Median	Total	Mean	Median
1969	.81	.77	.81	.66	.73	.83	.53	.58	.61
1970	.78	.79	.81	.64	.75	.86	.50	.59	.65
1971	.81	.83	.89	.62	.72	.81	.50	.60	.63
1972	.78	.87	.93	.54	.71	.77	.42	.62	.68
1973	.77	.87	.95	.49	.68	.76	.38	.60	.63
1974	.78	.89	.95	.51	.65	.71	.40	.58	.62
1975	.82	.87	.94	.49	.65	.71	.40	.57	.58
1976	.76	.85	.92	.51	.67	.73	.39	.57	.59
1977	.76	.86	.92	.50	.68	.75	.38	.59	.61
1978	.76	.85	.90	.47	.66	.73	.36	.56	.59
1979	.72	.87	.94	.47	.65	.72	.34	.57	.60
1980	.73	.88	.94	.47	.64	.69	.34	.57	.61
1981	.73	.86	.91	.52	.64	.72	.38	.56	.60
1982	.77	.84	.89	.47	.68	.75	.36	.58	.62
1983	.74	.86	.90	.54	.70	.80	.40	.61	.65
1984	.75	.84	.90	.48	.71	.79	.36	.60	.64
1985	.70	.83	.88	.60	.72	.82	.42	.61	.64

[a]Means and medians calculated for observations with nonzero values of variables. "Total" ratio is the ratio of aggregate values of the variables.

Table A.5

B&P RATIOS[a]

Year	Ceiling/Incurred Total	Ceiling/Incurred Mean	Ceiling/Incurred Median	DoD Share/Ceiling Total	DoD Share/Ceiling Mean	DoD Share/Ceiling Median	DoD Share/Incurred Total	DoD Share/Incurred Mean	DoD Share/Incurred Median
1969	.96	.95	1.0	.69	.72	.83	.66	.70	.78
1970	.96	.96	0	.70	.74	.87	.67	.72	.80
1971	.91	.93	1.0	.68	.72	.79	.62	.66	.73
1972	.92	.94	1.0	.71	.74	.82	.65	.69	.74
1973	.93	.94	1.0	.70	.73	.80	.65	.68	.72
1974	.92	.92	1.0	.71	.70	.77	.65	.64	.70
1975	.89	.89	.97	.71	.69	.75	.63	.63	.68
1976	.85	.87	.94	.70	.70	.77	.60	.61	.66
1977	.82	.88	.94	.73	.69	.77	.60	.61	.65
1978	.85	.88	.95	.71	.68	.75	.60	.61	.64
1979	.86	.88	.95	.71	.69	.75	.61	.60	.63
1980	.86	.87	.94	.68	.67	.71	.58	.59	.61
1981	.87	.88	.93	.68	.68	.74	.59	.59	.62
1982	.84	.86	.90	.72	.68	.75	.60	.58	.61
1983	.81	.84	.90	.76	.72	.80	.62	.60	.64
1984	.75	.79	.84	.77	.72	.81	.58	.57	.58
1985	.79	.80	.85	.75	.72	.81	.59	.58	.59

[a]Means and medians calculated for observations with nonzero values of variables. "Total" ratio is the ratio of aggregate values of the variables.

Table A.6

RATIOS OF IR&D TO DEFENSE SALES

Year	Incurred IR&D/ DoD Sales Total	Incurred IR&D/ DoD Sales Median	IR&D Ceiling/ DoD Sales Total	IR&D Ceiling/ DoD Sales Median	DoD Share/ DoD Sales Total	DoD Share/ DoD Sales Median
1969	.034	.025	.027	.020	.018	.016
1970	.033	.030	.026	.022	.017	.017
1971	.034	.028	.027	.024	.017	.018
1972	.048	.033	.037	.029	.020	.021
1973	.054	.034	.042	.031	.020	.021
1974	.052	.037	.041	.031	.021	.021
1975	.049	.036	.040	.032	.020	.021
1976	.051	.036	.039	.031	.020	.020
1977	.052	.039	.040	.033	.020	.021
1978	.056	.040	.043	.033	.020	.021
1979	.060	.037	.043	.031	.020	.022
1980	.055	.037	.040	.032	.019	.021
1981	.052	.038	.038	.033	.020	.022
1982	.057	.041	.044	.033	.021	.023
1983	.052	.037	.038	.031	.021	.022
1984	.058	.038	.043	.032	.021	.023
1985	.049	.037	.034	.031	.020	.022

Table A.7

RATIOS OF B&P TO DEFENSE SALES

	Incurred B&P/ DoD Sales		B&P Ceiling/ DoD Sales		DoD Share/ DoD Sales	
Year	Total	Median	Total	Median	Total	Median
1969	.019	.021	.018	.020	.013	.015
1970	.019	.022	.019	.021	.013	.015
1971	.022	.027	.020	.022	.013	.016
1972	.024	.029	.022	.025	.016	.018
1973	.026	.032	.024	.028	.017	.019
1974	.024	.028	.022	.023	.016	.017
1975	.024	.030	.021	.025	.015	.017
1976	.025	.032	.021	.028	.015	.017
1977	.025	.030	.020	.026	.015	.018
1978	.024	.029	.021	.023	.015	.016
1979	.024	.030	.021	.025	.015	.017
1980	.023	.027	.020	.025	.014	.015
1981	.022	.029	.019	.024	.013	.016
1982	.021	.026	.018	.022	.013	.015
1983	.020	.024	.016	.019	.013	.014
1984	.022	.027	.016	.021	.013	.015
1985	.021	.025	.017	.019	.013	.015

Table A.8

RATIOS OF COMBINED IR&D AND B&P TO DEFENSE SALES

	Incurred/ DoD Sales		Ceiling/ DoD Sales		DoD Share/ DoD Sales	
Year	Total	Median	Total	Median	Total	Median
1969	.053	.055	.045	.045	.031	.034
1970	.052	.056	.045	.046	.030	.036
1971	.056	.060	.047	.051	.030	.038
1972	.072	.066	.059	.058	.036	.044
1973	.080	.072	.066	.068	.037	.046
1974	.076	.073	.063	.068	.037	.043
1975	.073	.075	.061	.067	.035	.046
1976	.076	.077	.060	.068	.035	.044
1977	.077	.073	.060	.064	.035	.043
1978	.080	.072	.064	.065	.035	.041
1979	.084	.073	.064	.062	.035	.040
1980	.078	.069	.060	.060	.033	.041
1981	.074	.072	.057	.063	.033	.041
1982	.078	.069	.062	.058	.034	.039
1983	.072	.066	.054	.055	.034	.039
1984	.080	.070	.059	.058	.034	.043
1985	.070	.067	.051	.055	.033	.041

Appendix B

NECESSARY FOR THE PERFORMANCE OF THE CONTRACT

The formula describing IR&D as "necessary for the performance of the contract" eventually became transformed into the term, "a necessary cost of doing business."[1] These formulations suggest the questions, "Necessary for what, and for whom?" To answer these questions, we have to consider the situation of the 1930s. The imposition of profit constraints by the Vinson-Trammell Act that were defined as a percentage of costs led inexorably to a cost-plus system of contracting. Under such a system, to obtain the fruits of R&D in the weapons it procured, the government either had to pay for the R&D through contracts with industry or through government in-house efforts, or it had to allow the costs of IR&D in the price of the final products. In 1940, U.S. military procurement (excluding R&D) was $2.1 billion; government expenditures on military research and development were estimated at $67 million, or 3.2 percent of procurement.[2] By 1960, the ratio of R&D to procurement had risen to 20.0 percent, and by the 1980s, R&D was equal to a full 40-45 percent of military procurement budgets.[3]

In the 1930s, the military purchased final goods from industry on a manufacturing cost basis. For those weapons to be developed, the contractors had to invest funds from their own sources. It was reasonable and accurate in those circumstances to claim that IR&D was "necessary for the performance of the contract." As explicit DoD investment in R&D grew to sizable levels, congressional questions arose as to the necessary and reasonable nature of IR&D support by government. In present-day conditions, the appropriate question is whether firms, motivated by their own profit-seeking goals, would perform a sufficient amount of R&D to support national defense needs, given the sizable DoD budgets for military R&D.

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[1]This formulation is stated explicitly in, for example, Defense Department Instruction (DODI) 3204.1 (D), dated December 1, 1983. This particular instruction merely restates the same policy of previous years.

[2]Military R&D for 1923-1944 was estimated in Bush, 1980, Table 1, p. 86. Procurement for 1940-1945 is reported in Smith, 1959, pp. 6-7.

[3]For the years since 1951, defense R&D and procurement are reported in the annual *Statistical Abstract of the United States*

Companies in R&D-intensive product lines typically engage in considerable research activities. Such companies in the civil sector finance this R&D out of corporate funds generated by the full panoply of financial sources, hoping to earn a return on this investment in the price of their products. Defense contractors argue that if cost-based DoD contracting methods were introduced that did not allow IR&D cost recovery, profits would be forced down. This argument, however, stops too soon. If IR&D costs were not allowed as an overhead item, companies would reduce their IR&D expenditures. Moreover, there would probably also be an adaptation on the government side, which in fact occurred in the decade from 1949 to 1959 when general R&D was disallowed as a cost; during that period, IR&D was specifically allowed in many contracts as a result of negotiations in the procurement phase, rather than in a separate IR&D phase.

Recent research shows that government cost and profit policy has little effect on actual profits, but large effects on companies' expenditures and their participation in the defense market.[4] For example, if the DoD explicitly attempts to reduce costs or profit rates by ruling that certain costs are unallowable, or simply disallows the costs with no intention of influencing rates of return, financial markets and competition would induce firms to reduce their expenditures to maintain the market-required rate of return—or failing that, to drop out of the unprofitable defense sector.

IR&D costs, therefore, are a necessary cost of business to the government to the extent that it desires to encourage industry defense-oriented R&D; it is a necessary cost to business to the extent that companies find it is required for them to remain profitable participants in the defense industry. Policies that alter government support of IR&D will change industry expenditures, or induce firms to enter or leave the industry, or both.

Another reason for reexamining this justification for government support is that defense business, in many ways, has become a regulated industry. The array of procurement legislation, policy directives, price regulations, profit controls, government oversight, and public attention include all of the elements of a regulatory system. We have not always recognized this situation because companies within the industry face a kind of competition that is presumably absent in the publicly granted monopoly markets of the classically regulated industries and because negotiated contracts between buyers and sellers share many of the

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[4]See, for example, William P. Rogerson, *Profit Regulations and Prizes for Innovation: Theory and Evidence*, The Center for Mathematical Studies in Economics and Management Science, Northwestern University, Evanston, January 1988.

features of an unregulated market. Not only does defense market regulation differ from our customary notions of regulation, but we also understand it much less well. As a nation, we have backed into this regulatory system without the analysis of its structure and consequences that have been granted to such other regulated industries as public utilities.

The regulated character of the defense industry is a key to the examination of government support of IR&D: The terms of the regulation become a matter of public interest and policy. Regulations identifying the kinds of costs that will be reimbursed, the terms on which the reimbursement will be made, and the procedures for accomplishing this all become matters of public attention.[5] IR&D cost reimbursement has been an abiding feature of the defense industry's regulatory framework for some 50 years; as such, it has not escaped the scrutiny applied to other features of defense business.

In the history of IR&D/B&P support by the government, two distinct types of policy have emerged. One type concerns the goals of the government support (reimburse contractors for reasonable costs, promote IR&D, etc.). The other focuses on accountability. If government resources are to be used, Congress has generally demanded control over funding and assurances of useful results. The demands for accountability have varied over time. Until 1949, IR&D cost recovery was on automatic pilot: Recovery of contractor costs was determined by contractor expenditures. The 1949 regulations put strict clamps on DoD support of IR&D in an attempt to control costs in the postwar budget reductions. The revival of national support for R&D brought with it DoD concern for accountability, which then diminished in the following decade. Since the late 1960s, Congress has insisted on accountability, writing into the governing legislation the requirement for technical review and negotiations; it flirted with overall funding limits in 1969 and finally wrote such limits into DoD legislation in 1983.

Tensions arise between the dual sets of goals of efficiently pursuing the outputs of IR&D through a process that promotes accountability in the use of public funds. Such tensions exist in most government programs and we do not expect them to disappear in the case of IR&D.

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[5]This argument flows from the ideas and discussions of RAND colleague Tom Glennan.

Appendix C

EMPIRICAL ANALYSIS AND EVALUATION OF IR&D DATA

INTRODUCTORY ISSUES

This appendix presents the statistical analysis behind the quantitative findings described in the text. The analysis is based on a model of government and company behavior in which the parties react to each other in a dynamic interrelationship. It is necessary to model behavior explicitly in order to interpret the data on IR&D spending and cost recovery in a consistent, testable manner. Because there are several alternative views or explanations about IR&D behavior, we also test other models, which are shown to be inconsistent with the evidence.

This statistical analysis is designed to answer the following questions:

- Are industry's IR&D expenditures stimulated by government support of IR&D costs?
- Has government and industry responsiveness changed over time, particularly with respect to congressional ceilings?
- Does government support of IR&D affect expenditures on other company R&D and the distribution of effort among R&D categories such as basic and applied research?

The first question directly responds to the congressionally raised issues of justification for government support of IR&D and the potential benefits of this support. The remaining questions address concerns raised by proponents and critics of the process. We also address other issues bearing on the IR&D process and its potential benefits.

THEORETICAL CONSIDERATIONS

The process by which the DoD supports industry IR&D can produce several different kinds of effects with both private and broader social implications, depending on how the DoD share of IR&D is related to industry's IR&D expenditures. We consider here six alternative hypotheses on government and industry behavior. (1) DoD support of

IR&D may be administered as a "block grant," with little stimulatory effect. (2) DoD support may be administered as a block grant, but industry could respond as though the grant had a cost-sharing or price effect on IR&D. (3) The DoD support may be administered in a cost-sharing manner to produce a stimulatory effect through so-called "price effects." (4) The DoD support may be administered as a cost-share up to a ceiling, after which the marginal effects—and stimulatory price-effects—would vanish, leaving the whole amount essentially as a block grant. (5) DoD support may be administered to maintain a constant overhead rate for each company, producing little stimulatory price effect.[1] (6) The DoD cost share could be negotiated away in subsequent procurement contract bargaining, negating the effects on revenues and profits of the IR&D cost recovery process.

If the Defense Department share of IR&D expenditures is independent of a company's incurred IR&D expenses, the support takes on the character of a "block grant," which does not change the price of IR&D to the company. It may act to relax any constraints on capital expenditures by the company, however. We can infer the size of the effect of a block grant in a rough way from the fact that the average ratio of IR&D to defense sales is around 7 percent, and the marginal effect of a block grant—acting like additional revenues—is likely to be of that order of magnitude. Therefore, increasing revenues by $1 would probably stimulate an increase in IR&D of only around $.07, mainly because other types of investments would also have a claim on the additional funds.

This narrow economic argument must be modified as a result of observations of actual cases. It turns out that grants identified with specific purposes, distributed through functionally specialized organizations, often generate a so-called "sticky dollar" or "flypaper" effect.[2] That is, the funds tend to stick to the goals and organizations for which they were granted to a greater degree than economic theory predicts. This "stickiness" depends on budgeting procedures and other organizational processes.

Another possible effect of the DoD cost share acts through changing the price of IR&D. This effect is present if cost recovery varies with the marginal IR&D expenditure. Firms must expect that an additional

[1]This possibility was put forward by an individual on the basis of his company's experience in the IR&D negotiations.

[2]See, for example, Paul N. Courant, Edward M. Gramlich, Daniel L. Rubinfeld, "The Stimulative Effects of Intergovernmental Grants: or Why Money Sticks Where It Hits," and Wallace E. Oates, "Lump-Sum Intergovernmental Grants Have Price Effects," both in Peter Mieszkowski and William Oakland (eds.), *Fiscal Federalism and Grants-in-Aid*, The Urban Institute, Washington, D.C., 1979.

dollar of IR&D expenditure will generate an identifiable increase in the DoD cost share, in effect reducing the cost of IR&D to the firm by the amount of the marginal government support. A lower price of IR&D should stimulate firms to undertake more R&D than they otherwise would. From the late 1960s to the present, the average cost recovery by industry has been about 50 percent of IR&D expenditures. What is not clear from the average figure is whether the government's cost share varies with IR&D.

The cost recovery process prohibits firms from recovering more than the negotiated ceiling. For "over-ceiling" IR&D expenditures, the marginal rate of IR&D cost reduction could be zero, and the IR&D incentive could vanish if the ceiling did not vary with actual incurred IR&D expenditures. Because most firms spend more than the ceiling, the incentive effect, calculated in this way, might fall to zero. However, if the ceiling is not independent of firm behavior, but rather varies with the firm's IR&D planned expenditures, the incentive effect on planned expenditures would remain. Because actual expenditures are very closely related to the planned amounts, such an incentive would carry over to actual behavior.

One alternative view of government behavior contends that the key variable is the customary overhead rate of the firm. According to this view, the IR&D overhead rate (the ratio of DoD share to DoD sales) is fairly constant over time; therefore, once the sales figure is estimated, the DoD share is simply calculated as the product of the customary overhead rate and the level of projected sales. According to this hypothesis, the DoD share is unrelated to a firm's IR&D expenditures, and hence there is no price effect and little stimulation of IR&D. A companion hypothesis states that a firm's IR&D decisions are unaffected by the DoD share and influenced primarily by expected or current sales.

Finally we consider the possibility of a relationship whereby the cost recovery negotiated at one step of the procurement process produces compensating changes at later stages by government contract negotiators who attempt to reduce the cost of goods to the government. Outcomes of this contract negotiation phase depend on competition, the urgency of the requirement, negotiation policies, type of contract, and all the other factors that influence final price. Companies may therefore not actually receive all of their negotiated IR&D recovery amounts, and the ultimate effect on profits may depend on competition, contract type, and many other contending forces. The question is whether an added dollar of negotiated IR&D cost recovery shows up as an added dollar of profits or revenues.

THE BASIC MODEL

The basic model flows from our view of the structure and time sequence of government and industry behavior gained from interviews with participants in both sectors. This view has industry planning its annual IR&D investments at a strategic level in the company with an experience-based expectation of the DoD share that will later be negotiated. This is essentially a rational expectations model of company behavior. The company is presumed not to plan its IR&D projects one by one throughout the year, but rather chooses an overall level based, among other things, on the amount of cost-sharing produced by the government support. The government, for its part, is presumed to negotiate an allowable ceiling after reviewing the company's IR&D plans.

Since expected government behavior presumably influences firms' IR&D decisions, and the companies' IR&D plans affect government negotiating responses, a simultaneous system of relationships is called for. Also, neither government nor firms react instantaneously to the other party. Industry must plan for changes in IR&D projects, personnel, equipment, and structures; government negotiating personnel are concerned with sharp changes in product costs. Therefore, lagged responses must be estimated.

The model that we use collapses the multistep process described in Sec. III into two equations. The process begins with firms' IR&D expenditures (I); the DoD then negotiates an allowable ceiling (A) that is a function of I; the final DoD share (N) is calculated, in essence, as the product of the ratio of defense sales (D) to total sales (S) and the ceiling: $N = (D/S)A$.[3]

The following equations describe the three-step process:

$A = G(I, X)$ Government behavior

$N = (D/S)A$ Accounting relationship

$I = F(N, Z)$ Firm behavior

where A, N, and I are endogenously determined, D and S are exogenous, and X and Z are vectors of other exogenous variables influenc-

[3]Strictly speaking, the DoD share of the ceiling is calculated according to whatever agreed method is used by a firm to allocate overhead costs to defense and nondefense sales. The rule of thumb most often used is that costs are distributed proportionally to revenues. A simple regression equation shows that the allocated cost share is essentially the product of the ceiling and the ratio of defense to total sales, $N = -.073+.995(D/S)A$ ($R^2 = .96$, 3322 observations, and the t-statistic on the coefficient of $(D/S)A$ is 273).

ing A and I.[4] Because N is essentially equal to $(D/S)A$, we can reduce the model to two equations in N and I: the DoD share and incurred IR&D.

To deal with the lag problem, we introduce an adjustment process in which each party changes the variable it controls by a fixed proportion of the desired value of the variable relative to its current value in each period. Let N^* and I^* be the values of N and I desired by the government and the firm, as determined by the values of the variables on the right side of the behavioral relationships;

$$N_t^* = D/S\ g\ (I_t, X_t)$$

$$I_t^* = f\,(N_t, Z_t)$$

The value chosen for the current period, N_t, will be

$$N^t/N_{t-1} = (N_t^*/N_{t-1})^{\alpha}$$

Substituting the equation for N_t^* into the above, yields:

$$N_t/N_{t-1} = (D/Sg(I_t, X_t)/N_{t-1})^{\alpha}$$

or

$$N_t = (N_{t-1}{}^{1-\alpha})(D/Sg(I_t, X_t))^{\alpha}\ .$$

Specifying the function g as $kI_t{}^{\beta}X_t{}^{\gamma}$,we get:

$$N_t = (D/SkI_t{}^{\beta}X_t{}^{\gamma})^{\alpha}N_{t-1}{}^{1-\alpha}\ .$$

or

$$N_t = (D/S)^{\alpha}k^{\alpha}I_t{}^{\alpha\beta}X_t{}^{\alpha\gamma}\ N_{t-1}{}^{1-\alpha}\ .$$

In this formulation, α is the short-run response parameter and β represents the long-run response. The estimating equation is

$$N_t = KI_t{}^{a}X_t{}^{b}N_{t-1}{}^{c}\ ,$$

[4]Variables in X and Z would include a company's line of business, past IR&D expenditures, and the growth of defense and commercial business.

where $\alpha = 1 - c$, $\beta = a/(1-c)$, and $K = (D/S)^{\alpha}k^{\alpha}$. Since we assume the same basic relationships for I, the core estimating model is:

$$N_t = K\, I_t{}^a X_t{}^b\, N_{t-1}{}^c \qquad \text{Government equation}$$

$$I_t = H N_t{}^d Z_t{}^e\, I_{t-1}{}^f \qquad \text{Industry equation}$$

From a policy perspective, the most important parameters to be estimated are the long-run partial elasticities $\beta = a/(1-d)$ and $\delta = d/(1-f)$.[5] This is because the principal type of policy change in which we are interested assumes exogenous shifts in government behavior with the key question being the size of the industry response. The marginal responses are easily calculated from the elasticities. Thus, the long-run marginal effect on I from an exogenous increment to N is: $\partial I/\partial N = \delta I/N$, where $\delta = d/(1-f)$ is the long-run elasticity of I with respect to N.[6] The dynamic multiplier or total long-run elasticity arising from an exogenous increment of the DoD share, followed by the feedback responses of both sides, is: $dI/dN = \delta/(1-\delta\beta)(I/N)$.[7]

We thus estimate three elasticities and three equivalent marginal responses or slopes for both government and industry. The long-run (partial) elasticity describes the steady-state response by one party to

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[5]The elasticity (e) of a variable y with respect to a variable x is defined as the percentage change in y produced by a given percentage change in x. This is equivalent to: $e = (dy/y)/(dx/x)$. In the equations assumed above, the elasticity is simply the exponent of the variable of interest. The marginal change of y as a function of x is: $dy/dx = e(y/x)$.

[6]This "partial" elasticity is equivalent to treating N as exogenous in the industry equation.

[7]The dynamic multiplier or total long-run elasticity is derived as follows:

$$\begin{aligned} &(1)\quad I = dN^{\delta}Z \\ &(2)\quad N = \Delta n + n \\ &(3)\quad n = bI^{\beta}X, \end{aligned}$$

I and N are defined as above, and the DoD share (N) is broken into two parts, an exogenous increment Δn, and an element n that depends on IR&D expenditures (I). Our aim is to determine $dI/d\Delta n$, the total differential of I with respect to Δn. Substituting Eq. (2) into Eq. (1), and taking logs, we get:

$\ell n I = \ell n d + \ell n Z + \delta\, \ell n(\Delta n + n)$. Recognizing that $\ell n(\Delta n + n) \approx \ell n n + \Delta n/n$, substituting Eq. (3) for n, and moving all terms to the right hand side, we get the implicit equation: $F(I,\Delta n) = O = -\ell n I + \ell n d + \ell n Z + \delta \ell n b I^{\beta} X + \delta\Delta n / bI^{\beta}X$.

The total derivative is $dI/d\Delta n = (-\partial F/\partial\Delta n)/(\partial F/\partial I)$. Taking the indicated derivatives yields:

$dI/d\Delta n = \delta I/[n(1-\delta\beta) + \delta\beta\Delta n]$.

As Δn approaches zero, this expression becomes:

$dI/d\Delta n = \delta I/n(1-\delta\beta)$, with an elasticity equal to $\delta/(1-\delta\beta)$.

an incremental change in the variable controlled by the other party (equivalent to movement along the first party's curve). (We use the word "partial" here because we assume that only one party reacts to an exogenous shift of the other.) The short-run (partial) elasticity tells what proportion of the steady-state partial response will be realized in the first year. The total long-run elasticity shows what would happen if there were an incremental shift in one party's curve, with a subsequent establishment of a new equilibrium brought about by the interactions and feedback effect of both parties. The statistical estimates indicate that industry's long-run (partial) elasticity of IR&D with respect to the DoD share is approximately 1.0, and the government's long-run (partial) elasticity of the DoD share with respect to IR&D is about 0.65; industry's total long-run elasticity is therefore approximately 3.0, and the government's is 2.0. In what follows, we concentrate on the long-run (partial) responses and drop the "partial" designation.

DATA AND OBSERVATIONS[8]

The values of the variables have been deflated to a 1976 base using two separate deflators: one for the R&D and B&P variables, and another for sales and all other variables. Except where otherwise noted, IR&D and B&P have been combined and treated as a single variable. For the initial analyses, the data are aggregated by company as reported in the IR&D data base for the years 1969 to 1985.[9] Before proceeding with discussion of the results, it will be necessary to consider the unit of observation used in this part of the analysis.

The original data are produced by the different kinds of corporate entities that enter into the IR&D negotiation process. With the larger defense contractors, the Defense Department administrators prefer to deal with corporate divisions or profit centers that sell a fairly homogeneous product to the government. In this way, they believe that they can take into account the very different technologies, research intensities, and market conditions that exist across the array of products that the DoD buys. The government also believes that negotiations with divisions will reduce the amount of R&D cross-subsidization within a company's product line. The data base consequently includes "simple"

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[8]IR&D and B&P financial data for the years 1969 to 1985, by individual business units negotiating advance agreements, were obtained from: Defense Contract Audit Agency (DCAA), *Independent Research and Development and Bid and Proposal Cost Incurred by Major Defense Contractors*. These reports were provided to RAND to be used for the present study on a proprietary and controlled basis.

[9]Below we analyze the effects of the deflators, of pooling IR&D and B&P, and of aggregating the data by company.

companies with no separate divisions, "complex" companies with many product divisions or profit centers (each engaging in negotiations), and complex companies that negotiate and report only on their defense business subsidiaries, divisions, or profit centers. The government, for example, negotiates IR&D cost recovery only with IBM's Federal Systems Division; the IR&D data base has information only on that part of the company.

An empirical analysis of the organizations directly engaged in the negotiation process would use a sample composed of a combination of "simple" companies and the divisions of complex companies that negotiate directly with the government. However, our company interviews suggested that the large, multidivision corporations often plan their R&D strategy from corporate headquarters, allocating R&D investments across division boundaries. The data support this view; we have therefore concentrated here on the aggregate company level, as it is defined in the IR&D data sources.[10]

THE BASIC EQUATIONS

We begin the analysis with ordinary least squares (OLS) single equation estimates that ignore the interaction effects between government and industry and that do not include a lag structure: We omit the lagged dependent variable. (See Eqs. (1) and (2) in Table C.1). We next add lags (Eqs. (3) and (4)), and finally estimate the set of simultaneous equations with lags by three-stage least-squares (3SLS) as shown in Eqs. (5) and (6). Because of its role in the calculation of the DoD share, the ratio of defense to total sales is included in the government equations, as is total sales itself. It could easily be argued that these sales variables ought also to be included in the industry equation. To identify and estimate the equations by 3SLS, it is necessary to place them in only one equation. However, we shall also show the effects of inserting these defense sales variables in the industry equation. See Table C.2 for variable definitions.

Despite the inclusion of a lagged dependent variable in both equations, the statistical necessity for the use of company dummy variables was indicated by the high correlations of lagged residuals, which showed significant autocorrelations as high as 0.6 for first to fourth order lags when company dummies were omitted. The company dummy variables reduced the autocorrelation of the residuals to under

[10]An additional level of corporate structure further complicates matters. The subsidiaries of large conglomerates, such as Allied-Signal Corp., are treated as separate entities in the IR&D data sources and in the statistical analysis.

Table C.1

COMPARISON OF ESTIMATION METHODS AND LAG EFFECTS ON GOVERNMENT AND INDUSTRY EQUATIONS

	Eq. (1)	Eq. (2)	Eq. (3)	Eq. (4)	Eq. (5)	Eq. (6)	Eq. (7)	Eq. (8)
R^2	.981	.960	.983	.980	.975	.975	.985	.973
Constant	−.965	.671	−.770	.273	−.917	.248	−.023	−.453
	(.038)	(.034)	(.065)	(.027)	(.072)	(.028)	(.068)	(.121)
(I+B)	.731		.562		.432			
	(.016)		(.020)		(.033)			
$(NI+NB)_{t-1}$			.238		.320			
			(.019)		(.026)			
D/S	.416		.342		.251		−.407	−.345
	(.025)		(.024)		(.030)		(.022)	(.028)
D	.241		.191		.247		.058	.174
	(.018)		(.017)		(.021)		(.018)	(.033)
(NI+NB)		.964		.429		.281	.564	.284
		(.012)		(.019)		[illegible]	(.022)	(.066)
$(I+B)_{t-1}$				.576		[illegible]	.411	.567
				(.018)		[illegible]	(.018)	(.039)
Long-run e	.73	.96	.74	1.01	.64	[illegible]	.96	.66
Short-run e	—	—	.76	.42	.68	.30	.59	.43

NOTES: All variables in logarithms; R^2 adjusted for degrees of freedom; company dummy variables in all equations; standard errors in parentheses; values deflated to 1976; variables are defined in Table C.2.

Method, Eqs. (1)-(4), OLS Eqs. (5)-(8), 3SLS.

Observations, 1154.

Dependent Variables, Eqs. (1), (3), (5) - (NI+NB).
Eqs. (2), (4), (6)-(8) - (I+B).

0.2 for the government equation and to under 0.15 for the industry IR&D equation. Because of the inclusion of the company dummies, the estimates are interpreted as average responses that allow the intercept to vary by company.

The long-run partial elasticities do not change by much as we move from the simpler to the more complex formulations. However, the estimates are all higher with OLS than with 3SLS because the single equa-

Table C.2

VARIABLE DEFINITIONS FOR EQUATIONS TABLES

I	-	Incurred IR&D by firms
B	-	Incurred B&P by firms
NI	-	DoD share of IR&D
NB	-	DoD share of B&P
D	-	Defense sales
C	-	Commercial sales
S	-	Total sales = C+D
e	-	Elasticity
ED	-	Expected defense sales
EI	-	Expected IR&D
EB	-	Expected B&P
+(X)	-	Value of variable X for positive change of X, zero otherwise
−(X)	-	Value of variable X for negative change of X, zero otherwise
R	-	Other company R&D
P	-	Gross operating profits before taxes
K	-	Capital
FPC	-	Percentage of fixed-price, competitive contracts
Σ(X)	-	Weighted sum of lagged variable X
(X)Corp	-	Total corporate value of variable X.
Basic	-	man-years of basic research
Applied	-	man-years of applied research
Devt	-	man-years of company-sponsored development
Systems	-	man-years of company-sponsored systems studies
Sample definitions:		
Simple	-	Companies without negotiating divisions.
Complex	-	Companies with negotiating divisions.
Divs.	-	Divisions of complex companies.
Combi.	-	Combination of simple companies and negotiating divisions (i.e., all negotiating entities) = Simple + Divs
Cos.	-	All companies at the aggregate company level (i.e.. simple and complex companies) = Simple + Complex.

All dollar values in millions

tion method does not recognize the simultaneity and feedback between the equations.[11]

Although estimation problems did not permit the inclusion of the defense sales variables in both equations at the same time, we wished to examine the effects of their inclusion in the industry equation. Eqs.

[11]Two-stage least-squares estimates (not shown) are quite close to those from 3SLS, suggesting the absence of significant mis-specification errors. See J. A. Hausman, "Specification Tests in Econometrics," *Econometrica*, Vol. 46, No. 6, November 1978.

(7) and (8) report the results of this inclusion. Eq. (7) is estimated by OLS; the results here can be compared to Eq. (4), which is similar except for the variables D/S and D. The long-run elasticity falls slightly from 1.01 to 0.96. Equation (8) shows the same equation, but estimated by 3SLS while omitting the defense sales variables from the government equation. We know that the latter is a misspecification of the government relationship because the ratio of defense to total sales arises prominently in the calculation of the DoD share. In this case, the estimation of industry's long-run elasticity falls to 0.66, the lowest value that we will observe in the statistical analysis. As such, it establishes a floor for the estimate of industry's IR&D response to the DoD share.

Alternative specifications were examined, which—because they barely differed from the core model represented by Eqs. (5) and (6) in Table C.1—are not shown. These alternatives included the following: quadratic independent variables (in logs); additional lagged terms of the dependent variables; substitution of forward-looking and lagged independent variables for the contemporaneous versions; use of linear and linear-quadratic variables instead of logs; and use of undeflated data. The linear models produced similar results to those of the logarithm equations at the sample means, but they exhibited severe heteroscedasticity problems. The log-quadratic estimates were almost identical to the log-linear equations within a range from one-tenth to three times the sample means. The undeflated estimates left the government's long-run elasticity unchanged, whereas the long-run elasticity for the industry equation rises a small amount from 0.94 to 1.01.

As indicated by Eq. (5), when estimated with the aggregated company sample, the long-run elasticity of the DoD share with respect to IR&D is .64; the absolute response evaluated at the ratio of aggregate N/I of 0.47 for 1985 is 0.30.[12] Thus, at the margin, the government contributed about $0.30 per dollar of industry IR&D. The short-run elasticity is 0.70. If a company's IR&D were initially to increase by a dollar, the government would eventually raise its payment by 30 cents, with about 70 percent of that, or 21 cents, coming in the first year (assuming in this computation that industry does not further react to the increase in DoD share). The appropriate organizational level for estimating government behavior is the corporate level for simple companies and divisions for complex companies. At that negotiating level, the estimated elasticities are somewhat higher—approximately 0.85.

[12]Depending on the purpose of the estimation, other values of N/I could be used. For example, the median value in 1985 is 0.6. The government response for the typical firm would therefore be 38 cents on the dollar.

Turning to the industry equation (Eq. (6)) we find that the companies respond quite strongly to changes in the DoD share, with a long-run elasticity of 0.94. At the 1985 aggregate ratio of I/N of 2.13, if industry initially receives one additional dollar from the government, industry spends \$2.00, or a dollar of its own beyond what it recovers from the government.[13] Industry's short-run responsiveness of 0.30 is somewhat more sluggish than the government's, primarily—we suspect—because companies' plans are tied to physical assets: scientists, equipment, and structures. If the DoD were to initially raise its share by \$1, industry's response in the first year would be to spend only \$0.66 with an exponential approach to the long-term \$2 response.

The long-run dynamic IR&D multiplier produced by an exogenous increase in the DoD share followed by full feedback effects is 2.36; the government's long-run dynamic multiplier produced by an exogenous increase in IR&D is 1.61.[14] Thus, a one-time shift by either party, followed by the responsiveness of both parties, will have considerably larger effects than indicated by the partial long-term elasticities calculated above, which assume no further response from the party initiating the exogenous change.

To estimate the effects of changes in government policy, it is useful to assume that government can undertake exogenous shifts in its behavior, with industry then responding to such shifts. Therefore we concentrate on the long-term (partial) elasticity rather than on the full dynamic elasticity.

Industry's absolute dollar responses have been calculated at an average ratio of I/N. For companies with low rates of cost recovery, the response will be proportionately greater; the reverse is true for high cost-recovery firms. The intuition behind this is that for firms that are already strongly supported (e.g., with N at 90 percent of I) such that most of their IR&D costs are borne by the government, additional support will stimulate small amounts of additional IR&D; conversely, for those companies paying the full burden of their IR&D expenditures, small absolute changes in the DoD share (large percentage changes) would have a larger stimulating influence.

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[13]At the aggregate ratio of I/N for the 17-year sample period of 2.36, industry's marginal response to the DoD share is 2.22.

[14]The dynamic multipliers for industry and government are respectively $(.94)/(1 - .94 \times .64) = 2.36$, and $(.64)/(1 - .94 \times .64) = 1.61$.

RESPONSES AT THE CORPORATE AND DIVISION LEVELS

The analysis so far has been of corporate behavior. However, about half the firms in the IR&D sample negotiate at the division or profit-center level rather than at the corporate level. Our choice of analytical level depends on the answers to several questions: What are the policy issues we wish to investigate? What are the behavioral processes in the firms and in the negotiations? How are the econometric estimates influenced by this behavior?

The main policy issue we are addressing in the statistical analysis was raised at the beginning of this appendix: Are industry's IR&D expenditures stimulated by government support of IR&D costs? To answer this question, it is necessary to model behavior and estimate questions that best capture industry response to government support.

On the basis of interviews with industry and government people and on the preliminary statistical analysis, we pictured the following model of firm and government behavior. Complex firms—that is, those with negotiating divisions—planned their IR&D investments at the corporate level. The corporate planners take into account division activities, including the DoD share of IR&D costs at the division level, but they also reallocate resources across division boundaries. At the division level, the resources available for IR&D therefore comprise those raised locally within the division and those distributed from corporate funds:

$$I_d = L_d + F_d$$

where I_d is division IR&D expenditures, L_d is division-originating resources, and F_d is the amount coming to the division from corporate funds. According to our interviews and preliminary analyses, we suspect that corporate funds allocated to a division depend—among other things—on the total corporate DoD share (N_T) and (negatively)[15] on the ratio of defense to total sales of the division:

$$F_d = f\ (N_{T,}\ (D/S)_d)\ .$$

The corporation probably taxes the DoD share negotiated by the divisions (at a tax rate $1-t$), so that the divisions keep only a fraction of their negotiated amount $n_d = tN_d$).

The following set of equations describes behavior at the division level:

[15]Note the negative coefficient of D/S in Eqs. (7) and (8), Table C.1.

$$I_d I = L_d + F_d$$

$$F_d = f(N_T, (D/S)_d)$$

$$n_d = tN_d$$

$$L_d = g(N_d) = g(t\ N_d)\ .$$

Therefore: $I_d = h(N_d, N_T, (D/S)_d)$

If these assumptions about corporate behavior are correct, we would expect: (1) estimates of IR&D at the division level (I_d) to show a lower level of responsiveness to the division value of the DoD share (N_d) than is shown by corporate level I to corporate level N; (2) the total corporate value of the DoD share (N_T) to be significant and positive in the division-level equation, and (3) the effect of the defense to total sales ratio (D/S) to be negative.

Table C.3 takes up these points. Eqs. (1) and (2) show 2SLS estimates for the division sample, similar to Eq. (4) of Table C.1. The long-run elasticity of IR&D with respect to the division-level DoD share is only about half the value (0.50) estimated at the aggregate corporate level. However, the addition of the total corporate DoD share shows both that this variable is significant and that it raises the total division long-run elasticity to the DoD share to 0.84 (Eqs. (3) and (4)). Furthermore, D/S has a significantly negative coefficient and lowers the value of the coefficient of total corporate DoD share from 0.104 to 0.027 (Eq. (5)). In Eq. (6), we move from the division level to the company level for the same set of companies. The company's responsiveness of IR&D to the DoD share is significantly greater than the division's, even when total corporate DoD share is included in the division estimates.

We conclude from this evidence that the corporation is the key planner of IR&D, that it responds more strongly to the DoD share than do the divisions, and that it reallocates funds from corporate to division levels and among divisions. Because of these internal corporate transfers, concentration on the divisions will not capture total corporate behavior. To estimate the effect of policy changes in the DoD share on industry behavior, we should examine the corporation, rather than the division.

Government behavior is a different matter. In our interviews we specifically probed as to whether parent company identity made a difference in the negotiated outcomes. Our respondents in both government and industry stated that the negotiators seemed to ignore corporate identity. We tested this view by adding corporate level IR&D expenditures to the equation for N_d using the division sample.

Table C.3

INDUSTRY BEHAVIOR AT THE DIVISION AND CORPORATE LEVELS OF COMPLEX COMPANIES

	Eq. (1)	Eq. (2)	Eq. (3)	Eq. (4)	Eq. (5)	Eq. (6)
R^2	.961	.961	.974	.960	.974	.969
Constant	−.412	.283	−.450	.010	.208	.156
	(.053)	(.023)	(.053)	(.043)	(.053)	(.056)
I+B	.555		.569			
	(.026)		(.026)			
(NI+NB)t-1	.318		.304			
	(.018)		(.018)			
D/S	.473		.472			
	(.023)		(.023)			
D	.088		.095			
	(.014)		(.014)			
(NI+NB)		.111		.109	.522	.444
		(.017)		(.017)	(.016)	(.035)
(NI+NB)Corp.				.104	.027	
				(.014)	(.011)	
(I+B)t-1		.780		.747	.386	.598
		(.017)		(.017)	(.015)	(.031)
Long-run e	.81	.50	.82	.43	.85	1.10
Long-run e (including corporate level variable)	—	—	—	.84	.89	—
Short-run e	.68	.22	.70	.25	.61	.40

NOTES: All variables in logarithms; R^2 adjusted for degrees of freedom, company dummy variables in all equations; standard errors in parentheses; values deflated to 1976; variables are defined in Table C.2.

Sample, Eqs. (1)–(5) Divs; Eq. (6), complex.

Estimating Method, Eqs. (1)–(4) and (6) – 3SLS: Eq. (5) OLS.

Observations, Eqs. (1)–(5) 2157; Eq. (6) 572.

Dependent Variable, Eqs. (1), (3), (NI+NB); Eqs. (2), (4)–(6), (I+B).

The results of this test are reported in Table C.4, Eqs. (1) and (2). Equation (1) is the division sample version of Eq. (3), Table C.1. In Eq. (2), Table C.4, we add total corporate IR&D, whose coefficient is

Table C.4

GOVERNMENT BEHAVIOR AT THE DIVISION LEVEL

	Eq. (1)	Eq. (2)	Eq. (3)
R^2	.975	.975	.974
Constant	-.389 (.050)	.379 (.059)	-.413 (.047)
(I+B)	.644 (.016)	.646 (.016)	.629 (.024)
(I+B)Corp.		-.004 (.011)	
(I+B)t-1	.261 (.014)	.262 (.014)	.260 (.016)
D/S	.522 (.018)	.521 (.018)	.523 (.021)
D	.069 (.012)	.069 (.012)	.085 (.013)
Long-run e	.87	.87	.85
Short-run e	.74	.74	.74

NOTES: All variables in logarithms; R^2 adjusted for degrees of freedom; company dummy variables in all equations; standard errors in parentheses; values deflated to 1976; variables are defined in Table C.2, except division dummy variable in all equations.

Sample. Eqs. (1)-(2) Divs; Eq. (3), complex.

Estimating Method, Eqs. (1)-(2) 3SLS; Eq. (5) OLS.

Observations, 2157; Eq. (3) 2763.

Dependent Variable, Eqs. (1), (2), and (3) (NI+NB).

totally insignificant. This result is consistent with the assumption that government behavior focuses on the negotiating entity—the division, in this case—rather than on the corporation.

Equation (3) of Table C.4 includes the same variables as Eq. (1), but estimated by 3SLS (the industry equation is not shown). The long-run elasticity is almost the same in both the OLS and 3SLS estimates, but it is significantly greater than when estimated from the company level sample. An elasticity of 0.85 translates into a marginal dollar response by the government to an additional IR&D dollar of \$0.36. These figures of about 0.85 for the government elasticity and 0.35 to 0.36 for its rate of response will be our "baseline" estimates.

We conclude that government behavior is best estimated at the level of the negotiating entity and that industry behavior should be represented (for present purposes) by corporate relationships. The chief qualitative results are unaffected by these distinctions, although point estimates of elasticities and marginal effects can vary according to the level of analysis. For analyses directly related to industry issues, we will use the aggregate company sample, and for government analyses, the combination division/simple company sample.

SEPARATING IR&D AND B&P

Until now, all the estimates have been based on the sum of IR&D and B&P. We now show separate equations for each category in Table C.5. Eqs. (1) and (2) at the corporate level examine industry behavior, and Eqs. (3) and (4) at the negotiating unit level estimate government behavior.[16] For industry, IR&D and B&P elasticities are quite similar to each other, differing by only 3.0 percent. The elasticities are not statistically different from each other or from the elasticities of the summed categories. Government behavior, when estimated at the corporate level, is also statistically undifferentiated across IR&D and B&P (results not shown).[17] However, at the negotiating unit level, we find government to be significantly more responsive to B&P than to IR&D (Eqs. (3) and (4), Table C.5). Because our main interest is industry response to the DoD share, for simplicity, we shall concentrate on the combined amounts.

TESTING THE HYPOTHESES

With the core model in hand, we are in a position to begin considering the consistency of the six hypotheses (stated above) with the evidence. If the DoD share is administered as a block grant, we would expect to find its marginal response to IR&D expenditures to be very low, but the long-run elasticity of DoD share to IR&D is about 0.85. This responsiveness of the government to industry spending demonstrates a clear marginal cost-sharing relationship that is inconsistent with both the block grant and the constant overhead rate hypotheses.

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[16]We omit from the table the second equation of the two-equation model and show only the relevant equation of each set.

[17]Lichtenberg found the government equation for combined IR&D and B&P not to be statistically different from the separate estimates, nor were the separate estimates different from each other. Frank R. Lichtenberg, "Government Subsidies to Private Military R&D Investment: DoD's IR&D Policy," unpublished manuscript, January 1988, p. 10.

Table C.5

SEPARATE ESTIMATES FOR IR&D AND B&P

	Eq. (1)	Eq. (2)	Eq. (3)	Eq. (4)
R^2	.961	.941	.934	.972
Constant	.255 (.031)	.208 (.021)	−.711 (.062)	−.312 (.060)
I			.236 (.019)	
(NI)t-1			.564 (.015)	
B				.699 (.041)
(NB)t-1				.251 (.026)
D/S			.138 (.017)	.566 (.028)
D			.155 (.014)	.030 (.015)
NI	.300 (.035)			
NB		.294 (.039)		
(I)t-1	.674 (.031)			
B(t-1)		.670 (.035)		
Long-run e	.92	.89	.54	.93
Short-run e	.33	.33	.44	.75

NOTES: All variables in logarithms; R^2 adjusted for degrees of freedom; company dummy variables in all equations; standard errors in parentheses; values deflated to 1976; variables are defined in Table C.2.

Sample, Eqs. (1)-(2) Cos; (3)-(4) Combi.
Estimating Method, 3SLS.
Observations, Eqs. (1), (2), 1154; Eq. (3), 2858; Eq. (4), 2809.
Dependent Variable, Eq. (1), I; Eq. (2), B; Eq. (3), NI; Eq. (4), NB.

Industry IR&D responds to the DoD share with an elasticity close to one and an average marginal investment response that is more the twice the level of a marginal increase in DoD share. This response demonstrates that industry is stimulated by the price effect implicit in DoD cost-sharing.

This evidence is inconsistent with the view of industry IR&D decisionmaking that pictures choices made on a project by project basis with a cost-recovery ceiling that is usually exceeded—implying zero cost-share on the marginal project. Rather, because firms tend to plan their IR&D strategically with an expectation of recovery that is based on their own expenditures, the marginal effects of cost reduction are felt at the critical decision points, which is demonstrated by the industry responsiveness to DoD share.

Equations (5) and (6) of Table C.1 therefore reject the hypotheses asserting a block grant, block grant and sticky dollar, constant IR&D overhead rate, and no price effect because of expenditures beyond the ceiling. The data are consistent with government cost-sharing in an IR&D cost-reducing manner and with industry stimulation by the cost effects.

The hypothesis that the IR&D overhead rate is constant within a company can be subjected to a more direct test. The overhead rate is the ratio of the DoD share to defense sales (N/D). The hypothesis states that this rate is a constant for each company or division but that these constants may vary uniformly across defense industry in response to defense budgets, procurement policy, and other forces. Dummy variables for each year would capture these effects. The stated hypothesis is equivalent to the following equation:

$$\ell n N = a \, \ell n D + \sum k_i + \sum t_i \quad ,$$

where k_i represents company and division dummy variables, and t_i are the time dummy variables. If the hypothesis were true, we would expect the constant term "a" to be close to one, the addition of other variables to the equation not to affect the coefficient on ℓnD, and additional variables to have small and statistically insignificant coefficients.

Table C.6 shows a set of equations based on a combination sample of the simple companies without divisions plus the negotiating divisions of complex companies. We also analyzed equations without time dummy variables and samples aggregated to the company level (with and without time dummies). All results were essentially the same. The coefficient on the defense sales variable is significantly less than one; inclusion of IR&D expenditures sharply reduces the coefficient on defense sales; the coefficient on IR&D is significantly greater than

Table C.6

TEST OF CONSTANT OVERHEAD-RATE HYPOTHESIS

	Eq. (1)	Eq. (2)	Eq. (3)	Eq. (4)
R^2	.9034	.9039	.9605	.9695
Constant	−2.37 (.080)	−2.30 (.082)	−1.54 (.054)	−1.17 (.050)
D	.699 (.014)	.704 (.014)	.381 (.011)	.278 (.010)
C		−.033 (.009)	−.176 (.007)	−.122 (.006)
(I+B)			.783 (.013)	.536 (.015)
(NI+NB)t-1				.342 (.013)

NOTES: All variables in logarithms; R^2 adjusted for degrees of freedom; company dummy variables in all equations; standard errors in parentheses; values deflated to 1976; variables are defined in Table C.2, except that time dummy variables and division dummy variables are included in all equations.

Sample, Combi.
Estimating Method, OLS.
Observations, 2696.
Dependent Variable, (NI+NB).

zero; and the inclusion of a lagged dependent variable produces tl OLS version of the basic government equation estimated in Table C. Thus the predictions of the constant overhead-rate hypothesis a inconsistent with the statistical results.

A similar test performed on the industry equation with IR&D as tl dependent variable yields identical qualitative results, and is n shown.

EXPECTATIONS OF FUTURE BUSINESS ON IR&D EXPENDITURES

A possible influence on IR&D expenditures is the expected growth DoD business, as firms could be expected to perform more IR&D tod in anticipation of future business expansion. The IR&D data ba reports both the current-year figures and the expected values for tl coming year. We were therefore able to determine the ratio of expected defense sales in the coming year to actual sales of the current year. The logarithm of this ratio was included in the industry equation. According to the estimates, a 10 percent expected increase in defense sales will increase IR&D by about 1 percent. (See Table C.7, Eq. (1).)

GOVERNMENT RESPONSE TO LOWER-THAN-PLANNED IR&D

A different consideration leads to a similar variable being constructed for the government equation. Our interviews with government negotiators indicated that they do not like to be fooled by companies whose actual IR&D turns out to be smaller than the amount on which negotiations have been based. We therefore formed the ratio of actual IR&D of the present year to that expected the year before for the present year and entered its logarithm into the government equation. The elasticity of this "surprise" variable is statistically significant but not very large at 0.11, indicating that a company that performed at a 10 percent lower level than expected will have its negotiated DoD share reduced by only about 1 percent, holding other things equal. (See Table C.7, Eqs. (3) and (4).)

TEST OF NONSYMMETRIC RESPONSES

We considered the possibility that government or industry would have asymmetric responses to positive and negative stimuli. For firms in particular it may be easier to reduce IR&D than to increase it, because an increase often requires additional resources, such as laboratory equipment and personnel. Also, some observers suggested that government negotiators were quicker to reduce their IR&D support when spending fell than to increase it when it rose. To test these possibilities, we constructed two variables each for the DoD share and for IR&D. One of these new variables is equal to its counterpart (DoD share or IR&D) when the change from the past year is positive, and zero otherwise. The second variable is just the reverse: It takes on the value of its related variable when the change is zero or negative, and is zero otherwise. Different coefficients on these variables would provide evidence of a differential response. The results are shown in Table C.8, Eqs. (1) and (2) for 2SLS estimates. The government response turns out to be identical for positive and negative changes in IR&D. Industry is slightly more responsive (but not significantly) to positive

Table C.7

TESTS OF EXPECTED DEFENSE SALES AND EXPECTED IR&D

	Eq. (1)	Eq. (2)
R^2	.976	.965
Constant	.228	−.463
	(.025)	(.046)
(I+B)		.614
		(.023)
(NI+NB)t-1		.266
		(.016)
D/S		.497
		(.020)
D		.099
		(.012)
(NI+NB)	.280	
	(.026)	
(I+B)t-1	.706	
	(.023)	
(ED)t+1/(D)t	.086	
	(.029)	
(I+B)t/(EI+EB)t-1		.112
		(.035)
Long-run e	.95	.84
Short-run e	.29	.73

NOTES: All variables in logarithms; R^2 adjusted for degrees of freedom; company dummy variables in all equations; standard errors in parentheses; values deflated to 1976; variables are defined in Table C.2, except that time dummy variables and division dummy variables are included in all equations.

Sample, Eq. (1), Cos; Eq. (2) Combi.
Estimating Method, 3SLS.
Observations, Eq. (1), 1154; Eq. (2), 2763.
Dependent Variable, Eq. (1), (I+B); Eq. (2) (NI+NB).

Table C.8

TEST OF ASYMMETRIC RESPONSE

	Eq. (1)	Eq. (2)
R^2	.982	.9[illegible]
Constant	−.869	.240
	(.070)	(.024)
(NI+NB)t-1	.325	
	(.025)	
D/S	.255	
	(.028)	
D	.227	
	(.019)	
(I+B)t-1		.700
		(.022)
+ (I+B)	.454	
	(.030)	
− (I+B)	.446	
	(.031)	
+ (NI+NB)		.301
		(.024)
− (NI+NB)		.265
		(.025)
Long-run e	.66	1.00/.88
Short-run e	.68	.30

NOTES: All variables in logarithms; R^2 adjusted for degrees of freedom; company dummy variables in all equations; standard errors in parentheses; values deflated to 1976; variables are defined in Table C.2.

Sample, Cos.
Estimating Method, 2SLS.
Observations, 1154.
Dependent Variable, Eq. (1), (NI+NB);
Eq. (2), (I+B).

increases in the DoD share with a long-run elasticity of 1.00, versus 0.88 for downward changes. However, both of these elasticities are within a few percent of the core elasticity estimates shown in Eqs. (5) and (6), Table C.1.

CHANGES IN THE RELATIONSHIPS OVER TIME

Great changes occurred in defense spending and in attitudes toward IR&D during the 17 years under statistical analysis. From 1969 to 1977, real defense sales of the companies in our sample fell by about 3 percent per year. The defense buildup began after that period, and in the subsequent years through 1985 defense sales rose at an annual rate of more than 11 percent. In the early 1970s, congressional hearings on the IR&D cost recovery process led to the institution of new regulations and procedures. Beginning in 1983, Congress suggested a limit to the total IR&D commitment of DoD. We sought to determine whether these changes in the overall environment produced differences in government and industry behavior beyond those already accounted for by the variables included in the basic equations.

To analyze the possible changes over time in the government and industry relationships, we estimated separate equations for three different time periods, thus permitting all of the coefficients to vary.

Table C.9 shows separate equations for each of the three time periods: 1969–77, 1978–82, and 1983–85. Again we show industry equations at the corporate level and government at the level of the negotiating units, omitting the nonrelevant equation of each set. The story told by these subsamples is that both government's and industry's long-term elasticities were stable across the changing environments of the different periods. The long-run elasticities were not significantly different in either statistical or policy terms.

OTHER COMPANY R&D AND IR&D

Some critics have asserted that government encouragement of additional IR&D could leave total R&D unchanged as companies simply reduced their other corporate R&D or shifted their R&D projects into the defense-oriented divisions to take advantage of the government support. We were able to test this assertion through the use of financial reports that publicly traded companies are required to submit annually to the Securities and Exchange Commission (SEC). One of the items in this 10K report includes company-sponsored research and development.[18]

[18]The SEC definition of this item is intended to exclude the amount of cost recovery firms negotiate with the government. Experts at Standard and Poors's Compustat division who standardize these data before their publication claim that, in general, reported R&D includes all of IR&D, plus other corporate research and development. Lichtenberg compared 10K R&D data with National Science Foundation survey data and found that firms performing IR&D reported substantially less R&D in the 10K report, suggesting

Table C.9

TESTS OF DIFFERENCES OVER TIME

	Eq. (1)	Eq. (2)	Eq. (3)	Eq. (4)	Eq. (5)	Eq. (6)
Time period	1969–77	1978–82	1983–85	1969–77	1978–82	1983–85
R^2	.972	.990	.990	.974	.975	.978
Constant	.195	.271	.505	−.292	−.357	−.392
	(.038)	(.048)	(.050)	(.080)	(.095)	(.096)
(NI+NB)	.274	.255	.525			
	(.044)	(.054)	(.042)			
(I+B)t-1	.702	.734	.430			
	(.038)	(.052)	(.044)			
(I+B)				.781	.666	.817
				(.042)	(.050)	(.068)
(NI+NB)t-1				.146	.281	.106
				(.025)	(.033)	(.048)
D				.047	.052	.057
				(.022)	(.028)	(.028)
D/S				.637	.507	.756
				(.034)	(.041)	(.069)
Long-run e	.94	.96	.92	.91	.93	.91
Short-run e	.30	.27	.57	.85	.72	.89

NOTES: All variables in logarithms; R^2 adjusted for degrees of freedom; company dummy variables in all equations; standard errors in parentheses; values deflated to 1976; variables are defined in Table C.2, except second equation in 3SLS estimates not shown.

Sample, Eqs. (1)-(3), Cos; (4)-(6), Combi.
Estimation Method, 3SLS.
Observations, Eq. (1), 553; Eq. (2), 372; Eq. (3), 229; Eq. (4), 1205; Eq. (5), 925; Eq. (6), 638.
Dependent Variable, Eqs. (1)-(3), (I+B); Eqs. (4)-(6), (NI+NB).

Other company R&D can reflect several different kinds of expenditures. A defense-oriented company[*] may not include all of its projects

that some amount of the DoD share is deducted from their company-sponsored R&D figures. To reflect these different views, we computed "other company R&D" (*R*) in two ways: (1) we subtracted IR&D (*I*) from the total company-sponsored R&D (*R&D*) (*R* = *R&D* − *I*); and (2) to this first estimate, we added back the amount of the DoD share (*NI*) to fully reflect the definition of "company-sponsored" R&D (*R* = *R&D* − *I* + *NI*). See Frank R. Lichtenberg, "A Comparison of NSF/Census and Alternative Estimates of Company and Federal Funds for Research and Development," Columbia University, 1987, pp. 13-17 (unpublished).

in the IR&D pool that it submits to DoD for scoring and for consideration of military relevance. Some projects may be so proprietary, sensitive, and important to a company's business strategy that the company prefers not to disseminate information on the project for fear of its being revealed to competitors. For other defense projects, particularly new product developments, the company may believe that it can recover the full cost of the development as a direct charge on future contracts rather than receiving only a portion of the cost through the indirect IR&D process. However, company interviews suggest that both of these categories are fairly small and that only a few companies do not report defense-related IR&D.

By far the largest category of other company R&D is related to work that is clearly not defense-relevant. Such R&D can take place in a defense-oriented division that negotiates IR&D cost recovery with the government, or in other divisions.

We matched data from SEC form 10K at the parent company level with those from publicly traded companies in the IR&D sample for the period 1976–1985. Out of the 1985 population of 108 companies that negotiated IR&D recovery, 68 also reported 10K financial information. The 1985 matching rate of 63 percent was lower in earlier periods. In 1976, of the 91 parent companies in the IR&D population, matches were found with 48 10K companies, or about 53 percent of the IR&D population.[19] With this matched, 10-year sample, we estimated a three-equation model, adding a relationship for other company R&D to the core two-equation model. We were particularly interested in observing the relationship between IR&D and other company R&D.

The results of the three-equation model estimation are shown in Table C.10, Eqs. (1)–(3). These estimates, based on the first definition of other company R&D (above), clearly demonstrate three results. (1) Other company R&D has no effect on government behavior in the negotiating of the DoD share (the long-run elasticity of DoD share with respect to other company R&D is 0 [illegible]); (2) IR&D is not affected by other company R&D, and (3) other company R&D is positively influenced by IR&D spending (the long-run elasticity is 0.31). In other words, other company R&D is a complement to IR&D, rather than a substitute. The more IR&D that is performed, the more is other company R&D undertaken; but the reverse effect is not observed.

The marginal dollar effect of IR&D on other company R&D is 0.48, meaning that if IR&D rises by $1, other company R&D appears to

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[19]We excluded three companies from the sample as extreme outliers: General Motors, AT&T, and IBM. These three companies each performed more than $2 billion in other company R&D and had a small percentage of their sales to the Defense Department.

Table C.10

IR&D EFFECTS ON OTHER COMPANY R&D

	Eq. (1)	Eq. (2)	Eq. (3)
R^2	.987	.987	.987
Constant	−1.17 (.100)	.294 (.041)	.764 (.152)
(I+B)	.441 (.049)		.068 (.039)
(NI+NB)t-1	.288 (.044)		
R	.008 (.010)	.004 (.009)	
D	.281 (.025)		
D/S	.200 (.032)		
(NI+NB)		.289 (.034)	
(I+B)t-1		.705 (.034)	
R(t-1)			.779 (.032)
Long-run e:			
with respect to (I+B)	.62	—	.31
with respect to R	.01	.01	--
with respect to (NI+NB)	—	.98	—

NOTES: All variables in logarithms; R^2 adjusted for degrees of freedom; company dummy variables in all equations; standard errors in parentheses; values deflated to 1976; variables are defined in Table C.2.

Sample, Cos.
Estimating Method, 3SLS.
Observation, 378.
Dependent Variable, Eq. (1) (NI+NB); Eq (2), (I+B); Eq. (3), R.

increase by about \$0.48.[20] These estimates also imply that if the DoD share were to rise by a marginal dollar, IR&D would increase by \$2, and other company R&D by about \$0.98.[21]

The stimulative effect of IR&D (or of the DoD share) on other company R&D is somewhat puzzling because the price of other company R&D is not affected by the DoD share (as shown by Eq. (1), Table C.10, additional expenditures on other company R&D do not increase the DoD share, nor is it intended to by law and regulation). We considered two possible explanations for the observed phenomenon. First, after discovering the statistical results, we queried several companies (major defense contractors) about the possible relationships, without informing them of our findings. Uniformly, they gave the same response. Materials, processes, and products developed in defense-oriented R&D sometimes had uses in other products and company divisions. In such cases, additional development efforts were required to transfer the technology to the other users. For these companies, the reverse flow from civil to defense R&D was considerably less important. In other words, these companies described a one-way complementarity between R&D and other company R&D.

The second explanation for this complementarity lies in the organizational process used in corporate R&D budgeting. R&D decisions are central issues of corporate strategy. R&D tends to be treated as a whole, and the amount of expected cost-recovery is an important piece of information in the budget allocations. Corporate officers could act as though DoD support of the IR&D portion of R&D investment also applies to other corporate R&D because (1) they are both thrown into the decision basket at the same time, or (2) "sticky dollar effects" influence all company R&D even though there are no economic price effects, or (3) the DoD share loosens funds constraints felt by firms.

One other possibility should also be mentioned. We noted above that corporate R&D allocations appeared to vary negatively with the proportion of defense business in a division. Because other company R&D is presumably not related to defense products, the apparent stimulation of nondefense R&D is consistent with a general reallocation away from defense work. Thus, according to this hypothesis, the DoD share encourages more IR&D but shifts it away from defense-intensive parts of the company; it may also lead to similar redistributions of other company R&D.

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[20]Quite similar results are obtained when the alternative definition of other company IR&D is used. The long-run elasticity of other company R&D with respect to IR&D falls from 0.31 to 0.27, but the dollar effect rises from 0.48 to 0.52.

[21]This result is obtained directly when the DoD share rather than IR&D is included in the equation for other company R&D.

THE EFFECTS OF DOD SUPPORT BY TYPE OF IR&D

Defense contractors perform company-sponsored research and development across the spectrum of R&D categories, from basic research to product development and system studies. We conjectured that because of the price effect produced by DoD support of IR&D, companies would shift their effort toward the basic end of their R&D activities. That is, by making IR&D cheaper, companies would be willing to undertake riskier projects with lower expected rates of return; because basic research is generally asserted to be less predictable and the results more likely to be unrelated to a company's main line of business, we believed that this category would benefit most from the DoD support.

Contractors that negotiate IR&D cost recovery submit one-page descriptions of their IR&D projects annually to the Defense Technical Information Center (DTIC). Included in this description are the total man-years devoted to the project and a classification of the work into one of four categories: basic research, applied research, development, and systems studies. These project descriptions were matched with the IR&D financial data; 204 matches were made out of the 300 separate companies and division negotiating IR&D or B&P in 1985. The sample included most of the larger IR&D performers and accounted for $4.46 billion out of the total $5.04 billion in incurred IR&D, or 88.6 percent.[22]

Not all companies engage in the full range of IR&D activities. Table C.11 shows the number of companies engaging in each R&D

Table C.11

IR&D CATEGORIES

	Basic Research	Applied Research	Development	Systems Studies	Total
Number of firms	60	152	194	142	204
Man-years/firm	33	193	399	94	598
Total man-years	1986	29397	77348	13291	122000
% of total man-years	1.6	24.1	63.4	10.9	100.0

NOTE: Man-years/firm calculated only for those firms actually performing a specified category of research. The figures, therefore, do not add horizontally to the "total" figure.

[22]The statistical analysis was performed under our direction by Frank Lichtenberg, Professor of Economics, Columbia University. Professor Lichtenberg was also a Research Associate of the U.S. Bureau of the Census and was given access to the DTIC data bank.

category, the average number of man-years per category for participating companies, and the aggregate number of man-years across companies. Less than 2 percent of IR&D manpower goes into basic research and only 60 of the 204 companies and divisions engage in basic research at all. Nearly the entire sample performed some product development work, which absorbed almost two-thirds of total IR&D manpower.

To investigate the marginal effect of the DoD share on IR&D manpower, we estimated equations with each negotiating company or division as an observation for the 1985 sample. Separate equations were estimated for each IR&D category for only those observations with a nonzero dependent variable: man-years of basic research, applied research, development, and systems studies. These equations, therefore, can be interpreted as showing the conditional effects of the independent variables on the dependent variable, given that the company performs some research in the designated category. We used absolute values of all the variables, and also used the logarithms. The results were substantially the same at the sample means, but we prefer the logarithmic equations because of heteroscedasticity in the linear residuals and because the very wide range of variable values tended to give great weight to outliers in the linear estimations. The results of the logarithmic equations are shown in Table C.12.

The elasticities of IR&D man-years with respect to DoD share tend to follow the same pattern as the absolute levels of man-years in each category. Thus, basic research has the lowest elasticity with 0.227, and development has the highest at 0.909. A given percentage increase in DoD share therefore will generate almost a proportional rise in development, about half the percentage increase in applied research and systems studies, and less than one-quarter of the rise in basic research manpower.

The marginal effects, or slopes of the equations, are shown at the bottom of Table C.12, calculated at the sample means. An additional $1 million of DoD cost share for an average company would induce an additional 27 man-years of development effort, eight man-years of applied, three man-years of systems studies, and about 0.6 man years of basic research. Again, we see that development is stimulated the most by government support of IR&D.

Turning to the marginal effects of defense sales and nondefense sales on the types of IR&D, Table C.12 shows these to have minor influences. Defense sales has a statistically insignificant negative effect for basic and applied research, a significant negative effect on development, and an insignificant positive affect on systems studies. The greatest effect is of nondefense sales on development, where a $1

Table C.12

IR&D BY R&D CATEGORY

	Eq. (1)	Eq. (2)	Eq. (3)	Eq. (4)
R^2	.025	.295	.565	.413
Constant	2.55	1.02	.714	−.034
	(1.78)	(.929)	(.481)	(.740)
NI	.227	.577	.909	.455
	(.343)	(.185)	(.107)	(.152)
D	−.098	−.152	−.344	.204
	(.329)	(.189)	(.111)	(.161)
C	.084	.338	.220	.195
	(.184)	(.088)	(.045)	(.102)
Slope at sample means	.56	8.3	27.1	3.2

NOTES: All variables in logarithms; R^2 adjusted for degrees for freedom; standard errors in parentheses; observations for 1985; sample includes only those observations with nonzero dependent variables; variables defined in Table C.2.

Sample, Combi.
Estimating Method, OLS.
Observations, Eq. (1) 53; Eq. (2), 136; Eq. (3), 179; Eq. (4), 130.
Dependent Variable, Eq. (1), Basic; Eq. (2), Applied; Eq. (3) , Devt; Eq. (4), Systems.

million increase would be associated with a positive rise in development efforts of 0.6 man-years.

Of the four IR&D categories, development absorbs the greatest share of IR&D manpower, it responds proportionately more to a stimulus of additional DoD support, and its absolute increase is also the greatest. None of the categories are very responsive to either defense or non-defense sales.

R&D EFFECTS ON PROFITS

The negotiation of IR&D cost recovery ceilings and the allocated DoD share is only one step in a process that establishes the price at which the government procures products and services from the private sector. Final prices are not only affected by a company's cost structure whose reasonableness is agreed to by government auditors, but also by the market conditions surrounding a company, its products, and the industry. For well-defined products in competitive markets, the cost structure (including IR&D costs) accepted by the government will have little influence on price; this will be established by market forces. Nonstandard products, such as new weapon systems, that make use of new technologies with a scant history of cost or price fall into quite a different category. The price the government pays will often be based on the costs of the contractor. If an item does not get into the cost base, it will not show up in the final price. The negotiated DoD share of IR&D in such cases is likely to add, almost dollar for dollar, to the contractor's revenues. This discussion raises the following questions: To what degree does the DoD share of IR&D actually appear in revenues and profits? What affects the inclusion of the negotiated share in price, and ultimately in profits?

Because DoD support of IR&D lowers the price of IR&D to the firms, firms are induced to accept a lower rate of return to IR&D investments and therefore fund projects that would not have been profitable without such support. Because of these subsidies to IR&D, we expected to find the marginal effect of IR&D on profits to be less than for other company R&D, where the subsidy is absent.

We also expected that product standardization and competition would affect the ability of contractors to realize their share in their DoD contracts. However, as we analyzed the variety of influences on company results, it became evident that a complex web of relationships is at work that links the DoD share to IR&D expenditures, IR&D to future contracts, and contracts to profits; product type and competition enter into the last two of these relationships. Because the available data did not permit estimation of a multi-equation model that adequately separated the relationships, we concentrated on the effects of IR&D, B&P, and other company R&D on profits. To estimate this relationship, we had to account for competition and time lags.

To account for competition and product type, we used information on the value of different kinds of contracts that companies had with the Defense Department in 1984. We obtained from the Federal Procurement Data Center a file of all government contracts for 1984. Using corporate parent codes (Duns identification numbers), we were able to link the DoD contract information with all of the companies in the IR&D data base for 1984. A contract type code allowed us to aggregate individual contracts according to whether they were cost or fixed-price contracts and whether they were competitive or noncompetitive. According to regulation, custom, and negotiating policy, fixed-price, competitive contracts tend to be used for more standardized products and services; the fact that they are designated as "competitive" indicates several alternative sources of supply. The percentage of a company's total volume of contracts with DoD that were competitive fixed-price was used as a measure of product type and market.[23] For all the companies in the contracts data base, 20 percent of DoD contracts were fixed-price, competitive. However, in the sample used in the equation estimations, this figure was 27 percent.[24]

To estimate the effects of R&D and B&P on profits, it is necessary to accurately incorporate the time structure of the relationships. One method of doing this is to include as variables a long series of lagged R&D variables and simply allow the coefficients on the lagged terms to explicitly describe the lag structure. Unfortunately, the very high level of correlation between the R&D expenditures from year to year makes it unlikely that their separate contribution can be estimated with any precision. In such conditions it is probably best to assume a functional form for the lag distribution on the basis of knowledge and general considerations.[25] We did just that in the estimations (above) of IR&D and cost-share, where we assumed an exponentially declining lag structure. In the present problem, the possibilities are broader. Studies of R&D investment suggest that the influence of past R&D on current profits rises to a peak anywhere from two to ten years in the past. Marketing expenditures, however, almost always have much shorter term influences—on the order of a year or two. We therefore decided to use a functional form—a binomial lag structure—that permits a wide possibility of results, from exponentially rising, to nonsymmetrical single peaked, to exponentially falling shapes.[26]

Our model assumes that the effect of R&D on profits in period t is equal to the weighted sum of R&D of past periods—*t*-1 . . . *t*-*i* . . *t*-*k*— where the weights sum to one, and are equal to the coefficients of the binomial theorem:

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[23]We experimented with other combinations of the contract indicators but settled on using fixed-price, competitive because it showed the sharpest statistical results and it most clearly represented the behavior we sought to measure. Noncompetitive, fixed price contracts accounted for 52 percent of the total, noncompetitive cost contracts for 13.5 percent, and competitive cost contracts for 5 percent.

[24]Some company observations had to be dropped because of insufficiently long strings of uninterrupted data; we required at least six years of data to estimate the lag structure.

[25]Zvi Griliches, "Issues in Assessing the Contribution of Research and Development to Productivity Growth," *Bell Journal of Economics*, Spring 1979, p. 106.

[26]The binomial lag is used by D. Ravenscraft and F. M. Scherer, "The Lag Structure of Returns to Research and Development," *Applied Economics*, Vol. 14, No. 6, December 1982.

$$R\&D_t = \Sigma^k{}_{i=1} W_{i-1} R\&D_{t-i} ,$$
$$W_i = (k!/(k-i)!i!)\, L^i (1-L)^{k-i} .$$

Ravenscraft and Scherer, who have investigated this approach, found that a five-period sum of weighted R&D expenditures ($k = 5$) produced stable estimates of the binomial parameter L. More terms in the sum uses up observations without improving precision, and fewer terms led to unstable estimates. For a five-period estimation, the weights for past periods one to five are: $(1-L)^4$, $4L(1-L)^3$, $6L^2(1-L)^2$, $4L^3(1-L)$, and L^4. The value of L is expected to be in the range of zero to one; values outside of this range produce cyclic coefficients. For small values of L near zero, the distribution is skewed toward more recent periods, and for very small values, an exponential distribution is approximated.[27] With $L = 0.5$, the lag structure approximates the symmetric normal distribution, and for values near 1.0, the weights are skewed toward past periods.

To estimate a binomial lag coefficient, it is necessary to use a nonlinear estimating process. The analysis proceeded in two steps. First, we estimated an equation by nonlinear techniques with just the R&D and B&P independent variables to estimate the lag structure. We then used this structure to calculate weighted R&D variables in OLS estimates that included additional independent variables. To eliminate heteroscedasticity problems and reduce the effects of outliers, we deflated all of the R&D variables as well as the dependent variable by dividing by total company assets. The dependent variable was gross operating profits before taxes. The first equation to be estimated had the following form:

$$P/K = a/K + b\Sigma I/K + c\Sigma B/K + d\Sigma R/K ,$$

where P is gross operating profits, K is total company assets, ΣI is a weighted sum of lagged IR&D, ΣB is a weighted sum of lagged B&P, and ΣR is a weighted sum of other company R&D. All sums were over a five-period lag. Experimentation with the lag structure showed that current year IR&D had no effect on profits, so the lags extended from $t-1$ to $t-5$. Other company R&D had a more extended period of effectiveness, beginning two years in the past, so its lags went from $t-2$ to $t-6$. Almost the entire B&P effects occurred in the year of expenditures (the binomial coefficients ranged from 0.01 to 0.05). To

[27]Exponentially declining weights are equivalent to the Koyck distribution, which is often used in estimating investment functions and was the lag function used earlier in this appendix.

simplify the estimates, we therefore dropped the lag structure for B&P and used only the current year values. The estimation results are shown in Table C.13, as reestimated by OLS techniques, using the non-linear estimates of the binomial lag coefficient. Table C-14 shows the weights of the individually lagged years. The binomial parameter for IR&D was 0.628, and for other company R&D 0.844. As mentioned above, initial estimates for B&P produced a binomial parameter of .01 to .05. For comparison, Ravenscraft and Scherer estimated an R&D parameter of 0.7 and a marketing parameter (similar to B&P) of 0.05, with average lags of 3.8 and 0.25 years, respectively.[28]

Table C.13

R&D AND B&P EFFECTS ON PROFITS

	Eq. (1)	Eq. (2)
R^2	.684	.743
1/K	−4.60	−4.18
	(2.31)	(2.20)
Σ(I)/K	.939	1.56
	(.450)	(.662)
B/K	4.13	3.43
	(.661)	(.621)
Σ(R)/K	2.13	1.93
	(.248)	(.480)
(FPC)(Σ(I))/K		−3.71
		(1.99)
(FPC)(Σ(R))/K		−1.57
		(1.49)
FPC		.151
		(.024)

NOTES: R^2 adjusted for degrees of freedom; standard errors in parentheses; observations for 1976—1985.

Sample, Cos.
Estimating Method, OLS.
Observations, 160.
Dependent Variable, (P/K).

[28]Ravenscraft and Scherer, Table 12. Eq. 1.5, p. 608. This close agreement in the lag structures for R&D and B&P with other published results suggests that we are measuring the same behavior and that the company samples do not deviate substantially from more general industry experience.

Table C.14

WEIGHTS OF PAST YEARS' R&D ON PROFITS

Lag	IR&D	Other Company R&D
t	0	0
t-1	.019	0
t-2	.129	.001
t-3	.327	.013
t-4	.369	.104
t-5	.156	.375
t-6	0	.057
Average lag	3.5	5.4

The first thing to notice from the lag structure is that IR&D has a faster payoff than other company R&D. Because a large proportion of IR&D efforts are in development activities, one would expect IR&D results to be closer to fruition than applied or basic research. Although we do not know the composition of other company R&D, we suspect that the close interactions between the companies and the DoD would push the IR&D projects closer to current applications than other company R&D.

The second important finding is that the coefficient on weighted IR&D expenditures is only half as large as on other company R&D. Our expectations in this case were confirmed. DoD support encourages firms to do more IR&D than profit maximization in the absence of cost recovery would have induced them to undertake and therefore drives down their rate of return. However, B&P produces about twice as much returns to profits as other company R&D.

To summarize the results thus far, B&P has its greatest payoff on profits in the year in which it is incurred and its total effect on profits is larger than either type of R&D. IR&D shows somewhat shorter-term profit effects than other company R&D, and its marginal effect on profits is in the direction desired by policy and predicted by theory—lower than other company R&D.

We now turn to an examination of the effects of competition and product type on the returns to R&D. These effects (shown in Eq. (2) of Table C.13) were measured by adding two cross-product terms: the percentage of fixed-price, competitive contracts (FPC) times the two R&D variables (I and R) yielding (FPC)(I) and (FPC)(R). The contracts variable (FPC) was also included by itself.

As expected, the cross-product coefficients are negative—the greater the proportion of fixed-price, competitive contracts, the smaller the effects of R&D on profits. Moreover, the IR&D effect on profits is more sensitive to this measure of competition, which is to be expected, because it relates directly to the defense business of the companies. If a company has no fixed-price, competitive contracts with DoD, the influence of IR&D rises to 1.56, compared with the other company R&D effect of 1.93. However, as these contracts increase as a percentage of defense business, the effect of IR&D falls to 0.63 at 25 percent, and to zero at 42 percent.

The declining effect of IR&D on profits from increased proportions of fixed-price, competitive contracts probably arises from competitive pressures and the probable reduction in the ability of contractors to realize the DoD share in the price of their products. Although the evidence for this is circumstantial, it is in full agreement with the views of those closest to the scene, the IR&D negotiators. As stated in a descriptive report on the IR&D process, "The actual impact of any DoD limitation placed on a contractor's IR&D or B&P cost recovery depends upon the types of contracts the contractor holds, the degree of competition involved in the contract awards, and the mix of government and non-government business. . . . In firm fixed price contracts, ceilings set by DoD have a much smaller impact and in many cases none at all. . . . Where a firm fixed price contract is placed on the basis of price competition . . . there is no consideration of elements of cost. Hence ceiling limitations have no impact whatever."[29]

Given this effect of contract type on the profits arising from IR&D investments, we should expect to find a depressing effect of fixed-price, competitive contracts on IR&D itself. However, estimates of this effect show it to be statistically insignificant. These effects are shown in Table C.15, Eqs. (1) and (2), where the contracts variable is entered into the core equation both as a separate variable and as an element of a cross-product with the DoD share. The observations are for the years 1983–1985, which are one year to either side of the year for which contracts data are available. For comparison, Eqs. (3) and (4) present the core equations for this sample without the contracts variables.

We can only offer conjectural explanations of the result that the proportion of competitive, fixed price contracts does not influence IR&D investment even though it affects the profitability of IR&D. Competition may stimulate additional IR&D even though, at the same

[29]Department of Defense, Working Group, *The Independent Research and Development Program: A Review of IR&D*, NTIS AD/A-004 610, June 1974, pp. 9–10.

Table C.15

EFFECT OF FIXED-PRICE COMPETITIVE CONTRACTS ON IR&D

	Eq. (1)	Eq. (2)	Eq. (3)	Eq. (4)
R^2	.991	.991	.991	.991
Constant	−1.64	.546	−1.72	.616
	(.191)		(.208)	(.073)
(I+B)	.487		.466	·
	(.121)		(.175)	
(NI+NB)t-1	.188		.218	
	(.095)		(.127)	
D	.383		.390	
	(.055)		(.070)	
D/S	.150		.054	
	(.095)		(.110)	
(NI+NB)		.492		.555
		(.078)		(.060)
(I+B)t-1		.401		.369
		(.057)		.056
FPC		.132		
		(.211)		
(FPC)(NI+NB)		.130		
		.116		
Long-run e	.60	—	.60	.88
for: FPC = 0		.82		
FPC = .25		.87		
FPC = .50		.92		

NOTES: All variables in logarithms; R^2 adjusted for degrees of freedom; company dummy variables in all equations; standard errors in parentheses; values deflated to 1976; variables are defined in Table C.2, except observations for 1983–1985.

Sample, Cos.
Estimating method, 3SLS.
Observations, 157.
Dependent Variable, Eqs. (1) and (3), (NI+NB); Eqs. (2) and (4) (I+B).

time, it reduces IR&D profitability and the prospects for cost recovery. A second interpretation, and one that is consistent with statements of company IR&D planners and financial executives, is that they essentially treat the negotiated DoD share as money in the bank; that is, they make their decisions on the face value of the amount and not on the expectations of actual cost recovery. In fact, when we raised this issue with contractors, in most cases we found that it was the first time that they had considered the possibility that they may not, in fact, receive the negotiated amounts.

INDUSTRY'S IR&D RESPONSE TO DOD SHARE

We have produced several estimates of industry's IR&D responsiveness to government IR&D support; these have varied by estimating method, by organizational level within the firm, by time period, by the variables included in the estimating equations, by lag structure, and by separation of IR&D and B&P. Such estimates also depend on the value of the ratio of IR&D (I) to DoD share (N) used in the calculation.[30] We can use the ratio of the aggregate values ($\Sigma I/\Sigma N$), the average ratio across observations $\Sigma(I/N)/n$, the median ratio, or any other that may reflect our analytical purpose. To portray the variability of the industry response, in Table C.16 we display the elasticities from the earlier tables together with the ratio of the aggregate values of IR&D to DoD share that is appropriate to the sample on which the equation is based. However, we do not include Eq. (2) of Table C.3, which reports on the division response to division level DoD share, neglecting the effects of total corporate DoD share. It was made only for comparative purposes.

The elasticities range from a low of 0.66 (for 3SLS estimates with defense sales variables in the industry equation and not in the government equation) to 1.10 (for corporate-level estimates of complex companies). The marginal responses vary from 1.66 to 2.39, when evaluated by the ratio of aggregates of IR&D and DoD share.

Alternative marginal responses can also be produced by different methods of forming the ratio I/N. For example, we can use the ratio of aggregates of 2.36 for the entire 17-year period (as in Table C.16), or the average ratio of the entire period of 2.41, or the median ratio for 1985 of 1.61. These different values will produce different marginal responses.

This range of estimates should reinforce the impression that there is no single, true value, but rather estimates that depend on sample, period, estimation technique, and purpose. Nevertheless, we feel confident in claiming an elasticity that is less than 1.0 and more than 0.8 for correctly specified behavior at the corporate level. However, as

[30] Recall that the elasticity $e = (dI/I)/(dN/N)$ and $dI/dN = e(I/N)$ where I = $IR\&D$ and N = DoD share. Not only do we find different estimates of the elasticity, but also different values of I/N.

Table C.16

VARIANTS IN INDUSTRY RESPONSE: ALTERNATIVE ELASTICITY AND SLOPE ESTIMATES

Table (Eq.)	Method	Sample	Other Features	Longrun e	Ratio of Aggregate IR&D to Aggregate DoD Share	Industry Response
1(2)	OLS	Cos	No dynamics	.96	2.36	2.27
1(4)	OLS	Cos	With lag term	1.01	2.36	2.38
1(6)	3SLS	Cos	Baseline estimate	.94	2.36	2.22
1(7)	OLS	Cos	With D, D/S	.96	2.36	2.27
1(8)	3SLS	Cos	With D, D/S	.66	2.36	1.56
3(4)	3SLS	Divs	With corp. DoD share	.84	1.98	1.66
3(5)	OLS	Divs	With corp. DoD share, D/S	.89	1.98	1.76
3(6)	3SLS	Complex	Cos with divs	1.10	2.17	2.39
5(1)	3SLS	Cos	IR&D only (no B&P)	.92	2.58	2.37
5(2)	3SLS	Cos	B&P only (no IR&D)	.89	2.03	1.81
7(1)	3SLS	Cos	With growth in D	.95	2.36	2.24
8(2)	3SLS	Cos	Asymmetrical response	.88–1.00	2.36	2.08–2.36
9(1)	3SLS	Cos	1969–1977 period	.94	2.03	1.91
9(2)	3SLS	Cos	1978–1982 period	.96	2.34	2.25
9(3)	3SLS	Cos	1983–1985 period	.92	2.22	2.04
10(2)	3SLS	Cos	With other corp. R&D	.98	2.26	2.21
15(2)	3SLS	Cos	1983–1985 period	.88	2.22	1.95
15(4)	3SLS	Cos	With % fixed price contracts	.82–.92	2.22	1.82–2.04

with all research results, such findings can be modified by future research and understanding.

SUMMARY OF STATISTICAL ANALYSIS

Industry responds to the cost-sharing nature of government's support for IR&D with an elasticity close to one, and with marginal expenditures of about $2; for an additional dollar that industry receives from the government, it spends an average additional dollar of its own as well as the dollar it receives.

Over the period from 1969 to 1985, both industry's and government's responsiveness has been quite stable. The congressional ceiling has had no measurable effect, at least through 1985 when our data coverage ends.

In a test of whether IR&D was a substitute for other company R&D, which would leave total industry efforts unchanged, we found just the opposite relationship. Other company R&D was positively related to IR&D such that if IR&D rose by $1, other company R&D increased by 48 cents. However, other company R&D had no effect on either the level of DoD support or on IR&D expenditures.

Breaking down IR&D into separate categories of basic and applied research, development, and systems studies, the data showed that development absorbs the greatest share of IR&D manpower (63 percent), it responds proportionately more to a stimulus of IR&D support (its elasticity is 0.91), and its marginal response is also the greatest (27 man-years for an additional $1 million of DoD share). Basic research, in contrast, is the smallest in each of these dimensions with only 1.6 percent of total IR&D man-years, and responding by less than a man-year of additional effort to $1 million of IR&D cost support.

Examination of the effect of IR&D on gross operating profits before taxes shows that IR&D has an expected lower return than other company R&D, mainly because government support induces industry to conduct more IR&D than its profit-making calculations would show to be reasonable. In terms of effects on profits, B&P has the highest returns, other company R&D is half the size of B&P, and IR&D is about half as much as that. The average lag between expenditures and their effect on profits is 5.4 years for other company R&D, 3.5 years for IR&D, and less than one year for B&P. The IR&D influence on profits is sensitive to competition as measured by a company's percentage of fixed-price, competitive contracts. Competition probably works to reduce the R&D payoff directly, but it also hinders the ability of contractors to incorporate the negotiated DoD cost share of IR&D into subsequent contract price negotiations. However, the percentage of a company's fixed-price, competitive contracts did not exert a depressing effect on IR&D investments.

The government's elasticity of DoD share to IR&D is around 0.85, and its marginal response is about 0.35. Industry can therefore count on an average cost-sharing rate of approximately $0.35 on the dollar. The DoD share is not administered as a block grant, or in a manner to maintain a constant overhead rate.

IR&D decisionmaking appears to be located at the company level, whereas government negotiating behavior is directed toward the negotiating unit—company or division. The analysis, therefore, concentrated on the company level for the illumination of industry behavior, and on the negotiating unit level for the government.

Industry treats IR&D and B&P in a similar manner; government treatment is similar at the company level, but at the level of the negotiating unit we find a DoD share elasticity of 0.54 for IR&D and 0.93 for B&P.

DoD support of IR&D therefore encourages more IR&D, more other company R&D, and more product developments tied to future military systems. The marginal profit on IR&D is less than in other kinds of corporate research and development, which demonstrates that the policy is having its intended effect. Companies apparently plan, allocate, negotiate, and execute R&D from a broad corporate perspective, whereas government—in its IR&D negotiations—treats divisions as the key players. Both industry and government require some years to fully respond to each other's behavior and to the external environment.

Policies designed to influence behavior should be aware of the different kinds of incentive effects inherent in alternative policies. The present analytical effort should provide a starting point for the evaluation of future alternatives.

Appendix D

OTHER CURRENT POLICY ISSUES AND QUESTIONS

OWNERSHIP OF IR&D RESULTS

In recent years, the military services have tried to increase the benefits that they receive from IR&D by requiring access to proprietary data developed in IR&D projects. Because IR&D was not performed under contractual arrangement, the developing firm had full rights to proprietary data, but those rights are now being questioned. The Army in particular has been pushing for access rights to any data developed under DoD cost reimbursement.

We cannot comment on the legality of the proposed policy, but we can comment on its probable effects. From our case studies and discussions with corporate IR&D managers, we predict that eliminating contractors' proprietary rights to data will reduce the amount and quality of work performed under IR&D.

If contractors are denied the opportunity to profit from the results, IR&D will be less attractive and they will do less of it. Exceptionally promising projects (and the scientists most likely to produce important discoveries) will be segregated from the IR&D cost-reimbursement pool and funded entirely from corporate sources. As a result, contractors' IR&D portfolios will be smaller and increasingly less technically promising.

DoD negotiators perceive that this is already happening more frequently than it did in the past. As a result, the amount of IR&D performed is reduced and DoD does not have access to the data it sought in the first place.

In many ways, the IR&D cost-recovery process resembles other government programs intended to stimulate private behavior—for example, the investment tax credit to encourage capital investment. We know of no instance of this type of program in which the government takes ownership of the result of the intended private behavior.

SHOULD IR&D COST RECOVERY BE LIMITED TO CURRENT DOD CONTRACTORS?

Under the current system, firms can recover IR&D costs only if they have DoD contracts, and then only in proportion to their DoD business share. Other firms can obtain DoD support through R&D grants and contracts. Some small businesses and private entrepreneurs complain that this arrangement is inequitable, that it creates an inherent barrier to entry into defense business, and that DoD misses important innovations as a result.

A new entrant may be at a competitive disadvantage because the present cost-recovery process generally allows only IR&D costs incurred in the current year to be considered in the IR&D project pool. In reality, the effects of IR&D on profits build up over many years so that investments made three to five years in the past influence today's sales and profits. One way of balancing the advantages to new and old firms would be to permit time averaging of IR&D investments so that past years' investments could enter into this year's base. Such a process could be little different from the current practice of amortizing and depreciating capital costs. Although the amortization of R&D is generally not recommended as an accounting practice, the IR&D regulations could establish such a rule for cost-recovery purposes.[1] In general, though, it is not feasible to provide cost recovery to a company that does not sell to the DoD, which includes every noncontractor company in the country.

Another method of broadening the possible contributions of firms not now selling to the Defense Department would be to increase the use of contracts and grants to such firms. Greater opportunities for entrepreneurs and small businesses may pay dividends. But the elimination of the current IR&D process in favor of such arrangements would have several important costs. New discoveries and technical developments would be less likely to be made by organizations that understood DoD's future weapon needs and knew how to assemble new technologies into functioning defense systems. Furthermore, the total volume of industry R&D would fall because of the loss of the stimulus effects of the present cost-sharing process.

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[1]Accounting standards recommend charging all R&D to current expenses because the high degree of uncertainty as to future benefits does not allow the matching of R&D expenses with specific revenues. See Financial Accounting Standards Board (FASB), Statement No. 2 (FAS 2), Accounting for Research and Development Costs, issued October 1974, paragraphs 37–49.

DOES THE IR&D PROCESS FAVOR LARGER CONTRACTORS?

Some concern has been expressed in congressional hearings that somehow the IR&D cost recovery process favors the larger or more profitable defense contractors so that the "rich get richer" at the expense of the smaller companies. We tried to detect biases in either process or policy that could favor the larger companies. To do this, we looked at three measures that could detect any actual bias in the IR&D process.[2] The behavior with respect to company size was random. Although IR&D has a positive payoff on future profits and is encouraged by government support, because the rate of support is unrelated to company sales, we see no evidence of bias in the process.

Interviews with government and industry representatives did not suggest any tendencies toward favoring the larger contractors. The expressed concerns, therefore, appear to be without merit.

ARE COMPANIES FAVORING B&P OVER IR&D?

Industry representatives and government officials have expressed a fear that industry is increasing its B&P expenditures at the expense of IR&D, to the detriment of the defense technological base. With our detailed data base through 1985 and aggregate data through 1986, we attempted to determine whether there is a *prima facie* case for these concerns. To analyze this issue, we constructed the ratio of aggregate B&P to aggregate IR&D and the median ratio.[3] The analyzed sample included all the negotiating companies and divisions. Results are shown in Table D.1.

The ratio of the totals describes events in terms of the aggregate distribution of resources. The median figure calls attention to typical behavior. For the 18 years of data, both measures show that B&P reached its lowest level relative to IR&D in the years 1982 to 1984. Aggregate data for 1986 suggest a jump in B&P to the levels of the

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[2]The three measures included the ratio of the allowable ceiling to incurred IR&D, the ratio of the DoD share to incurred IR&D, and the residuals from the government equation that related the cost share to IR&D. The residuals were intended to reveal any systematic deviation from expected government behavior. We estimated correlations of these three measures against total company sales and defense sales. For all the cases, the highest squared correlation (R^2) was .04, indicating no detectable relationship across firm size.

[3]Other percentile ratios were examined, but they told the same story as the median. We did not use the average ratio across observations because some extreme outliers sharply bias the average (for some firms with very little IR&D, the ratio can reach a level of 300).

Table D.1

RATIOS OF B&P TO IR&D

Year	Observations	Ratio, Total B&P to Total IR&D	Median Ratio, B&P to IR&D
1969	155	.52	.81
1970	147	.55	.81
1971	141	.62	.94
1972	148	.50	.84
1973	186	.48	.92
1974	204	.47	.87
1975	201	.49	.94
1976	195	.49	.97
1977	187	.47	.88
1978	190	.44	.84
1979	201	.40	.82
1980	209	.43	.76
1981	219	.41	.75
1982	225	.40	.67
1983	236	.39	.66
1984	259	.38	.71
1985	290	.43	.69
1986	339	.49	

mid-1970s, but not as high as seen in the early 1970s. On the basis of this evidence, we do not find that B&P is eating into IR&D expenditures to a worrying extent. However, if procurement budgets should fall, we would not be surprised to see a response in higher B&P commitments as companies scrambled for defense business. The earlier periods of high B&P were associated with stable or declining procurement. Of course, DoD policies could exacerbate this trend, but an acceleration of B&P spending is not disclosed by the available data through 1986.