MAINTAINING TECHNOLOGICAL LEADERSHIP:
The Critical Role of IR&D/B&P

Aerospace
Industries
Association

FOREWORD

Independent Research and Development (IR&D) and Bid and Proposal (B&P) efforts form the cornerstone of aerospace and defense technology advancement. Without industry sponsored IR&D/B&P, our nation would be unable to maintain its superiority in weapons systems design, development and production.

This white paper, prepared by the Aerospace Industries Association, explains the critical role that IR&D/B&P plays in maintaining our technological leadership and focuses on the need to recognize that industry can no longer unfairly subsidize the cost of this most important asset. IR&D/B&P, like other overhead costs, should be treated as a normal cost of doing business, and the government should not restrict the allowability of these costs in contract pricing. Through greater understanding of the issues as well as the benefits associated with IR&D/B&P, we should be able to dispel the misconceptions and develop an appropriate national policy regarding IR&D/B&P.

We are grateful to those companies and individuals who have unselfishly given of their time and resources to produce this paper.

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EXECUTIVE SUMMARY

American technological preeminence is eroding. Increasing international competition poses a threat to our industrial leadership, our ability to compete in the global market, our domestic economy, and our national security.

Given our potential adversaries' ability to mount military forces numerically superior to those of the free world, a major underpinning of the U.S. strategy for national security is the ability to field forces that are technologically superior. The ability to meet this challenge is directly dependent upon our defense industry's continuous emphasis on the development of advanced technology. Through Independent Research and Development (IR&D) and Bid and Proposal (B&P) effort, in conjunction with government-funded research and development efforts under contract, industry is devoted to sustaining this technological lead. Unlike government-funded R&D efforts under contract, however, IR&D/B&P is initiated and paid for by industry.

IR&D is a vital element in efforts of the aerospace and defense industry to focus on the technologies that are essential to our future industrial competitiveness and security. A 1988 AIA survey found that half of industry's efforts to develop nine key aerospace technologies for the 1990s were conducted under IR&D.

The inherent strength of IR&D/B&P is that it is a natural expression of our open market economy. It offers significant benefits that complement the R&D contracted for and managed by government agencies.

- IR&D/B&P is flexible. It enables quick reaction to changing technology unencumbered by the constraints of contracted R&D.
- IR&D/B&P is efficient. A bottom-line imperative ensures that IR&D is targeted at projects that have realistic prospects of success.
- IR&D/B&P supports competition and is, therefore, cost-effective. It encourages alternative solutions to government needs, which generates competition.
- IR&D/B&P fosters innovation. Contractors focus on projects in which their expertise, competitive strength, and customer needs uniquely intersect.

Because of these inherent strengths, IR&D/B&P has made fundamental contributions to virtually every major technological development in the aerospace and defense fields. From broad areas such as computer miniaturization and laser technology, to specific weapons systems, IR&D/B&P has played an essential role.

Despite the many advantages afforded by IR&D/B&P, the government, for reasons inconsistent with the real concept of IR&D/B&P, limits the IR&D/B&P costs that each contractor may include in contract prices. Limitations on IR&D/B&P costs are often based on the mistaken belief that IR&D is different from commercial R&D. Contrary to common misconceptions:

- IR&D/B&P is *not* directly funded by the government. It is paid for by contractors and allocated proportionately to all customers, including the government, as a part of overhead costs. However, the government imposes a ceiling which limits the amount of its allocation.

- IR&D/B&P is *not* a subsidy to industry. In current practice, it is a subsidy by industry of our national aerospace and defense efforts.

- IR&D/B&P is *not* an "extra" cost. It is an essential activity for industry. To remain viable, a company must invest in its future.

- IR&D/B&P costs *are* controlled. In an increasingly competitive environment, companies must carefully assess costs when setting IR&D/B&P budgets. Companies make such decisions with close scrutiny and control.

- Smaller businesses are *not* excluded from IR&D/B&P. In fact, they are not subject to costly and restrictive advance negotiations on IR&D/B&P costs. Therefore, they have an advantage over larger contractors.

The aerospace and defense industry must maintain its technological leadership. It cannot do so if the costs of IR&D/B&P are not recognized in the pricing of products. According to the Defense Science Board, "Reductions in contractor IR&D spending can have serious future impact on our ability to provide our military with the technically superior weapons they require."

The following actions are recommended:

1. Leadership must continue to come from the highest levels of government in advocating a strong commitment to IR&D/B&P. The consistent support of key executives within DoD and the Services is crucial.

2. Industry should be able to allocate to government contracts their full share of actual IR&D/B&P costs without ceiling limitations. Industry and government should work together to develop transitional steps designed to achieve this goal under the framework of existing laws.

3. The government should streamline and standardize administrative requirements associated with the IR&D/B&P negotiation and technical review processes.

We in the aerospace and defense industry are prepared to work with the government to maintain strong IR&D/B&P programs so that we can maintain our technological leadership. We view this as a team effort with much to be gained by both the government and industry.

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INTRODUCTION

The national security of the United States, now and in the future, is a question of numbers. Unlike our potential military adversaries, however, the key numbers are not troops and guns; more important to the United States is the number of ideas explored, researched and rejected, pursued or developed. The defense strategy of the United States is based on leveraging technology to offset the numerical superiority of our adversaries. Our security depends not only on manpower, but brainpower. It has for several decades.

A memorandum from the Office of the Chief of Staff of the War Department, dated 30 April 1946 and signed by Dwight Eisenhower, stated, "The efforts of the last war are clear....The armed forces could not have won (it) alone. Scientists and businessmen contributed techniques and weapons which enabled us to outwit and overwhelm the enemy." Brainpower was a critical factor for the U.S. in World War II, and will continue to be in the future.

United States defense and space agencies currently capitalize on efforts of America's scientists and businessmen in two ways:

1. Research and Development (R&D) is conducted by DoD in its own research facilities and purchased through contracts and grants awarded to companies, universities and independent laboratories. This R&D is performed under terms and conditions specified by the military services. It is a line item in the defense budget known as Research, Development, Test and Evaluation (RDT&E).

2. Independent Research & Development (IR&D) is independently initiated, controlled and financed by individual companies. IR&D covers the full spectrum of R&D activities, including expansion of basic knowledge, exploitation of scientific discoveries, improvement of existing technologies and creation of new ones. Closely linked to IR&D is the Bid and Proposal (B&P) effort, by which contractors, at their expense, develop and support specific technical bids and proposals, solicited and unsolicited, to potential customers. The B&P effort is usually directed specifically toward detailed technical requirements spelled out in requests for proposals (RFPs). IR&D/B&P is not a line item in the defense budget. It is a component of a company's overhead expense.

Contracted R&D is a well-understood concept. IR&D/B&P is not. This paper will fully explain what IR&D/B&P is, how it works and why it is important to our national security.

Overhead consists of the normal costs of running a business — electricity, heat, facilities, administration, etc. — that cannot be attributed to a single contract or project. These normal costs of running a business are included in the prices of products a company sells, regardless of customer.

IR&D/B&P is considered a normal and necessary cost of doing business too, with one significant difference from other overhead costs: the government places a ceiling on the combined IR&D/B&P costs that a contractor can allocate as overhead to government contracts, regardless of what the contractor actually spends. In 1972, the Government Procurement Commission made the following recommendation: "Recognize in cost allowability principles that IR&D and B&P expenditures are in the Nation's best interests to promote competition (both domestically and internationally), to advance technology, and to foster economic growth. Establish a policy recognizing IR&D and B&P efforts as necessary costs of doing business."

This paper is based on three fundamental principles:

1. IR&D/B&P is essential to our national security and economy;

2. IR&D/B&P is a necessary complement to contracted R&D; and,

3. The IR&D/B&P costs incurred by industry are necessary costs of doing business and industry should be able to include those costs through overhead in the prices of products sold to all customers.

These principles are not, however, embraced by all. IR&D/B&P has come under periodic attack from the government and debate continues over the extent to which industry should be able to include its IR&D/B&P costs in the prices of products sold to the government.

To maintain our technology edge — and reap the security benefits we have consequently enjoyed — we must chart a prudent course into the future. But to make wise choices requires understanding of the role and the benefits of IR&D/B&P.

Section I of this paper explains the importance of IR&D/B&P.

Section II outlines the history of IR&D/B&P, the misconceptions that have shaped the debate over IR&D/B&P, and the current administrative process.

Section III addresses the impact on our defense agencies, the aerospace and defense industry, and the nation of the decisions that must be made.

Finally, Section IV, recommends a course of action.

The positions taken in this paper complement those expressed by the Defense Science Board Independent Research and Development Subgroup as stated in Appendix IV of "The Final Report of the DSB 1988 Summer Study on the Defense Industrial and Technology Base." Industry strongly endorses the conclusions of that paper and recommends it to those who wish to investigate this subject further.

SECTION I

The Value of IR&D/B&P

IR&D/B&P is vital to the security strategy of the United States and to a robust, competitive American economy. Both our security strategy and our industrial competitiveness are based in technology. Through IR&D/B&P, industry pushes the frontiers of technology. Advanced concepts are explored, new processes perfected, new products created.

IR&D/B&P is, for each company, an investment in its future — its future capacity to meet needs of customers and to make a profit by meeting those needs more effectively and efficiently than its competitors. And as such, each company's IR&D/B&P costs are scrutinized rigorously in the harsh and demanding light of business survival.

For the government, IR&D/B&P represents the avenue by which it receives the best ideas of industry and industry's best judgment as to the possibilities of technology for defense applications. The Defense Science Board's 1988 Final Report on The Defense Technology and Industrial Base included the following assessment in Appendix IV - Independent Research and Development:

> *. . . the competing technical solutions offered by industry provide DoD with options on the form as well as the details of the solution. These options give DoD the ability to choose the best technical solution within the budget constraints it faces. It is these options which are the product of IR&D.*

In addition, IR&D/B&P provides the government a means of increasing competition and enables contractors to develop technological processes that can reduce prices.

The fruits of free enterprise

IR&D/B&P is a natural manifestation of both our form of government and our economic system. The government is not in the business of running businesses; rather, it purchases products on the open market and behaves as other consumers in shopping for the best product at the best price.

Companies compete for that business, which means that over time they must improve existing products, create new products to meet new needs, lower prices, or do all three to remain competitive. The primary way to accomplish any of those objectives is to invest in research and development. Through company-funded R&D, or IR&D, scientists and engineers focus their efforts on what they know best, on projects where their expertise, their competitive strengths, and their customers' current and future needs uniquely intersect.

In this important respect, IR&D is the vehicle that creates for our defense and space agencies the best ideas and products industry can develop. As long as the government continues to turn to industry to purchase products, it implicitly requires its suppliers to invest in IR&D in order to remain competitive.

B&P is an integral part of this competitive process. Contractors prepare and submit detailed proposals that lay out the technical worth and quality of their bids, which provide government agencies complete and comprehensive information as a basis for selecting a contractor. B&P therefore supports both technical and price competition in response to government requirements. As product designs improve and prices drop, the government benefits.

B&P costs incurred by aerospace and defense contractors have increased significantly since the passage in 1984 of the Competition in Contracting Act which led to a dramatic increase in the number of competitive requests for proposals. As a result of increased competition since that time, the military services have reported savings of hundreds of millions of dollars.

A necessary complement to contracted R&D

The value of IR&D/B&P cannot be measured, however, only by the fact that it is a natural, efficient expression of our economic principles. IR&D, in particular, also plays a vital and specific role in the development of technology for our defense, because it is a necessary complement to contracted R&D that is managed by government agencies.

Because of its characteristics, IR&D has been a primary factor in virtually every major advance in aerospace and defense technology in the past 40 years. From rockets to radar, computers to composite materials and integrated circuits, IR&D has helped shape current aerospace and defense technology.

1. IR&D is flexible because it is independent.

IR&D enables quick reaction to changing technology or windows of opportunity. IR&D can be quickly initiated, terminated or redirected, which makes it more responsive to new technologies and to anticipated changes in customer needs. Company management decisions are unencumbered by the formality and procedural constraints surrounding contracted R&D.

2. IR&D is efficient.

Each company targets its IR&D at specific situations and problems in which it has unique expertise or competitive strengths. Kodak's IR&D in sophisticated photo-optical systems provides a good example. In a competitive economy, each company's IR&D must eventually lead to products from which that company can profit. This bottom line imperative ensures that IR&D is targeted carefully at projects that have realistic prospects of meeting customer needs. IR&D investments must be managed as efficiently as any other for acceptable return in the private sector.

3. IR&D supports competition and is, therefore, cost-effective.

Because companies explore their individual approaches to long-range government needs in advance of development contracts — as Boeing did with complex avionics systems for the B-52 and Rockwell did with flight control systems on the KC-135, C-141 and C-5 transport aircraft — alternative technical solutions are developed and meaningful competition is encouraged among contractors. IR&D provides for a flow of ideas, which may improve the customer's mandated performance and system characteristics and lead to more cost-effective solutions.

4. IR&D fosters innovation.

IR&D invites and encourages new, innovative concepts often contrary to conventional wisdom. Both industry and DoD are constantly seeking breakthroughs — radical departures from existing technology — resulting in dramatic benefits. IR&D often creates these breakthroughs. Contracted R&D, on the other hand, usually builds on these breakthroughs to develop working systems. With IR&D, industry's scientists attempt to expand the courses of technology and meet the anticipated needs of our defense and space agencies. Such was the case with

Northrop's IR&D in new boron fiber/epoxy resin for aircraft structures that has permitted weight reductions in the F/A-18A aircraft by up to 30%.

Moreover, a company's IR&D programs attract and hold innovative people because good ideas can be promptly funded and explored. Through IR&D, scientists and engineers can pursue their own visions — of aircraft that avoid radar detection, of helicopter rotors without bearings — novel and unorthodox as they may be, under the critical, informed review of management.

What has IR&D produced?

IR&D has played a vital role in virtually every major development in aerospace and defense technology. It has contributed to the most advanced defense systems in the world and to our space exploration efforts. It has also developed technologies that have changed the way we live. IR&D has led to breakthroughs in computer miniaturization, integrated circuits and laser technology, all of which have benefited our aerospace and defense programs, but also have been broadly applied throughout society.

Three examples of quite different products created and developed through IR&D: Honeywell's Ring Laser Gyro (RLG); Texas Instruments' Forward Looking Infrared System (FLIR); and the F-16 developed by General Dynamics, are described briefly in the following paragraphs.

The RLG demonstrates the broad applicability and specific benefits to our defense of a single intensive IR&D project. The FLIR represents an IR&D initiative that was at first rejected by DoD for lack of an existing requirement, but eventually became a required permanent sensor. The F-16 has numerous significant capabilities that were made possible by many IR&D projects that came together in one complex system. These examples are representative of thousands of successful IR&D projects that have changed dramatically the world of aerospace and defense technology.

Honeywell's Ring Laser Gyro

The effort applied by Honeywell to the ring laser gyroscope (RLG) is a clear illustration of the innovation that can occur with IR&D investment. A revolutionary capability was developed for guidance, navigation, position and control applications based on a new principle, using laser beams instead of a spinning wheel or a vibrating part. Uses for the RLG have proved even broader than initially anticipated. The RLG is now used on a wide variety of commercial and military aircraft, missiles, and even on howitzers to increase their accuracy and survival rate.

Honeywell's RLG and System Applications

Current Military

H-423 LINS (F³)
USAF Standard Navigator

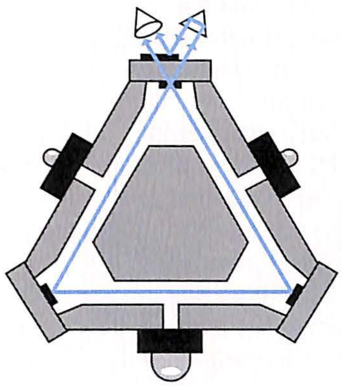
- F-4
- F-111
- C-130
- A-7
- MH-53J
- OV-1D

H-770 LINS

- F-15E
- F-15A-D
- Upgrades

Modular Azimuth
Positioning System
(MAPS)

- M-109 HIP
- U.K. Warrior
- AGLS



Commercial

- Boeing 737
- Boeing 747
- Boeing 757
- Boeing 767
- Airbus A-310
- Airbus A-320

New Military Systems/Applications

Integrated Flight
Management System
(IFMS)

- Advanced Aircraft
- Missiles
- Unmanned Vehicles
- Standoff Weapons

H-764 Small Common
Inertial Navigation System

- Small, Low-Cost INS for Next Generation Aircraft

- JAS-39
- F-16
- C-17
- Army TACMS
- FRG F-4
- Transall
- LHX
- AIWS
- UAV
- Sea Lance
- MSOW
- AH-64
- A-12
- ATF

Figure 1: Honeywell's Ring Laser Gyro, a revolutionary guidance, navigation and control system developed through IR&D, is now used in a wide variety of commercial and military aircraft, missiles and vehicles.

Honeywell's independent research began in 1965 and was funded initially by tens of millions of dollars in corporate investments. Many new principles and algorithms had to be developed to change this system from a laboratory curiosity to a practical device. Research addressed reducing instabilities and drift, rapid feedback to optimize performance, and mirror factors to enhance the gyro life. Additionally, a large number of detailed methods and processes were established to allow the RLG to be produced efficiently and effectively.

The RLG is an example of the synergy that can exist between commercial and military sectors through IR&D. Honeywell's IR&D led to commercial production at a volume that enabled Honeywell to continue improving the RLG while lowering costs. As performance and reliability improved and costs dropped, the military reaped the benefits.

The RLG is ten times more reliable than the conventional gyros it replaces, has a five times faster warm up which is critical for rapid takeoff of aircraft, and it has a high immunity to G forces and shock, which are important in missiles. Recent IR&D efforts have led to a major size reduction, while maintaining the same performance capabilities. For applications in missiles, RLGs are now the size of a quarter.

Texas Instruments' Forward Looking Infrared System (FLIR)

One of the most successful target detection systems has been the FLIR system. This electronic infrared (IR) system resulted in large part from Texas Instruments' IR&D programs beginning in 1962. FLIR makes it possible to deliver weapons and provide surveillance at night and under poor visibility conditions by providing a continuous real-time TV-like display of terrain and targets, using a completely passive IR sensor and optics system.

Initial concepts for the FLIR system were formulated and feasibility demonstrated in TI's IR&D programs in 1962-63. The first FLIR system was based on many key developments from IR&D, including mercury-doped germanium IR detectors, a multi-beam CRT display and a complex mechanical scanning optical system.

TI's initial unsolicited proposal to the Advanced Research Projects Agency in 1963 for FLIR funding was rejected due to lack of existing requirements for an IR sensor of this type. Ultimately, TI convinced the Air Force Avionics Lab to initiate a competitive FLIR feasibility demonstration program in 1964. By 1967, an improved system had been developed and flight-tested with company funding. Because initial development, problem solutions and flight testing had been conducted under IR&D, TI was able to propose and accept award of a quick-reaction contract for limited production of FLIRs later in 1967 for installation on gunships in Southeast Asia. Five years of IR&D effort led to this significant breakthrough.

The success of the FLIR in combat led to a DoD letter to industry in 1972 acknowledging the establishment of FLIR as a permanent sensor requirement in DoD, and requesting industry to determine concepts which could reduce production costs to affordable levels for multiple applications in effective deployment quantities. In response, TI initiated IR&D programs to develop a common module FLIR concept. Today, FLIR systems are operationally deployed worldwide by all U.S. military services.

General Dynamics' F-16

General Dynamics' F-16 aircraft demonstrates the scope of IR&D investments. GD's IR&D investment related to the F-16 began in 1968 and continued through the prototype program in 1974 and 1975. IR&D investment has continued as part of the constant search for technology to enhance supportability, survivability and performance. The accompanying illustration shows a few of the numerous technologies that were studied and stretched to produce an aircraft superior to any in the sky. The F-16 provides one example of the value and importance of the technical expertise that resides within just one company among

F-16 Innovations Developed Through IR&D

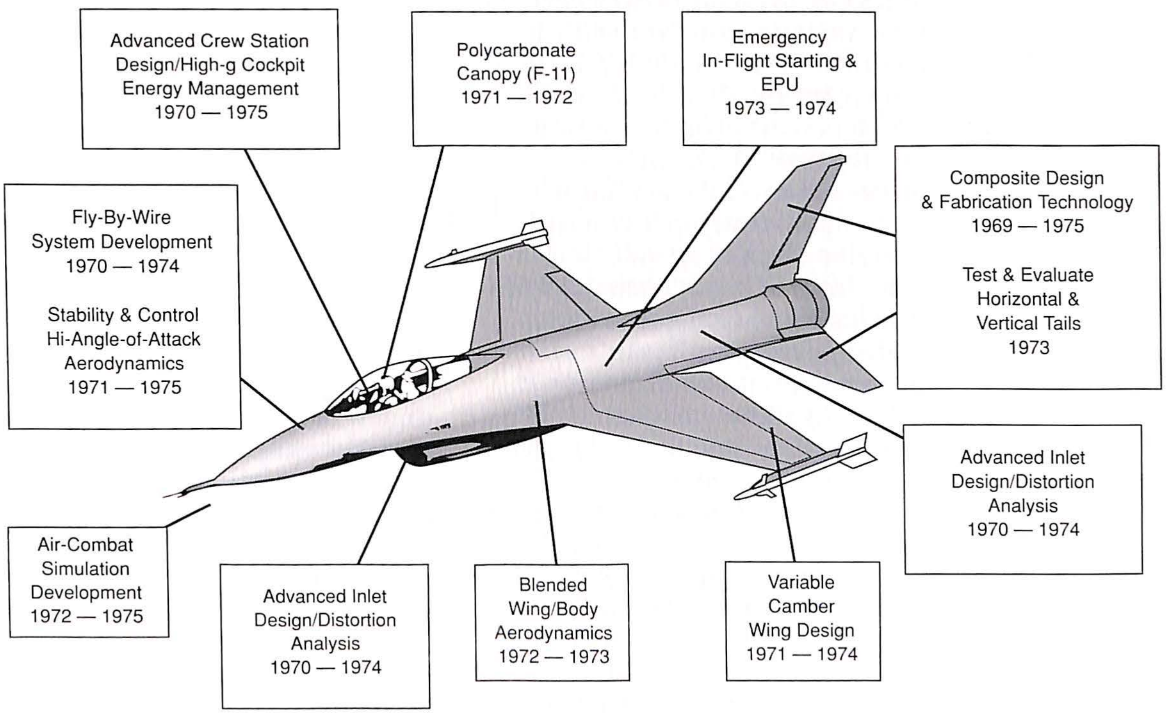


Figure 2: Many IR&D investments by General Dynamics contributed to the development of the F-16. A few of the numerous technologies that were studied and stretched to produce the F-16 are noted

aerospace and defense contractors. Without IR&D, that expertise may not be available for our national defense.

For many additional examples of the contributions of IR&D, see the Appendix or "National Benefits of IR&D" published in 1988 by the Aerospace Industries Association. The examples provided in that publication demonstrate the diversity of IR&D projects. They also indicate the scope of IR&D, from basic research through technology development and technology integration to system applications — a range of activity that only industry is capable of performing. Regardless of where fruitful research begins, whether in universities, government labs or industry labs, industry must understand it and work with it so that the full benefits of that technology can be incorporated into effective products.

SECTION II

Controversy over IR&D/B&P: History and Current Practice

Despite the many significant benefits derived from IR&D/B&P, it has periodically been a subject of debate. At issue is the extent to which the government will allow contractors to include IR&D/B&P with other overhead costs in the prices of their products. At the present time, the government places limits on those IR&D/B&P costs significantly below what industry actually spends.

In times of crisis, such as World War II and when we rose to the challenge of Sputnik, the government has been more willing to allow the costs of investigations into technological possibilities as a part of contractors' overhead. The trend in recent years, however, has been to place increasingly greater restrictions on IR&D/B&P allowability.

While the technological challenge facing the United States now does not have the potent rallying power of a Sputnik, it poses perhaps a more pernicious threat. We now face not one, but many nations with rapidly increasing technological capabilities. Should we lose our technology edge now, we may not be able to recover as quickly and forcefully as we did when we were startled to find that we would be, at best, the second nation into space.

The evolution of IR&D/B&P

The issue of IR&D/B&P costs was first raised when our nation's industries were called on to respond in the time of greatest need. The earliest attempt to define contractors' research and development costs was in 1940 just before the nation plunged into World War II. Treasury Directive 5000, issued in 1940, addressed what costs could be recovered by military contractors in their pricing.

The acquisition emphasis at the time was not on who could provide equipment and supplies at the best price, but which companies had the capacity and the know-how to develop and produce them immediately. The prices paid for that equipment, when competitive bidding was an unaffordable luxury, were based on what they cost to produce, plus a fair measure of profit. Cost was the primary factor in price. Logically, R&D was identified as a reasonable and legitimate component of contractors' costs.

In 1949, however, greater limitations were placed on industry R&D costs through revisions to the Armed Services Procurement Regulation (ASPR). General research, unless specifically provided for in a contract, was considered a cost which DoD would not allow contractors to factor into prices.

In the aftermath of Sputnik, the 1959 revisions to the ASPR recognized the allowability of both independent research and independent development to the extent that they were reasonable and allocable. The cost of research was to be allocated to all work of a contractor, and the cost of development was to be allocated to the product line to which it applied.

The revisions established for the first time a standard of "reasonable" cost, review of a contractor's IR&D program to determine the allocable costs, and the practice, although it remained optional, of negotiating advance agreements on maximum dollar limitations and the share of a company's total IR&D costs that could be allocated to the government. The 1959 revisions, while recognizing the importance of IR&D to the government, attempted to place controls on the costs that could be allocated to the government.

The 1959 revisions were debated extensively for the next ten years. The debate focused on appropriate means of classifying research costs as opposed to development costs, and allocating burden (additional overhead costs) to IR&D. High level groups in DoD and GAO worked on the problem. None of the myriad proposals for revision of the cost principles was implemented before Congress intervened in 1969-1970. In October 1970, Congress passed legislation that established guidelines for allocating IR&D/B&P costs.

Public Law 91-441, the Military Procurement Authorization Act for FY71, remains in effect, with minor exceptions, in the form it was passed. P.L. 91-441 requires:

- Advance agreements on allowable IR&D and B&P costs (i.e. ceilings) for contractors allocating to DoD contracts IR&D/B&P costs above an annual threshold ($4.4 million for a contractor or $550,000 for an operating unit of a firm), with a penalty of substantial reductions in allowability if an advance agreement is not made;
- Technical evaluation of IR&D work by DoD; and
- A determination by DoD that IR&D projects have a potential military relationship (PMR) to the extent that costs are allocated to defense contracts.

From FY83 through FY88, Congress also established ceilings on the total amount of allowable IR&D/B&P costs. These ceilings provided the limits within which DoD had to negotiate advance agreements with individual contractors. Congress did not impose an IR&D/B&P ceiling for FY89, but DoD established its own ceilings for the purpose of negotiations with contractors.

The changing environment

As the decisions described were being made, aerospace and defense contracting was also evolving. Some of the key conditions that led to concern over contractor costs as they affected prices were ameliorated.

1. The contracting environment changed substantially. DoD acquisition policy moved away from cost-reimbursement contracts, and fixed-price contracting became much more prevalent. Today, 80% of contract dollars are awarded under fixed-price contracts, which has shifted cost risk from the government to industry.

2. The Competition in Contracting Act of 1984 required far more competition for government contracts than existed previously. This has resulted in an increase in competitive DoD procurements from 45% before the Act to nearly 60% in 1988.

3. Government procurement policy reforms increasingly crowded out capital available for investment in IR&D/B&P. Reforms that limit contractor ability to fund IR&D/B&P investment requirements include:

- Increasing contractor inventory carrying cost requirements for cost sharing and fixed price contracting on high-risk development contracts;

- Reductions in attainable profit margins under a revised profit policy; and,

- Changes in cost principles that limit allowability of normal costs of doing business, such as travel and legal fees.

Greater price competition and an increase in fixed-price contracting together have reduced the need for government to control and regulate costs; the marketplace does it more effectively and less expensively.

At the same time, however, another change has occurred that makes government limits on IR&D/B&P costs more than unnecessary, it makes them potentially dangerous.

The technological pre-eminence of the United States has diminished as other nations have become more technologically competent. If the aerospace and defense industry cannot include a fair share of its IR&D costs in prices of products sold to its largest customer, industry is penalized even as it must compete more aggressively around the world and perform on the technological frontier at home. In such a technological environment, the aerospace and defense industry cannot compete on balanced terms if it must carry the burden of conducting IR&D under the present practice.

Further, as pointed out in the Defense Science Board 1988 Summer Study Report, procurement practices emphasized in the last few years, such as second sourcing, multi-phased competitions, complex procurements with leader-follower arrangements, and stretched source selection cycle times with multiple Best and Final Offers (BAFOs,) all lead to increased B&P investments. As IR&D/B&P ceilings are reduced, industry tends to favor B&P efforts over longer term IR&D efforts in order to maintain its business base. Advanced technology studies, represented by IR&D, suffer.

Misconceptions of IR&D/B&P have fueled debate

The extended, often heated, debate over IR&D/B&P has been fueled in part by a persistent lack of understanding. Discussions of IR&D/B&P have often become mired in misconceptions, based on the mistaken belief that IR&D is somehow different from commercial R&D.

R&D is highly praised in the commercial world, but as soon as it is called IR&D it is criticized. When a company takes on the government as a customer, the company's R&D is no longer lauded as one of its visionary strengths, but suspected to be a boondoggle. In fact, the process of R&D and its value to customers is the same regardless of who the customer is. R&D does not undergo a sudden transformation the moment a company makes a sale to the government. For example, TRW's IR&D in micro-electronics manufacturing, which led to speeds of seven million characters a second in high speed data searches, is no less important (and was no less costly) just because DoD could use it for signal intelligence collection and analysis that was 16 times faster than previously possible and at one-fourth of the hardware cost.

In the commercial world, companies routinely factor R&D into the cost of getting products to market and, consequently, the prices they charge. And no one questions the practice. It is considered not only an acceptable, but a *necessary* cost of developing competitive products.

Knowledgeable consumers assume R&D costs are one of many factors that go into the pricing of products. They do not judge products or prices based on research and development costs; they consider only whether they are getting a good product at a competitive price. While consumers do not ask for a breakdown of R&D costs, they select products that incorporate the latest technological developments, which are the results of R&D. In other words, they expect and, by their choices, demand R&D, even when they do not consciously attribute part of the price to R&D costs.And they are willing to pay for it.

Other misconceptions of IR&D/B&P center on questions of funding and control of costs. Contrary to common misconceptions:

1. IR&D/B&P is *not* directly funded by the government

Perhaps the greatest obstacle to serious discussion of IR&D/B&P and its vital role in the security of the United States is the mistaken perception that it is directly government-funded. IR&D/B&P is not offered for sale. As a customer, the government neither buys IR&D/B&P as a commodity, nor subsidizes industry's IR&D/B&P. Rather, it buys goods and services priced to include a proportionate share of the contractor's costs — including IR&D/B&P.

DoD did not, for instance, pay Westinghouse to conduct IR&D in ultralow sidelobe antenna arrays for ground-based radar. But when Westinghouse independently developed the technology to enhance radar system performance through reduced clutter, reduced sensitivity to obstacles and reduced vulnerability to jamming, it included some of the cost of its research in the prices of its products.

IR&D/B&P cannot, therefore, be compared with government contracted R&D, which is directly funded.The government writes no checks to contractors for IR&D/B&P; instead, the government allows a contractor to include in prices a portion of its IR&D/B&P costs, *if and when* the contractor makes a sale to the government.

2. IR&D/B&P is *not* a subsidy to industry

The government does not subsidize IR&D/B&P. On the contrary, industry is penalized by not being able to include in government contract prices a proportionate share of contractors' actual IR&D/B&P costs. IR&D/B&P is a subsidy by industry of our national aerospace and defense efforts. Limitations on allowable IR&D/B&P costs require industry either to return less money to its shareholders, reduce its IR&D/B&P investment or raise prices to all non-government customers. Any of these actions makes the company less competitive in domestic as well as international markets.

To mandate that one customer will enjoy a preferred position unfairly discriminates against all other customers. It is particularly unfair when a single customer is in the position to enact such a mandate for its own benefit. In effect, the government has placed an additional burden on its suppliers that, of economic necessity, is passed on to shareholders and other customers.

3. IR&D/B&P is *not* an "extra" cost to the government

IR&D/B&P is an essential activity for industry. To remain viable in a competitive environment, a company must invest in its future. That investment represents a cost of being in business and staying in business. Every customer of the company bears part of the cost and enjoys the benefits of that investment. As a customer, the government should also bear part of those costs, in the same proportion as any other customer. In fact, because government will not accept its full share, IR&D/B&P costs represent not an extra charge to government, but a discount.

4. IR&D/B&P costs *are* controlled

Much of the debate on IR&D/B&P policy has focused on the degree to which government can control IR&D/B&P costs. While controlling costs is a legitimate concern of DoD and Congress as the stewards of public money, the debate assumes that without direct control by DoD there would be no control at all on industry's expenditures. It is an assumption that ignores the reality of the marketplace.

Each company evaluates what it must do to remain technologically competitive in the future, and balances the associated costs against the potential return. Especially as aerospace and defense contracting has become more competitive in a substantially fixed-price environment, companies must carefully assess their competitive costs when they determine their R&D budgets. If they spend too much on R&D, they must accept lower rates of return or raise their prices to uncompetitive levels. And if defense contractors do not win contracts, they get *nothing* from their customers for their IR&D/B&P or any other cost. If they spend too little, they risk being left behind technologically and losing contracts to companies with more aggressive IR&D/B&P policies. No company can afford to make such decisions without careful scrutiny and deliberation.

Smaller Businesses Benefit From Formula vs. Negotiated Ceilings

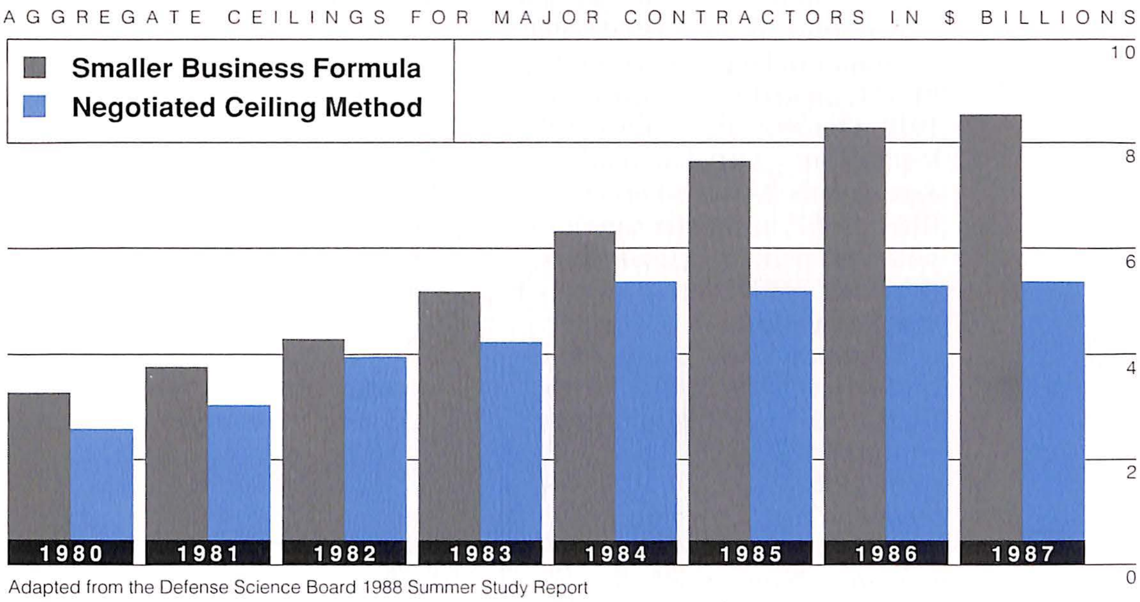


Figure 3: Application of the smaller business formula would have resulted in higher ceilings than the actual negotiated ceilings for major contractors.

5. Smaller businesses are *not* excluded from IR&D/B&P

Smaller contractors actually have an advantage over large contractors in the IR&D/B&P process. The allowable IR&D/B&P costs for smaller businesses are not subject to advance agreements required by P.L. 91-441, nor are they subject to overall DoD IR&D/B&P ceilings. Allowable IR&D/B&P costs for businesses that do not meet the threshold of P.L. 91-441 are determined by a formula. The formula generally allows smaller businesses a higher percentage of their IR&D/B&P costs than larger contractors are allowed. To illustrate this point, Figure 3 shows the increase in ceilings that major contractors would have achieved if they had been able to use the same formula applied to small contractors.

Moreover, smaller businesses are not subject to the lengthy, time-consuming and expensive advance agreement negotiation and technical review processes.

SECTION II

Current administration of IR&D/B&P

Administration of IR&D/B&P continues to be governed by P.L. 91-441, passed by Congress in 1970. The basic provisions of that legislation — negotiated advance agreements, technical reviews of IR&D/B&P, and determination of potential military relationship (PMR) of IR&D/B&P projects — remain in effect.

The paragraphs below, which outline the administration of IR&D/B&P, point out industry's concerns with the process. This is done in the hope that short-term steps can be taken to improve the system even while the larger issue of achieving full allowability of IR&D/B&P costs is being addressed.

The advance agreement negotiations establish a ceiling, or the maximum IR&D/B&P costs, that the government will recognize in each contractor's overhead for both commercial and government sales.

The percentage of the contractor's business with DoD then determines DoD's "share," or percentage of the ceiling that is allocated to DoD as part of overhead costs on contracts. The "share" is a direct result of the contractor's mix of DoD and other business.

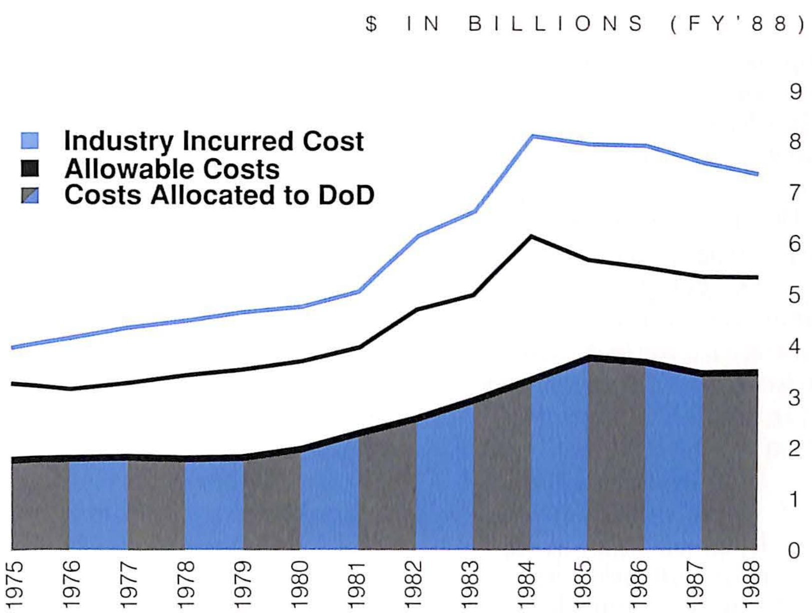
This approach would be reasonable if the starting point, the ceiling, were based on a contractor's "actual" IR&D/B&P costs. But it is not. On average, the ceilings negotiated by DoD recently have been less than 75% of the IR&D/B&P costs incurred by industry. In other words, government is getting billions of dollars worth of "free" R&D from industry. In fact, DoD has access to $2 worth of IR&D/B&P for every $1 included in defense contract prices.

Figure 4 illustrates this point by showing industry-wide IR&D/B&P incurred costs, allowable costs, and the amount allocated to DoD for each year back to 1975. The recent downturn in industry spending (in FY 1988 dollars) is due to ceiling restrictions beginning in 1985.

Further, each of the three services uses different standards and criteria in negotiating IR&D/B&P advance agreements. The result is inequitable treatment of contractors. Specifically, in FY 1988, it is understood that there was a 10% difference in cost allowability (represented by the ceiling as a percent of planned costs) between the average contractor negotiating with the Air Force compared with the Army, and a 5% difference between the average contractor negotiating with the Air Force versus the Navy.

Technical reviews of each contractor's IR&D projects are conducted annually through submission of Technical Plans or

IR&D/B&P Expenditure and Allowable Cost Trends



Source: DCAA Annual Report to Congress

Figure 4: IR&D/B&P costs allocated to DoD represent only about one-half of industry's actual incurred costs. Continued restrictions on allowable IR&D/B&P costs lead to reduced industry investment.

"brochures" and by on-site reviews every third year. On the positive side, on-site reviews provide government scientists and engineers access to the full range of industry's IR&D and serve to cross-fertilize thinking on advanced technical problems. These reviews provide industry with direct government perspective on future systems requirements and allow interactive discussions of contractor IR&D plans. On the negative side, the brochures require an inordinate amount of time and expense for both government and industry. A large company's annual brochure typically totals between 7,000 and 10,000 pages. The cycle of reporting and review often takes over a year to complete at an annual cost to industry estimated to be over $200 million and consumes thousands of hours of engineering talent.

In addition, each contractor's IR&D/B&P program is reviewed for Potential Military Relationship, which requires preparation and submission of two additional reports annually.

SECTION III

IR&D/B&P: Looking Down the Road

IR&D/B&P is industry's primary discretionary resource for developing new technologies for our economy and our security. In a cooperative effort among industry, government and academia, AIA has initiated a program entitled, "KEY TECHNOLOGIES FOR THE 1990s," that is focusing effort on and formulating a national strategy for development of those technologies essential to maintaining U.S. aerospace and defense leadership over the next decade. In a recent survey, AIA found that half of industry's work on these "KEY TECHNOLOGIES FOR THE 1990s" is performed through IR&D.

Continuing the present system of limiting allowable IR&D/B&P costs creates doubts within industry as to the economic wisdom of sustained high-level investment in technology. This could have grave repercussions for the government, the aerospace and defense industry, and the nation.

Impact on the government

Our ability to deter, detect and respond to threats depends on the technology now generated through both IR&D/B&P and contracted R&D. Without IR&D/B&P, however, we would quickly lose the technology edge that leads to superior weapons. Without superior weapons, our geopolitical and military interests would have to be redefined because we cannot match our potential adversaries gun for gun, soldier for soldier. Nor could we rely for long on the cushion of deterrence that superior technology now provides us.

Not only would we risk losing our edge in weaponry, but we would stretch development time for those weapons we could field. IR&D/B&P provides the technical capacity to cut lead times. Through IR&D/B&P, contractors experiment with and narrow the options available for development of new systems.

IR&D/B&P also provides industry the capacity to respond in a time of crisis. Just as a professional military personnel structure keeps us prepared at all times to respond to crises, so the scientists and engineers of industry keep us staffed to meet potential threats.The expertise they provide could not be developed quickly in an emergency. Without the technological superiority that extends the reach of our military forces without expanding the size of our forces, our key military alliances would of necessity be altered.

IR&D/B&P also has a significant impact on the level of competition for DoD contracts. More equitable IR&D/B&P allowability encourages more contractors to investigate avenues of meeting the functional requirements of our military and in doing so increases price competition.

As IR&D/B&P affects our defense strategy by impacting sales to foreign governments, especially our allies, it also affects our defense costs. A competitive American aerospace and defense industry will make more foreign sales, which reduces prices to the U.S. Government, and improves the balance of payments.

Impact on industry

Continuing a policy of requiring industry to subsidize the cost of its technology development for the government also will have a significant negative impact on industry.

If the government continues to limit IR&D/B&P cost allowability, contractors have three untenable options — if they choose to continue doing business with the government:

1. Reduce investment in IR&D/B&P;
2. Reduce return to shareholders; or
3. Increase prices to non-government customers.

All three options have the same result: a weakened American aerospace and defense industry that gradually loses its present technology edge in the world.

- To reduce investment in IR&D/B&P means that contractors will eventually lose business to foreign concerns which do not face the financial constraints on IR&D/B&P imposed by the U.S. Government and, therefore, can aggressively seek new solutions and new ideas, and produce more advanced products.
- To reduce return to shareholders means paying higher financing costs, with a predictable effect of eventually making American companies unable to compete with foreign companies that can obtain money more cheaply either in capital markets or through government subsidies.
- To increase prices to non-government customers means, once again, losing the ability to compete for markets in the U.S. and around the world.

Each response leads to the same conclusion: the deterioration of an industry that is critical to our national defense and economy.

Impact on the nation

The ramifications for our nation of continuing policies that diminish our technological leadership are also clear.

The economic security of the United States will be threatened. Without the technological superiority we now hold, we may not be able to effectively compete in world markets. Without continuing advances in technology, we may find our potential adversaries quickly closing the existing technology gap.

The economy of the United States would also suffer. The aerospace industry remains one of the major net contributors to our trade balance, even while competing against foreign companies subsidized by their governments. Aerospace industry exports in 1987 amounted to $23.9 billion, or nearly 10% of total U.S. exports in dollar value.

SECTION III

Technology Trade Balance Comparison

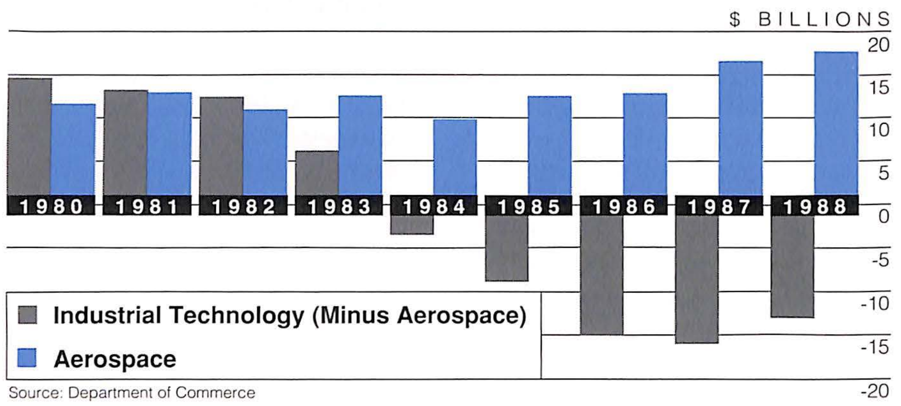


Figure 5: The aerospace industry's contributions to U.S. trade balances. In every year but 1986, the trade surplus of the aerospace industry alone has balanced deficits accruing in all other areas of industrial technology.

Moreover, as illustrated in Figure 5, in every year but 1986, the trade surplus of the aerospace industry alone has balanced deficits accruing in all other areas of industrial technology.

The aerospace industry is also a major employer and contributor to our domestic economy. In 1987, the aerospace industry alone employed over 1.3 million people or nearly 7% of all those employed in U.S. manufacturing.

Moreover, in the past 40 years, the aerospace and defense industry has made major contributions to technical knowledge that has been widely applied throughout American industry. Aerospace and defense contractors pioneered developments in integrated circuits, computer miniaturization, and lasers to name only a few of the technologies from which our society is reaping benefits.

At a time in our history when we are giving more serious attention than ever to our industrial base and our national competitiveness, it would be negligent to ignore a government policy that detracts from our competitiveness. It would be negligent, indeed, to forsake the research and development that could lead to breakthroughs in the key technologies of the twenty-first century and maintain America's technological leadership in an area critical to our nation.

SECTION IV

Recommendations

Given the serious implications for our security and economy of continuing present IR&D/B&P policies, the following actions are recommended:

1. Leadership must continue to come from the highest levels of government in advocating a strong commitment to IR&D/B&P. The consistent support of key executives within DoD and the Services is crucial.

2. Industry should be able to allocate to government contracts their full share of actual IR&D/B&P costs without ceiling limitations. Industry and government should work together to develop transitional steps designed to achieve this goal under the framework of existing laws.

3. The government should streamline and standardize administrative requirements associated with the IR&D/B&P negotiation and technical review processes.

We in the aerospace and defense industry are prepared to work with the government to maintain strong IR&D/B&P programs so that we can maintain our technological leadership. We view this as a team effort with much to be gained by both the government and industry.

APPENDIX

Examples of IR&D Benefits

Composite Materials

- **Composite Structures**
Under IR&D, Grumman Corporation has developed advanced composite structures optimized for structural efficiency, aeroelastic performance and life-cycle cost. The effort has generated many government contracts, including the X-29 Technology Demonstrator.

- **New Boron Fiber/Epoxy Resin for Aircraft Structures**
Textron Aerostructures IR&D over a 13-year period allowed development and subsequent improvement of composite materials — lighter, yet stronger than the metals they replace — made of boron fibers bonded together by epoxy resin. Such a composite is used as a reinforcing material for the titanium dorsal longeron of the B-1B, reducing weight and improving aircraft performance.

- **Composite Cases**
A decade of Thiokol IR&D on composite materials led to development of significantly lighter solid rocket motor cases, a benefit to the Peacekeeper and small ICBM missile programs.

- **New Composites for Vehicle Armor**
Increased armor protection for military land vehicles at lighter weights is the principal benefit of Martin Marietta's IR&D in composite materials, which included development and field-testing of composite armor designed to counter threats up to .50 caliber.

- **Composite Repair Blades**
An IR&D effort by Kaman Aerospace involving simulated damage and trial repairs of composite rotor blade components produced a process and a tool (now standard in the military services) that permit field personnel to repair and/or maintain composite helicopter rotor blades without sending them to a depot or even removing them from the aircraft, affording significant life-cycle savings.

- **Missile Nose Tips**
IR&D by Textron Defense Systems involving research in high temperature materials and development of new techniques for manufacturing and quality control of carbon composite materials provided improvements to the Peacekeeper ICBM, specifically advanced nose tips for the re-entry vehicles and a new antenna window.

- **Carbon/Epoxy**
McDonnell Aircraft's carbon/epoxy IR&D effort began with the objective to expand the design technical base and develop weight and cost-effective structure. Numerous structural concepts

were fabricated and tested and have yielded many production applications, including the F/A-18 wing and horizontal stabilizer skins and the AV-8B wing, forward fuselage, horizontal stabilizer, speedbrake and miscellaneous secondary structures. Carbon/epoxy technology applied to the Harrier has doubled the aircraft's payload/range capability.

- **Titan II Composites**
  As a direct result of IR&D effort by Martin Marietta, composite material Skirts/Payload Adapters on the Titan II reduce the weight and cost over 20% and 40%, respectively.

- **Thermal Protection Tiles**
  Lockheed Missiles & Space Company has developed under IR&D a rigid, foam-like material made of silicon dioxide. This lightweight, machinable material has significantly lower heat transfer characteristics than other insulators and can be used at very high temperatures. Current application of the tiles on the Space Shuttles provides the necessary thermal isolation to the shuttle's structure during atmospheric reentry.

Stealth

- **Low Observables Technology**
  Lockheed's Advanced Development Projects organization recognized that the survivability of air vehicles was critically dependent on significant reductions in radar cross-section and on appropriate reductions in other signature observables. A major IR&D program has been ongoing for many years with activity on new analytical methods, on the geometrical shaping of vehicles, and on the development of new radar absorptive materials. Applications of these low observables technologies have resulted in vehicles like the recently announced F-117A, which the Air Force has said is in operational deployment.

- **Airframe Design**
  Rockwell International conducted extensive IR&D to reduce the observability of the B-1B to enemy airborne and surface radars. The program produced several new technologies that collectively reduced the B-1B's radar cross-section by one to two orders of magnitude, thus significantly improving the aircraft's ability to penetrate enemy defenses.

- **Low Observables**
  Math models and computer codes applicable to low Radar Cross Section (RCS) vehicle design covering the full spectrum of threat frequencies have been developed under Northrop IR&D. These methods have been used in areas such as configuration shaping, analysis of local scattering centers and design of control surfaces for the advanced airplane concepts. Research also included design of radar absorbent materials and structures.

Radar

- **Advanced Radar**
  United Technologies Defense and Space Systems Group IR&D on synthetic aperture radar and radar missile guidance has produced a system for simultaneous radar precision guidance of multiple standoff weapons against multiple surface targets. The technology is being applied in advanced tactical aircraft and in the USAF/Army Joint STARS program to field a common radar and attack control system for land/air battle management.

- **Passive Radar**
  Conventional radars are readily located by enemy systems that detect transmitted energy, and thus are operationally vulnerable to directive jamming, anti-radiation missiles and electronic intelligence targeting. An IR&D effort by ITT Gilfillan has generated technology for a passive surveillance system, one that does not transmit energy. It utilizes the energy transmitted from a remote radar emitter, which can be either cooperative or uncooperative, friendly or enemy radar.

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- **Tactical Radar Antenna**
Westinghouse IR&D on antenna systems, in particular on ultra-low side-lobe arrays for ground-based tactical radar, provided technology for greatly enhanced radar system performance through reduced clutter, reduced sensitivity to obstacles, and reduced vulnerability to jamming.

- **Advanced Radars**
Raytheon IR&D performed over a span of more than two decades provided advances in phased array radar concepts, development of critical components and design/construction of several types of demonstration arrays. This work provided a technology base for later full-scale development of advanced phased array radars for Army/Air Force air defense, surveillance and aircraft landing systems.

- **Avionics**
McDonnell Aircraft Company's IR&D studies paved the way for an enhanced radar capability for the F/A-18 in the reconnaissance and attack role. The objectives of the effort were to develop a high resolution/fixed target track mode, provide a medium synthetic aperture radar mode, and demonstrate stand-off reconnaissance, ship classification, and weapon delivery in adverse weather. The Navy has approved the Operational Requirement for the APG-65 upgrade, which was followed by a contract for the Radar MOU negotiation package. Production is anticipated to begin in mid-1991 at a low level, followed by full production in 1994.

Computers

- **Spacecraft Computer**
"Hardening" space systems, improving their ability to survive in a high-radiation nuclear environment, is a priority objective of the Department of Defense. General Electric's RCA Aerospace developed under IR&D a radiation-hardened spaceborne computer that was certified for use in the Defense Meteorological Satellite Program.

- **Computer Memory**
Honeywell research, conducted for the most part with IR&D funds, resulted in development of an advanced computer memory, based on a new concept in which Large Scale Integrated Circuit metallization was employed in lieu of plated wire memories. Applicable to such programs as the Strategic Defense Initiative, the new memory offers a fourfold speed increase, together with significant reliability and radiation resistance improvements and major reductions in volume and costs.

- **Engineering Design Graphics**
Under an IR&D program starting in 1980, Lockheed

Aeronautical Systems Company recognized that the ability to design in three dimensions, even with two dimensional displays, promised major advances in the ability to design and build complex air vehicles. They have developed a new systems approach and the algorithms for the accurate description of aerospace vehicle geometries. Working with several universities, with data base suppliers such as IBM, and with display suppliers such as Hewlett Packard, they have developed a system under IR&D that allows the design of complex systems up to the assembly level. This new system is being used in the design and manufacture of the LRAACA (Long-Range Air Anti-Submarine Capable Aircraft) for Navy use and of the ATF (Advanced Tactical Fighter) for the Air Force.

- **Programmable Processor**
  TRW IR&D in Very Large Scale Integration and Very High Speed Integrated Circuits (VHSIC) resulted in development of a programmable processor and the linking of many such processors to attain speeds of seven million characters a second in high speed data search systems. Applicable to DoD text search and improved signal intelligence collection/analysis, the development allows data to be searched up to 16 times faster than is possible with current systems, with fourfold savings in hardware costs.

- **Advanced Circuits**
  Large scale IR&D investment by Honeywell in VHSIC technology helped expedite a new generation of silicon integrated circuits. Among Honeywell VHSIC applications in development are systems for underseas surveillance, space signal processing, automatic target detection and computer-generated imagery for trainers.

- **VHSIC**
  IR&D by ITT/GTC involved development of fabrication techniques for integrated circuits that use gallium arsenide as the semiconductor material and design of circuits applicable to advanced military needs. The development makes possible very high speed signal processing with low power and small size components. It also allows extension of high-frequency technology to systems such as radar and communications, where small size and low power consumption can offer significant advantages.

- **High Throughput Signal Processors**
  High throughput signal processors have been developed on IR&D at Raytheon around a small set of semi-custom VHSIC chips. These are being used in a variety of signal processing applications for missile/airborne and surface weaponry.

- **AI Techniques for Message Processing**
  Under IR&D, Boeing has developed a state-of-the-art syntactic analyzer, which covers English grammar more completely than any other system. Boeing has brought this technology to a level of performance suitable for operational use in any command, control or logistics system for which it is desirable to enforce a simple English style in text messages and documents.

- **Hybrid Wafer Scale Integration (HWSI) Memory Development**
  Fairchild Space Company's IR&D is actively transferring the technology from VHSIC-sponsored research in government laboratories to develop extremely dense, highly reliable memory hybrids for use in military environments. Applied to processors such as the Generic VHSIC Spaceborne Computer (GVSC) or in systems such as Boost-Phase Surveillance and Tracking Systems (BSTS), the HWSI memory development affords 200% to 300% improvement in package density over discretely packaged components.

Communication

- **Electronic Counter-countermeasures (ECCM) Communication**
The Air Force sought for many years to develop tactical ECCM communications capability through pseudo-noise spread spectrum techniques. Under a 1976 IR&D project, Magnavox began development of an alternative frequency-hopping, anti-jam scheme that could be economically retrofitted to existing tactical radios. This highly successful IR&D effort led to contracts for the "HAVE QUICK" system, now the Air Force standard for ECCM voice communications being used by the other services, and that is the basis for the new NATO "SATURN" standard. Contracted R&D on alternate spread spectrum systems for tactical anti-jam voice communications was terminated. Development of this system, along with very large life-cycle cost savings to DoD would not have been initiated (at least for several years) without IR&D investment.

- **Blue Excimer Laser Communication**
Northrop has had an increasing level of IR&D investment in this technology area since 1983. Emphasis has been on developing advances such as advanced injection laser design, reliable Raman frequency conversion, increased power-handling capacity for sapphire windows, and improved gas processing to reduce contamination. One outstanding result was industry's first demonstration of blue light from a sealed, high-temperature Raman cell operated at 1300° C for more than 1600 hours. Northrop was selected to develop the Laser Transmitter Module for the Navy space-based Submarine Communication Satellite (SLC-SAT).

Sensors

- **Laser range finder**
The world's first working laser was demonstrated in June 1960 at the Hughes Research Laboratories under IR&D funding. Hughes quickly exploited that invention and, through a continuing IR&D program with subsequent contract development and production, has become the leader in tank laser rangefinders, high energy laser optics and precision pointing and tracking. Laser IR&D continues at Hughes on a broad front: free electron lasers; compact (hand held), low cost, eye safe rangefinders and designators; high power optics; CO_2 laser rangefinders and transceivers for laser radar and chemical aerosol detection; precision pointing and tracking

techniques; conjugate and adaptive optics for laser beamforming and alignment; and techniques for laser countermeasures.

- **Nuclear sensors**
Grumman IR&D in the area of nuclear detection and event analysis has resulted in the development of new and improved high sensitivity gamma ray and neutron sensors for remote sensing applications. These sensors have provided the basis for the capability to make measurements in nonlaboratory environments, with special applications to a number of scientific and DoD related requirements, including those involving verification.

- **Optics, sensors and lasers**
TRW IR&D investments totalling millions of dollars have developed technologies upon which major spacecraft systems depend. Examples in the scientific spacecraft arena include the Gamma Ray Observatory (GRO), the High Energy Astronomical Observatories and the newly initiated Advanced X-ray Astronomical Facility program. The GEODDS defense system for observing and tracking unannounced space objects was also an outgrowth of IR&D/B&P projects. In the laser weapons area, such high energy laser programs as MIRACL and ALPHA resulted from multimillion dollar, multiyear TRW IR&D/B&P investments. Superconductive electronics are currently being developed via IR&D projects and are expected to have a major impact on future defense and space systems design. Without heavy IR&D investment, TRW would not have been able to build the sophisticated payloads that give the spacecraft the ability to perform their mission. TRW's long-term investment in high power lasers led directly to the recent successful demonstration at White Sands where a missile in flight was destroyed by a high energy laser.

- **Autonomous Docking Sensor**
A McDonnell Douglas IR&D program designed, built and tested a breakthrough attitude sensor that facilitates autonomous, remote rendezvous and docking of space vehicles and stations. Rendezvous and docking are critical operations to a wide range of future manned and unmannned missions, including servicing of Space Station Freedom, servicing and repair of unmanned satellites, and return of samples from planetary and asteroidal bodies in missions such as Mars Rover/Sample Return.

- **Towed Array**
Allied Bendix Aerospace IR&D focused on advancements in towed arrays for detecting enemy ships. Among improvements effected are a 10-decibel reduction in acoustic sensor self-noise, which resulted in greater enemy vessel detection capability for the array, computer modeling advances that provided significant array cost reductions for the Navy, and materials/design advances that collectively reduced the systems parts count by 60%.

Navigation

- **Advanced Gyro**
A primary requisite for submarines carrying underwater-launched, long-range ballistic missiles is a capability for very high precision navigation for long durations without updates from external sources. This is accomplished by Ship Inertial Navigation Systems (SINS), which employ gyros and accelerometers to track ship motions and provide continually updated position information. Rockwell International's IR&D to develop improved gyro concepts with less navigation error resulted in development of an advanced, electrostatically supported gyro that was retrofitted in existing submarines and integrated into new construction, extending the time submarines can remain submerged with high navigational accuracy.

- **Ring Laser Gyroscope**
Honeywell research, mostly performed under IR&D,

APPENDIX

developed technology for an advanced ring laser gyroscope that affords revolutionary capability for guidance, navigation, positioning and control. Developed for the F-15 fighter and for strategic and tactical missiles, the gyro offers 10 times better mean-time-between-failures, five times faster start-up and high immunity to G forces and shock.

Propulsion

- **Aircraft Engines**
  General Electric Company's Aircraft Engine Business Group conducted extensive IR&D involving engines that evolved into propulsion systems for the F-14, F-16, and F/A-18 military aircraft.

- **Space Motors**
  IR&D by Thiokol has advanced a number of technologies — propellants, igniters, composite materials, exit cones, etc. — associated with small upper-stage rocket motors used to inject satellites into orbit. This work resulted in current availability of a series of reliable, high-performance upper-stage boost systems. More than 90% of the free world's satellites are sent into orbit by Thiokol space motors.

- **Solid Propellants**
  Under IR&D funding, Hercules Aerospace conceived and developed a family of high-energy slurry propellants that improved rocket motor performance and allowed meeting range/payload requirements within volume, weight and cost restraints for the Trident, Peacekeeper and SICBM strategic missile programs.

- **Thrusters**
  A major example of the direct use of TRW's propulsion technology developed under IR&D is the accurate and critical thrusters used on the Lunar Lander and the thrusters that will be used with the Orbiting Maneuver Vehicle or "space tug" that is currently under development by TRW for NASA.

- **Propellants**
  Under IR&D, Aerojet Solid Propulsion developed and demonstrated high energy nitroglycerin advanced propellant technology. This advancement was essential for the achievement of the demonstrated cost, performance and safety capabilities of the SICBM Stage II.

- **Liquid Rocket Engine Chambers**
  Aerojet TechSystems, during three years of IR&D programs, developed new liquid rocket thrust chamber designs and fabrication techniques, using refractory metals such as columbium and rhenium. These new approaches double the previously encountered temperature and pressure limits and increase operational

life significantly. These new materials and techniques, developed through IR&D, contributed directly to new rocket engine designs for space propulsion, including use in the Space Concepts/Integrated Technologies (SCIT) Program as well as in the most advanced lightweight, compact, high-performance engine being developed by the Air Force, the XLR-132.

Control Systems

- **Engine Control**
  An 11-year IR&D program by Pratt & Whitney (now a part of UTC's Power Group) resulted in development of a digital electronic engine control system that provides multiple advantages over mechanical control for current and future military aircraft engines. Continuing IR&D has produced an extra-reliable dual redundancy control system that will eliminate the need for a mechanical backup and reduce weight and cost.

- **Flight Control System**
  IR&D by General Dynamics' Fort Worth Division resulted in development of an advanced quadruple-redundant, digital fly-by-wire control system now incorporated in the company's F-16 fighter.

- **Adaptive Optics**
  In 1987, Lockheed Missiles & Space Company demonstrated active optical systems to control atmospheric perturbations in ground-based solar telescopes. Active adjustment of a segmented mirror has improved performance to the diffraction limit, even in the presence of appreciable atmospheric turbulence. Incorporation of this unit in ground based telescopes will improve performance and scientific productivity of solar telescopes around the world.

- **Control Actuator**
  Allied Bendix Aerospace IR&D generated development of a high pressure flight control actuation system for rotary and fixed wing aircraft that can reduce the weight of the craft's hydraulic system by 40% and thus increase payload and/or performance.

Systems Technology

- **Advanced V/STOL Technology Program**
  The Model 360 is an Advanced Technology Demonstrator Aircraft incorporating advanced technology in composite structures, aerodynamics and avionics. It has been developed over a period of eight years in a Boeing IR&D project. Its first flight was made in June 1987. In 1988, it flew more than 85 hours for subsystem checkout and optimization, and for envelope expansion to level flight speeds of over 200 knots. In the envelope expansion, its acoustics, dynamics, handling qualities, and structural loads were evaluated. It provides for integration of advanced technologies for future systems.

- **Flying Test Bed**
  Tomorrow's utility and attack helicopters will be required to fly nap-of-the-earth patterns, in some cases with only a single pilot. This prospect demands assessment of the effect on crew workload and the potential benefits of advanced systems. For such assessment, Sikorsky (now part of the UTC Defense and Space Systems Group) developed — under IR&D — the Shadow experimental flight demonstrator helicopter. Equipped with a number of advanced cockpit systems, the Shadow significantly advances the Group's design capability by allowing the company to choose the optimum configuration for a given mission at reduced cost.

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