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INDIVIDUAL STUDY PROGRAM

THE PROBLEM OF TECHNOLOGY TRANSFER:
REAL OR IMAGINED?

STUDY PROJECT REPORT
PMC 77-1

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THE PROBLEM OF TECHNOLOGY TRANSFER:

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Individual Study Program

Study Project Report

Prepared as a Formal Report

Defense Systems Management College

Program Management Course

Class 77-1

by

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May 1977

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DEFENSE SYSTEMS MANAGEMENT COLLEGE

STUDY TITLE: THE PROBLEM OF TECHNOLOGY TRANSFER: REAL OR IMAGINED?

STUDY PROJECT GOALS:

(1) Collate and analyze previous USAF management actions in the technology transfer field
(2) Review the technology transfer programs of other Services
(3) Recommend changes in the technology planning process and procurement policies

STUDY REPORT ABSTRACT:

This study project report provides an analysis of the process by which the Air Force transfers or transitions technology from less than major system advanced development projects performed in Air Force laboratories to use in operational systems. An examination of the DoD and Military Departments policies, procedures and technology base management techniques leads to a description of the factors that tend to camouflage or provide roadblocks to the transition process. These factors are placed into "Communications/ Motivation Groups" and are evaluated for their impact on the process. Conclusions are reached concerning the Air Force laboratory organizational structure, use of off-the-shelf hardware, contractor independent research and development, and contract procedures. Recommendations discuss documentation, changes in organizational structure, and modification of procurement and contracting procedures.

SUBJECT DESCRIPTORS: Technology Transition, Air Force Laboratories, Technology Base Management.

NAME, RANK, SERVICE	CLASS	DATE
Warren W. Cook, Maj, USAF	PMC 77-1	May 1977

EXECUTIVE SUMMARY

This study project report contains an analysis of the process by which the Air Force transfers or transitions technology from less than major system advanced development in the Air Force laboratories to use in operational systems.

A knowledge and understanding of this process is important to Air Force research and development decision makers because of the great emphasis placed on technology transfer by the Department of Defense (DoD) and Congress as a yardstick for measurement of program success. Funding provided for technology base programs is directly proportional to the transfer efficiency as perceived by those decision makers.

An examination of the DoD and the three Military Departments' policies, procedures and technology base management techniques provides insight into the factors that tend to camouflage the transfer process from observers outside the Air Force and tend to produce roadblocks to successful transition. The factors resolve themselves into either a communications or a motivation problem.

Four communications/motivation groups are identified:

- Within the Air Force
- Outside the Air Force to DOD and Congress
- Between the Air Force and the contractor
- Between the Air Force and the other Services

Conclusions are reached that basic management structure exists to improve the technology transfer process; and that changes are necessary in the concepts of the use of off-the-shelf hardware, independent research and development, competitive prototyping and incentive contracting.

Recommendations include emphasis on investment strategy documentation as a communication vehicle, changes in the organization structure to eliminate layering, emphasis on competitive prototyping in lieu of off-the-shelf, introduction of the concept of preferred procurement and modification of incentive contracting procedures.

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INTRODUCTION

Purpose of the Study Report

The purpose of this study project is to perform an objective appraisal of the general problem of transfering or transitioning less than major system advanced development technology from the laboratory environment to use in operational systems. The fact that this transition process is perceived to be a problem by the technology community indicates some action should be taken to improve it. How much of the problem is real and how much imagined will determine the nature and scope of these actions.

Specific Goals of the Project

The specific goals of the project are:

- To understand the environment within which the technology base is developed and utilized;

- To understand the technology base management techniques of the other Services and relate them to management actions taken by the Air Force;

- To identify those aspects of Air Force technology base management that tend to camauflage the transfer process from outside observers or produce roadblocks to technology transfer; and

- To recommend management actions to improve both the perceived and actual technology transfer process.

Scope and Limitations of the Paper

It is not the intent of this paper to recite a litany of examples where technology has crossed the "valley" into system application. This would not prove nor disprove the existance of a technology transition problem. Rather, it would only show that some technology is transitioning. What is far more important is the environment the Government has created to stimulate technology transition, how that environment is working and how it could be improved. This paper will examine the structure of transition, what management actions have been taken by the United States Air Force (USAF) to improve the structure and its image, the limitations of those actions and some possible improvements.

Throughout the discussion we will tend to use the avionics technology area as the example. This is necessary for three very cogent reasons. First, the avionics technology area is unique in that unlike the jet or rocket engine business, there are virtually hundreds of contractor sources from which DoD must chose when selecting hardware for R&D or production. Literally, everone with a voltmeter is in the avionics business. This certainly broadens the competition field, but it also dilutes the resources spent and tends to obscure the transition process. Second, avionics has always been high risk/high pay-off and expensive.

Because major system programs desire to avoid high risk and expense, it tends to be one of the most difficult areas to transition. Finally, on the practical level, the experience of the author is centered in the airborne electronic warfare field and while the hardware and techniques used in the electronic warfare (EW) field are not well known to the general public, they are representative of the most difficult type of technology to transition because they are expensive, sophisticated and difficult to demonstrate.

Origin and Definition of Technology Transfer

In attempting to attach some rational method of evaluation to the benefit derived from the millions of dollars spent for exploratory and advanced development each year, top level decision maker throughout DoD and Congress have hit upon the idea of "technology transfer". Briefly stated this is the concept that one can evaluate the worth of a development program by the amount of output technology from the program that is eventually used in operational systems. The most vivid parallel use (or misuse) of the technology transfer method can be found in the NASA experience in the years since 1970. While not actually involving operational systems per se, hundreds of thousands of dollars and manhours were expended by NASA to show that the money spent going to the moon had some beneficial impact on the everyday life of Americans. Their success at proving technology transition has been no better with the Congress than that of the DoD.

Year after year the various Secretaries of Defense and their Directors of Defense Research and Engineering have been trying to explain to Congress the worth of exploratory and advanced development to the mission of the DoD. Again in his annual report to the Congress for FY 1977, Mr. Rumsfeld in commenting on the level of effort approach taken by Congress in past years, specifically asked that the ever downward trend of of spendable dollars in R&D be reversed and Congress provide the real growth needed to:

> "- Strengthen the U.S. technology base to create options for future development;
> - Demonstrate selected alternatives chosen from among new options;
> - Select the best system or systems and manage the resulting development and production efficienty and effectively; and
> - Concentrate on completing current U.S. development programs to achieve improved displayed capabilities" (17:viii)

To a great extent this plea fell on deaf ears or at least skeptical ears that belong to people who gage technology development efforts by transition rates and not by contribution to the general pool of knowledge. The actual increase obtained in RDT&E was 3.7% after inflation (18:C-14).

The enigma of this situation is that it must be obvious to anyone who has been involved in any phase of technology development that, in fact, eventually virtually all technology is "transitioned". One does not discard forever a practical technique or component simply because no application or home is immediately available. The very essence of creative thought springs from applying the unlikely to the impossible. Technology transfer is then a matter of timing rather physics or fate. It is our timing that we in the DoD must improve and toward that end, examine the real and imaginary components of technology transfer.

BACKGROUND

Research and Development Policies of the DoD

Over the years the DoD has examined and re-examined the research and development business and the methods by which it managed its resources. Each time studies were done a basic theme was detectable: provide for Government owned and staffed laboratories, and let them alone long enough to do their job.[13] The basic concept involved is that the Government be able to turn to technical advice from its own internal sources as an alternative to sources outside the Government. By building a strong technology base and a group of people who understand it, top management in the Department of Defense (DOD) can be sure of one source of technical advise that is not biased by any lure of a production contract or large profit. Hopefully the Department can also avoid any technological surprise developed by an enemy that could negate deployment or about to be deployed weapon systems.

The key concepts are technical building blocks, preliminary compatibility studies and systems design. In broad terms, this may be called an option creating and option perserving strategy for DoD research and development[19:372] in which resources of manpower and funding are expended in relatively small amounts on a broad spectrum of projects so that the system designer need only to pick and choose that technology that fits his system requirements.

Unfortunately, as will be evident later, the option creating/preserving concept presupposes an environment wherein successful development does not necessarily mean a follow-on procurement. In other words, there are no guarentees or incentives comtemplated that would lead a contractor to believe that any effort would necessarily follow from a successful development program. This approach also assumes the technology base developed by the laboratories is broad enough to contain all the options a system developer would desire and that enough resources had been expended on each option to bring the option up to the point that adequate demonstration had been accomplished and confidence was high the option would succeed in engineering development.

The structure devised under Secretary McNamara, wherein development is grouped according to its phase (basic research, exploratory development, advanced development and engineering development) is still used with one additional refinement. That is the designation of certain activities in advanced development as non-system oriented vis-a-vis the brassboard system approach used in most advanced development. This breakout was an attempt by DoD to make visable those gap-bridging developments that are more advanced than exploratory development but not directly aimed at a system application.

In parallel with this formal structure DoD has also recognized and encouraged the accomplishment of internally controlled research on the part of defense contractors.

Independent Research and Develop ent (IR&D) program goal is to supplement directly funded development efforts by allowing contractor to pursue technology in their speciality area and consider it as part of their overhead costs. This provides the contractor with a "back room" source to improve his competitive position.

The combination of laboratory and IR&D activities lead to the six main points of the DoD R&D strategy:

- Strengthen the technology base
- Achieve improved operational capability
- Plan for competition and demonstration
- Avoid proliferation
- Manage the total cost
- Maintain the industrial base

This strategy forms the environment within which the Services must function and reflects a commitment on the part of DoD to continue to participate in technology development but remain ever conscious of the usefulness and cost of its R&D expenditures.

R&D Structure and Policy of the Military Departments

Interpretation and implementation of DoD research and development guidelines have yielded very similar structures in each of the military departments. Each Service has some form of acquistion management group supported by a laboratory structure consisting of specialized centers of expertise. These laboratories use all three forms of research and development funding (basic, exploratory and advanced) and generally do the bulk of their development work through contractors. To set the stage for discussion of Air Force management techniques we will first look briefly at the Army and Navy approach. This is not intended as an exhaustive review of the Army and Navy systems, but will only touch on those points directly associated with the technology transfer function.

ARMY

The Army makes a very sharp distinction between those efforts considered as major systems in advanced development and technolgy base efforts. Technology base efforts in exploratory development and non-system advanced development are designed with five major objectives in mind. First, the technology base efforts must insure a flow of fundamental knowledge related to military technologies. Second, the technology base activities must insure that an awareness is maintained within the Army of the state-of-art in scientific developments, and that the scientific community is kept aware of Army needs. This two-way communications process provides a continuous appraisal by Army scientists of techniques and components and allows the civilian sector to concentrate their efforts on known areas of interest. Third, the technology programs are charged with the maintenance of a broad base of basic and applied research from which the requisite techniques and components may be drawn to provide support for systems development and to provide a solid basis for determining the technical feasibility, time required and cost of proposed programs. Fourth, because of the great cost and uncertainty involved in new systems development, the technology base programs minimize the need for state-of-the-art breakthrough required during engineering development to assure the new system will meet operational requirements. Finally, the technology base program should provide the major technological advances needed to gain and maintain qualitative superiority in military techniques and material.(4:3)

It is obvious from the objective described by the Army that they place great responsibility on this laboratory activity. It is also obvious that without strong support in the form of resources and policy guidance to the eventual user of the technology, the acquisition agency, the five technology base functions will not be fulfilled. To assure a positive approach to the support and utilization of technology base efforts, the Army has established a basic policy or strategy of research and development.

The first aspect of Army research and development strategy is the recognization that development programs are both risky and expensive. Sufficient funds must be programmed to provide for the technical uncertainty inherent in the development effort. This must include programming for necessary design and engineering, testing, fault location and, of prime importance, fault correction. The second major aspect of Army research and development policy is that of creating and maintaining competition for as long as possible in the development effort. Managers must include in the acquisition planning and resultant development contracts provisions for introduction of a second source if and when the system development contractor encounters significant sub-system technical difficulty. In some cases, the system contractor will be required to provide a second source on high technical risk sub-systems or components, and maintain competition between these sources at least until full scale production. In other cases the Army will maintain one of the advanced development prototype sub-system contractors through initial production and fielding of the system.(4: Chap 4)

A final point must also be made regarding the organization with which the Army implements their objectives and strategies. In an attempt to maintain the desired tight coupling between the laboratory and the development program, the Army has minimized communications barriers by placing the system program manger (PM) and the laboratory in the same acquisition organization. The laboratory and its associated manpower and technolgy are thus available to the PM on the same basis as other support agencies within his present command. We will see later that is not universally accepted as the optimum solution to technology development or transfer.

NAVY

The Navy approach to technolgy base management and, in fact, research and development in general does not make a sharp distinction between technology base program and system developments. Generally, the Navy's concept is that research, development, test and evaluation (RDT&E) is but one of the elements that contribute to the production of operational capability. Equipment, people, facilities, material and information must all be managed and combined to produce the required operational capability.[7:2-7]

The function of the laboratories in this approach are to accomplish projects that will improve Navy capability; maintain a base of scientific talent to preclude the possibility of technological surprise; enable the Navy to enter the R&D market place as an enlightened and qualified buyer; maintain a corporate technical memory of past technical problems and solutions; and provide continuously available technical capability to exploit new technological breakthroughs on a quick reaction basis.[7:F-4] Implicit in this list of functions is the requirement that the Navy laboratory system stay in very close communications with both the system developer and the operational user.

Implementation of the Navy's approach is best exemplified by the concept of "advanced prototyping". The fundemental precepts of the program are first, "hardware not studies; and second, tests not analysis".(7:6-8) Under this advanced prototype approach, contractors or in-house laboratories produce hardware working under general performance goals with a minimum of documentation and external control. Equipment is then tested under the most realistic operational conditions possible and its military utility evaluated. Equipment covers the entire spectrum of components and subsystems through brassboard and full-up systems. Effort may be accomplished by in-house manpower or competitive or sole source contracts. Any class of money, exploratory, advanced or egineering development may be used.

The objectives of the advanced prototype effort parallel closely those cited in the overall DoD policy. First, the prototype process creats demonstrated options from which future operational system developments can be selected. Second, because of the low profile approach, competition and free use of in-house talent the program sunk costs are held to a minimum. Third, in the process of testing the prototype and getting it to perform (or not perform at times) the Navy technical management personnel gain knowledge in making realistic system transfers. Fourth, a large amount of the guess work can be eliminated in the prediction of program costs; and finally, technology advancement and transfer is accomplished while preserving and strengthening the contractor and government design teams.(7:6-8)

The Navy organization to accomplish technology base activities is a mixed bag with some laboratories and development organization reporting to a central Director of Navy Laboratories while others are connected directly with an acquisition oriented command.(7:F-1) While this appears to be inconsistent, the strong emphasis on matrix program management in the Navy tends to promote the crossing of organizational lines to obtain support this forcing the PM to use laboratory people and technology rather than exlude them, and sponsor advanced development within the program office.

Air Force

From a policy standpoint, the Air Force takes much the same approach to technology base management as the Army. A sharp line is drawn between any advanced development work aimed at major system development and the development of the technology base. The Air Force Laboratories are charged with the responsibility of devising, advocating, and managing the technology base efforts. Specifically, the laboratory responsibilities are to:

- Assure that critical discoveries, innoviations and inventions are identified for rapid exploitation by the Air Force,

- Participate in planning and implementation of the acquisition of systems, subsystems, and equipment for use by the operational forces,

- Assist in the resolution of technical problems and deficiencies encountered in development programs,

- Provide technical impact to long term military planning and decision making, and,

- Assist in the evaluation of the performance of military equipment.[6:2]

Technical impact to long range planning is provided for during the conceptual phase of major programs through the medium of a "Technology Roadmap". The technology roadmap is a description of the technical capabilities needed to support concept validation and a schedule of the development tasks required to obtain those capabilities. Identification of risk and environmental impact is also included. The primary input to the roadmap comes from the laboratories with a secondary input in the form of "technology needs" from AFSC acquisition divisions.[3:2-5] Responsibility for the actual demonstration of the technology referenced in the roadmap may or may not be placed under laboratory management dependent on the working relationship established between the program office and the laboratory, and the criticality of the technology to downstream decisions concerning the system program.

Management of the exploratory development funds used by the laboratories is under the direct control of the laboratory commander. He allocates his resources to programs that he perceives as the most needed technology for future Air force requirements. Advanced development funding, on the other hand, is allocated and directed by the Air Staff. The laboratory proposes and plans the efforts, provides management and technical expertise, and day-to-day monitoring of contract progress.

Organizationally the laboratories are independent of the product acquisition divisions. Command reporting is accomplished through the Director of Laboratories at Headquarters AFSC to the Commander of AFSC. Some modification to this structure has been accomplished in the very recent past by placing two of the laboratories under product acquisition divisions, but the bulk of the laboratories report directly to HQ AFSC.

With this brief overview of the offical policies concerning technology base management in the three Services, we can now turn to a detailed look at the procedural aspects of Air Force technology base management and at the specific techniques AFSC has implemented to improve technology transition.

Air Force Technology Base Management

The concept of technology transition and technology base management is peculiar to the laboratory environment and has been since the laboratories absorbed part of the advanced development work from the acquisition divisions in the middle sixties. Those advanced development programs controlled by a major program office during the conceptional and validation phases are rigorously geared to the program cost, schedule and technical requirements. Those in the laboratory are on, the other hand, only tied to the program rather tenuously by the Technology Roadmap or other agreements that say the laboratory is to support the program office. In an effort to improve this situation, the Air Force System Command (AFSC) performed a Laboratory Utilization Study with the express purpose of defining the connection between the laboratory and the program office, and improving both the real and preceived technology transition between them. The initial findings were rather disheartening:

> "The functions of the laboratories are not well understood particulary, the laboratory role in planning and implementing the acquisition of systems. The lack of personnel mobility; the existance of other engineering organizations (e.g. FCRC, ASD/EN); and the Air Force concept of program office/contractor relationships have served to largely exclude laboratories from the development acquisition process". (15:4)

As a result of this finding and strong indications from program managers that the laboratory "peddles" its product under the guise of the current buzz words when in fact only titles have been changed on the same old projects,(15:A-1) AFSC came to the conclusion that the communications process between the program office and the laboratory had completely broken down. To rebuild that communication and collaterally enhance the technology transition process, AFSC has implemented four technology base management actions:

- Reorganization of the laboratory structure,
- Mandatory assessment of laboratory programs by acquisition divisions,
- Establishment of a system of "Development Goals", and
- Formulation of a technology investment strategy.

A brief examination of each of these actions is necessary to fully understand the current USAF concept of technology base management.

Reorganization was implemented with the stated purpose of making the communication process between the laboratory and the acquisition division more efficient. The Laboratory Utilization Report recommended:

> "The AFSC product division should control the advanced and engineering development funds expanded in the laboratory. The intent is to improve relevancy of the projects, bring laboratories closer to system planning and acquisition, and provide a direct link for the transfer of technology". (15:6)

AFSC took action on the recommendation by creating a super laboratory at Wright-Patterson AFB, Ohio (Air Force Wright Aeronautucial Laboratories (AFWAL)) that combined the existing hardware oriented labs at Wright-Patterson; assigned management of Rome Air Development Center to Electronic Systems Division, Hanscom Field, Massachusetts; and eliminated the Aerospace Research Laboratories at Wright-Patterson. A previous organizational change had placed the Air force Armament Laboratory under the Armament Development Test Center at Eglin AFB, FL. The creation of AFWAL maintained all the existing laboratory technical and management structure but provided a single management contact point for Aeronautical Systems Division program managers.

The second management action created a system for assessing and advocating technology base advanced development programs with the expressed purpose to "provide an effective basis for recommending the allocation of resources, and enhance the transfer of demonstrated technology into weapon system development programs and into the operational inventory."(5:1) The concept is based on the mandatory and systematic assessment by the acquisition divisions of all advanced development technology base projects proposed by the laboratory each year. The assessment describes each advanced development project in terms of its pay-off in potential applications, technological opportunities, or and cost reduction; its schedule match with potential application and changes necessary to affect a match; its risk in demonstrating the technology successfully; its cost; and its priority i.e. high-really need it, medium - nice to have, low - forget it, we can't afford it.[(5:A-1)] To add credibility to the assessment, a policy is also established that an endorsement of an effort by the assessing agency implies the intent to use successfully demonstrated technology if the intended application is still viable.[(5:3)]

In order to provide the acquisition division with a reasonable program to assess AFSC's third action was to establish a system of development goals to provide planning guidance for technology base programs and to serve as a yardstick in assessing how well proposed and on-going efforts address USAF Needs. These goals which are derived from the various higher headquarters planning guidance documents e.g. The Program Planning and Guidance Memorandum (PPGM), the Joint Research and Development Objective Document (JRDOD), Program Management Directives (PMDs) etc; are divided into the classic areas of:

Strategic Offense
Strategic Defense
Tactical Warfare
Airlift
Command Control and Communications
Reconnaissance
Mission Support (1).

General goals are then stated within each of these such as:

Provide bomber flexibility
Improve ballistic missile throw weight
Improve bomber range/pay-load

System concepts or preferred solutions are purposely avoided to encourage planners and technologists to conceive analyze and propose innoviative technology efforts to solve pressing Air Force Problems. (1:)

To translate the Development Goals provided by the AFSC planners into a structured program, the Director of Laboratories instituted a Command-wide procedure for the review of exploratory and non-system advanced development. The Technology Investment Strategy looks at each activity in the laboratory, compares it with Air Force mission needs and evaluates the contribution made by that program to the filling of those needs. The objective is to provide a systematic approach to the allocation of exploratory and advanced development resources and by so doing impress higher headquarters, Office of the Secretary of Defense (OSD) and Congress that AFSC knows what it is doing and why.(17:) In view of the complex nature of the technology base programs, the primary value to be derived from the Investment Strategy effort is the dialog among the laboratories and between the laboratories and development planners at higher headquarters. This dialog should contribute to the development of a corporate attitude within the laboratory community and increase laboratory orientation towards Air Force requirements.(17:)

These management actions, policies and procedures form the basis for the current USAF technology base management approach. We shall now look more deeply at their potential effectiveness in solving the communication and technology transfer "problem".

CAMOUFLAGE AND ROADBLOCK FACTORS

In the process of organizing to accomplish any endeavor in the Government, it is axiomatic that whatever is done will have some elements of efficiency but that those elements will be totally obscured by extraneous actions that add nothing to the accomplishment of the mission. It is also axiomatic that whatever is done will concentrate on the most easily identified issues and 90% of the effort will be expended on 10% of the problem. These phenomina are both at work in the technology base management of the USAF. Some percentage of the management actions taken, to date, to speed the flow of technology into operational systems has in fact been effective. A far greater percentage, however, has merely clouded the issue and diverted management talent away from working on the real roadblocks to the transition of technology. Before we can answer the question of a real or imagined technology transfer problem, we must first identify the issues and assess our success or failure in addressing them.

The AFSC Laboratory Utilization Report correctly identified "communications" as the primary roadblock to technology transition. Unfortunately the communications problem the report centered on was not broad enough to encompass the whole technology base management "system", nor did it contain the concept of motivation. In other words, the best communications system in the world is nothing but a circuit through which intelligence flows. If the intelligence does not effect the desired response then the system is useless. The communications problem then should be stated in these four communication/motivation groups:

- Group 1

Communications between the various elements of the Air Force i.e. operational users, headquarters, acquisition divisions, program offices and laboratories

Motivation of the laboratory to accomplish the desired technical effort

Motivation of the program offices within the acquisition division to use the laboratory product

- Group 2

Communication between USAF and the DOD and Congress

Motivation of Congress to appropriate the "up front" resources necessary to demonstrate technology options

Motivation of DoD to allow the technology demonstrations to accomplish the demonstration mission without interference.

- Group 3

Communications with the contractor to let him know what we want.

Motivation of the contractor to produce the product within the desired cost schedule and technical performance goals.

- Group 4

<u>Communication</u> with other Services

<u>Motivation</u> of all Services to cross feed technology and work toward common sub-system equipment.

We can now look at each of these groups to determine if the communication element has removed the camouflage and the motivation element has cleared the roadblock.

In Group 1, within the Air Force, the solution applied is the classical approach to a complex problem: reorganization and repeated review. Looking at each of these solutions, the addition of another management layer between the laboratory and its customer, the acquisition division, only serves to acentuate the problem of isolation of the two groups. Now both groups, i.e. the individual speciality laboratories and the acquisition divisions, have a buffer upon which to blame any communications breakdown. Conversely, both groups also have a funnel that restricts the flow of information when they do wish to communicate. Added to this camouflage factor are the three assessments/reviews that have been implemented to communicate the desires of the customer to the laboratory and the ideas of the laboratory to the customer. These could prove to be roadblock removers if the process of assessment doesn't breakdown into a test of wills at the field level or a constipation of the approval process at the higher headquarters.

The impact of the system of development goals on the motivation of the laboratory toward accomplishing the most desired technical effort is one of quandry. Considering his program must be blessed by both the acquisition division and the development planners at the headquarters, the laboratory planner must make a decision to choose the unstructured path of technology advancement that follows the very broad guidelines of the development goals, or the structured path of providing technical solution within certain time and cost constraints to a system program. Either way one of the two assessment groups will not consider his program responsive. Added to this delima is the question of preparing an investment strategy that conforms to desires of the Director of Laboratories at HQ AFSC. A strategy that must bridge the gap between two functional offices without offending either and still tell a coherent story to DoD and Congress. The Director of Laboratories recognized this problem and the limitations of investment strategy when in his FY 78/79 Investment Strategy Study Report he stated:

> ". . .even when all of these criteria (accuracy, validity, objectivity) are met, all models used for evaluation still fall considerably short of replicating the real world. Study methodologies, no matter how complex, cannot contain all of the variables which influence decision making". (17:)

In other words, it doesn't make sense to use a micrometer on a doughnut.

On the positive side, it should also be pointed out that forcing the laboratory to deal with the acquisition division on a seller to customer basis has removed or at least diminished one source of roadblock previously experienced. In the past, the laboratory commander, and indeed the whole laboratory structure, has been motivated toward making the operational user (Strategic Air Command, Tactical Air Command, Aerospace Defense Command and Military Air Command) the "customer" in their planning when in fact their customer was the acquisition division. This situation was analogus to the tire or battery manufacturer trying to convince the new car buyer that he should demand their product when it will be GM or Ford who will actually build and equip the machine. This placed the acquisition division in direct competition with the laboratory and in conflict over who should receive the credit for innovation and technological advance. Changing the orientation of the laboratory should remove the roadblock.

Motivation of the program manager in an acquisition division to use the laboratory product has been and is still very low. This has been the result of three key factors. The first is a lack of management consistancy in the laboratory. Program management and program managers at the laboratories are technologists. As several authors have pointed out, this does not lead to tough minded management techniques in cost, schedule or configuration control. In fact, those skills are not only lacking in the people managing programs, they are not the type of skill the laboratory environment propogates. People are hired in the laboratory for their technical expertise, are forced to also perform the function of a program manager and are soundly condemed when programs are not managed well. Another facet of this first key factor is the rather capricious way in which program funding for technology base efforts changes on an overnight basis. This lack of stability in schedule and program leaves the system program manager with little, if any, guarantee that technology funds supporting his program will not be used to cover an unfunded requirement on another system. The tendency to mortgage the future to pay for the present is all to prevalent.

The second key factor is the pressure on program managers to use "off-the-shelf" hardware in lieu of new technology. While this would, on the surface, appear to reduce risk, the advocate of off-the-shelf hardware for new systems application seems to miss key aspects involved in the use of that hardware. First, the hardware was designed for some other system operating in some other environment and, therefore, is not optimized for the new application. This leads to reliability and performance problems. Second, no advantage or return on investment is extracted from the technology development resources expended in the field. Thus, the gap between system capability and the advancing technological threat widens while technology transfer rate drops.

Finally, since the hardware was not designed for the application, the program has to either build an interface or modify the off-the-shelf to fit, and the program manager is backed into a research and development effort anyway. Use of off-the-shelf also leads to a decending spiral that chokes off technology transfer:

- Technology programs are evaluated on the amount of technology transitioned
- High transition means more dollars and more work
- Systems on the other hand, are evaluated on low risk and, therefore, want to use demonstrated off-the-shelf hardware
- Systems use more off-the-shelf and transition goes down
- Transition goes down and technology budgets go down
- Budgets go down and less research and development is accomplished
- Less research and development accomplished means less demonstrated technology
- Less demonstrated technology means more use of off-the-shelf hardware . . . etc. etc. etc.

The third key factor is really derived from the second and that is program managers who push the state-of-the-art and take risks are not rated highly in the minds of the higher level decision makers. Consequently, when a program manager is given the choice of improving his system performance by a large percentage at an increased risk, and taking marginal performance at low risk, he will pick the low risk even if the cost is the same. This very conservative approach does lead to low risk programs, but the downstream penalities are not adequately assessed. These penalities are particularly severe in the area of electronic warfare where a changing threat dictates maximum capability and flexibility to cope with the next innovation on the part of the enemy, and marginal systems are suddenly obsolete before they are deployed.

Group 2, Air Force to DoD and Congress, presents a different challenge to the process of communication and motivation. There success in eliminating the camouflage is all important because it is the perceived amount of technology transition that drives the success of funding requests. Actual success in this group has been less than overwhelming because the Air Force has not adequately communicated the basic realities of technology base development nor provided a solid way of tracking the end item use of technology already developed. The five realities of cost, complexity, uncertainty, diversity and time must be understood before rational decisions can be made. Technology is expensive. To develop it takes the best brains, and adequate funding must be provided if any progress is to be made.

Technology is also complex. One line descriptions cannot convey the necessary information on the theory and application of the particular technique or system. Technology base development does involve uncertainty. No amount of waiting around and extending programs is going to give you a no risk program. Uncertainity must be recognized as a valid aspect of technology base development. Some things will fail, if they don't, we are not pushing hard enough. The technology required to support modern systems is as diverse as it is complex. Elimination of one field of endeavor to maintain funding in another is more damaging the cutting both back. Technological breakthroughs cannot be legislated, they must be attained through continuous persistent effort and they take time. Continual tinkering with the technology base program will only slow the process and lead to higher costs.

The investment strategy studies, properly handled, could provide the education/communication source to emphasize the five realities and tie together the progress of technology with operational agreement and systems development. Motivation to both Congress and the DoD to provide the funding needed and laissez-fare management desired, will only come if credibility is established and consistancy of information is maintained.

The Group 3, Air Force to contractor, communication and motivation tasks are the best understood, the least emphasized, and potentially the most productive of all the groups. Communications with and motivation of the contractor are the real keys to successful transition of technology. Basically, the Government has two ways to communicate its needs to the contractor and two ways to motivate the contractor toward a more efficient use of the technology base in systems development. The Government communicates its needs through formal requests for proposals (RFP) and through the review and approval of contractor Independent Research and Development (IR&D). Motivation of the contractor is accomplished through competition and incentives. Major changes are necessary in each of these areas if we are to make the maximum use of our technology base reserves.

The preparation of RFPs and what they should specify is a major source of controversy that exceeds the scope of this paper. Suffice to say that if the RFP and subsequent contract reflect the changes to be recommended in this paper, they will have made their contribution to increased efficiency of technology transition.

Discussion of the remaining three topics is so intertwined that seperation of the communication function from the motivation function is impossible. We will then look at IR&D, competition and incentives individually, but with reference back and forth to each one.

IR&D has provided both a communication and motivation function since its inception. Essentially, the contractor proposes to do work on his own to better his competitive position and the Government gives its guidance to assure the contractor is working in areas of maximum interest. While this process has worked reasonably well in the past, the time has come when the Government can no longer afford this procedure. Technology is now too expensive to allow helter skelter IR&D in which many contractors make a small investment in a large number of technology areas just to keep competitive. This is not and will not produce the desired level of technology advancement nor utilization. The stark reality of the situation is that the need for technology base development and transition does not allow the luxury of gambling on the fact that unstructured IR&D will either produce the technology or keep companies competent to compete. A major change in philosophly is required if IR&D is to continue as a viable entity.

In the same light, our concept of competition has and must continue to change. Critical to this change are the continued and increased use of competitive prototypes, implementation of preferred procurements and elimination of poor performers from qualified contractors listings. The competitive prototype concept or "fly-before-buy" has spread to several of the major technology areas as indicated in AFSCP 800-3:

> "The approach now considered more suitable for system acquisition includes increased use of prototypes or models geared to design evaluation, performance, and production potential. Development prototypes vary from a breadboard of a system or techniques associated with a flying laboratory to complete flying prototypes". (3:3-20)

The key issue in development prototypes is to keep competition alive between the contractors as long as possible, narrowing the field to a single contractor at the last possible moment. This brings up the second item, the concept of preferred procurement.

Preferred procurement is nothing more than a committment on the part of the Government to procure production quantities from one of the successful advanced development prototype contractors. While this sounds simple enough, program managers have been reluctant to award what amounts to a sole-source contract to the winner of a prototype demonstration. The advantages of such a procedure so far outweigh the possible problems that as technology becomes more expensive and advanced it will virtually become a way of life. Typically, the benefits can be described as follows:

- Long range planning by the engineering development (full scale development) agency or program office becomes a great deal easier because something is known about the follow-on effort.

- Transition of technology is guarenteed this will help to alleviate the long lead time currently experienced before technology transitions into systems, and the "not-invented-here" feeling of the acquisition division.

- Competition is real not apparent. Only those contractors truly qualified by virtue of having built hardware can compete.

- IR&D will improve because the contractor will focus on the things he does well. Losers in the original competition identify their weak areas and can change the direction of their goals to coincide with their talents.

- Better logistic planning can be implemented because the logistition is aware of what to expect and a certain amount of long range planning can be implemented.

- Improved incentive for the contractor to give it his best effort because he sees the production effort as a source of revenue and profit. It also allows him to focus on real business thus lowering his overhead through increased efficiency, fewer people and fewer false starts.

Elimination of poor performers from the qualified bidders list is nothing more than tough minded management. In our desire to maintain competition and a broad industrial base the Government has unwillingly fostered and even preserved companies long after they should have gone broke. We can look at the example of jet engine technology and how it transitions. While there are small sub-contractors who build specialized parts of the engine, virtually all US aircraft engines are built by General Electric or Pratt and Whitney. Poor performers in the jet engine business were weeded out years ago and are now either concentrating on other fields or are out of business. Technology in jet engines, therefore, has a guaranteed transition path.

Avionics, of course, is a much more diverse field and to say we could ever get down to just two suppliers, would not be practical. However, it must be recognized that the talent pool is finite, and spreading that talent pool across many many companies dilutes, defocuses and degrades our technology base development and transition efforts. We can no longer afford to maintain every company with a volt-meter on our qualified bidder's list regardless of their past performance.

While it cannot be denied that competition is a great incentive for contractors to perform, there are some additional incentive techniques used after the contract is signed. All the incentive techniques are based on the concept that the contractor's basic motivation is to make a profit and by giving more profit for desired results the Government values and taking away profit for undesirable results, the Government will obtain a better product. Unfortunately in the technology transition environment of advanced and engineering development, none of the techniques work.

The reasons none of the incentives work are first, while the end objective of any company is to make a profit, the intermediate objective during the technology development and transition phase is to survive. Survival means a potential for a production contract and production contracts are where profit is to be made. It follows then, that to survive one must participate, to participate one must win contracts, and to win contracts one must have a competitive price. This focus on price then is the second reason: the contractor will always scope the bid to the money available. This makes the entire contract somewhat artifical and hardly worth applying very precise incentive criteria (the micrometer on the doughnut again). This brings up the third reason: the Government cannot afford to make the incentive profits large enough, in an advanced or engineering development contract, to exert much more than gentle pressure on the contractor. A maximum profit of $2 million on a $20 million contract while a significant amount of money, pales in the shadow of a billion dollar production and support contract. Finally, even the negative incentive of the firm fixed price (FFP) contract has not worked well as a technology transition device because of the psychology of failure. Contractors do not wish to gamble on new technology if the possibility of both failure and loss of profits exists. Both of these negative factors are present in FFP contracting.

It is evident from this discussion of contractor incentives that some new or different form of contracting is warranted. It is beyond the scope of this paper to describe an entirely new technique, but a general philosoply can be discussed based on concepts already available within the limits of the Armed Services Procurement Regulation. Briefly, the approach would be to structure the contract such that the focus on loss of profit of a fixed price contract is combined with the flexibility in technical innovation of a cost contract. The contractor would share the risk or "bet" on those things he is expert at by bidding fixed price. The contract would be multi-phased and provision for renegoiation of the next phase price based on previous phase results would be included. This would limit the contractor's potential for losses while maintaining Government control of contract price. Things over which the contractor has no control would be contracted on a cost-plus-no-fee basis. Thus, his fee is derived soley from those areas in which he has expertise and assumes risk, but he is not assuming so much risk that he will trade away technology or improved performance.

Opportunity for technology transition in Group 4, that of interservice communications and motivation, is virtually untapped. While some joint programs do exist, they are constantly bombarded by the parochial interests of each Service and if they succeed it is in spite of, not because of the management practices of the individual Services. More likely, any transition that does take place is done by the contractor through the medium of selling the same technology to two or more Services. While this does accomplish a large amount of transition, the expense is staggering. We can no longer afford technology that is painted blue for the Air Force, grey for the Navy and green for the Army. Motivation in this area is part of the charter of the Director of Defense Research and Engineering, but prudent management on the part of the Air Force would dictate an expanded interest in the laboratory activities of the other Services.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This paper started with the thought that if there was a "problem" of technology transfer it may have real and imaginary parts. From the discussions of the various Service approaches, the camouflage factors and the road-blocks, it can be seen that the real problems of technology transfer are to maximize the process and communicate the success to higher authority. The imaginary part is the notion that the Services have done nothing about it. This is not to say that the process cannot be improved, it can. But improvement will only come with radical change to our way of thinking and DoD contracting.

From the foregoing discussion, we can draw the following conclusions:

- Technology transition may not be the best measure of merit for the evaluation of technology base programs, but it is the one DoD and Congress understand. It behooves us, therefore, to concentrate on the communication of successes.

- All three Services have worthwhile aspects of their technology base management programs and the movement toward more use of competitive prototypes is a positive factor in technology transition.

- More than enough organization, documentation, assessment and review procedures exist for the Air Force to assure that the laboratories are focused on the needed technology base efforts.

- No real structure exists, however, for the formal commitment of technology based programs to transition to system programs upon successful demonstration.

- Communications between and motivation of the laboratories, a system program office, DoD, Congress and contractors are the key factors in technology transition; not the technology itself.

- The off-the-shelf syndrome must be supplemented by increased use of competitive prototypes and preferred procurement.

- The current concept of IR&D must be changed and structured to focus on specific problems that relate to the individual company expertise.

- Competition must be maintained as long as possible in the development cycle.

- More stringent rules must be applied to the evaluation of qualified bidders, and poor performers deleted.

- The structure of incentives must continue to evolve new, more relevent incentive contracting techniques that neither threaten ruin to the contractor or exorbitant prices to the Government.

- There is virtually no formal cross feed of technology between the Services except through contractors and professional socities.

Recommendations

From the discussion and the conclusions drawn above, the folowing recommendations are made:

(1) Use the investment strategy document throughout the Government and Congress as the baseline for information about the successes of the program and the reasons it should continue.

(2) Reorient Air Force thinking toward long range planning on the lines used by the Army and Navy. As part of the assessment process from the acquisition division, require a project home and funding be identified to assure that funds are programmed in the outyears and no transition gap is experienced.

(3) Eliminate intermediate layers between the laboratory and the acquisition division and either return control of advanced development funding to the acquisition division or make the individual laboratory commanders directly responsible to the acquisition division commanders.

(4) Orient laboratory technology base management techniques along program office lines to ease the communications process, i.e. use of cost and schedule reporting, configuration tracking and control, and design review; and fence the advanced development budget to prevent raids on the project resources by system programs.

(5) De-emphasize the use of off-the-shelf and return to the concept of up-to-date avionics technology for new aircraft.

Aircraft like the F-16 are not built using old wing parts from F-86s, and there is no reason to treat avionics any differently, if adequate competitive prototyping is done. kinds of projects.

(6) Develop new procedures in IR&D aimed at a more structured approach that emphasises Government requirements rather than maintenance of the industrial base.

(7) Initiate the concept of preferred procurement in which only those contractors who build successful prototypes are guaranteed that they will be the companies bidding on a particular production program.

(8) Improve procedures for evaluation of qualified bidders to eliminate those with poor performance records.

(9) Direct the use of contracts that share the risk between the Government and the contractor and drop all forms of technical performance and schedule incentives in advanced and engineering development contracts.

(10) Integrate mandatory evaluation of the technology available from other Service laboratories in all assessments of advanced and engineering development proposed programs.

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