STUDY OF A CONTRACTORS CAPABILITIES CENTER AND THE TECHNOLOGY TRANSFER PROCESS

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FINAL REPORT
15 March 1966 - 30 June 1968

Contract No. NASr-63(09)

MRI Project No. 2965-D

For

Chief, Dissemination Branch (Code UT)
Technology Utilization Division
Office of Technology Utilization
National Aeronautics and Space Administration
Washington, D. C. 20546

PREFACE

This report presents the findings and recommendations of a research program that examined the feasibility of a NASA contractors Capabilities Center and certain implications for Technology Utilization, in general, which were developed during the course of the investigation. The report summarizes the findings of an earlier preliminary report (Feasibility of a NASA Contractors and Sub-contractors Capability Center - Phase I, Midwest Research Institute, 18 August 1966) and then in separate sections presents additional findings and recommendations concerning the Capabilities Center design and Technology Utilization Programs.

The research was conducted as Task (09) of basic contract NASr-63 and was Midwest Research Institute Project 2965-D.

The principal investigators were Mr. Howard Gadberry and Mr. Robert E. Roberts. The judgments expressed are those of the investigators and do not necessarily reflect the views of the National Aeronautics and Space Administration or the official positions of the companies and other government agencies surveyed during the course of the project. However, acknowledgement is made for the cooperation and contributions of a number of offices, companies, and individuals without which this study could not have been made.

Approved for:

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6 September 1968

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Introduction and Methodology

NASA's contractors are evolving many technical capabilities important to the achievement of space missions. These capabilities have potential application in other public and private fields. Rapid access to these capabilities through a systematized and consolidated reference file would have immediate benefits for NASA's procurement activities and would foster the diffusion of these new technologies throughout the full range of private and public economic endeavor.

This report examines the feasibility of a comprehensive, multi-user, NASA Contractors Capabilities Center and sets forth some insights into the technology application process. These insights can provide guidance to designers and operators of formalized technology transfer programs--such as NASA's Office of Technology Utilization.

The investigations were based on the premise that a valuable and workable Capabilities Center would have to augment the existing, informal system of capability identification, expression, communication, and application. Therefore, selected NASA contractors were interviewed to define broadly the types of capabilities they had developed, types of descriptive information required, major constraints to be recognized in design of the center, and opinions of contractors as potential suppliers of information to the center and as potential users of the output. Subsequent investigations sought similar data from other user classes--primarily, different interests within NASA--and interpreted these findings both in terms of Center feasibility and improved management of technology transfer.

Survey Findings

The survey disclosed that contractors do not typically identify or name their capabilities in terms of technical tasks or processes required in the performance of contracts. Instead, they adopted an "outside" viewpoint and named capabilities in terms of the item or service finally delivered to the buyer. In their capability statements contractors also included a number of nontechnical, organizational, and control procedures which the contractors believed were important in the supplier selection process. Consequently, the process of capability identification and expression was found to be extremely difficult and complex, and presented formidable conceptual and information processing problems. Among the specific findings were:

* Contractors' capabilities are identifiable, but they are not necessarily identifiable in a form useful in a reference file.

* Capabilities are not viewed in a technical frame of reference. They are not defined as abilities to perform discrete technical tasks or named in accordance with required technical actions or described simply as mixes of technical resources.

* Contractors see capabilities in market-oriented, company goal-conditioned ways. Like all business, aerospace contractors must be concerned with perpetuating the firm and earning a profit. Capabilities are addressed to these ends and capability statements are an integral and important part of the marketing process. Within this limit, company goals condition the visibility of capabilities, the importance attached to them, and the problems to which they are addressed.

* Capabilities are mission-directed and organismic. Capabilities represent a combination of component elements having a value or utility greater than the sum of the parts. They are assembled in response to an expressed or implied need. Since they are tailor-made, an objective must be specified prior to the development of a useful capability statement.

* Contractors have difficulty expressing their capabilities abstractly without a reference point. Even with a reference point, capability expression is a difficult task. As a result, contractors have evolved a marketing procedure that is very personal, depends upon technical interfaces, and avoids explicit capability statement.

* Capabilities are expressed in order of importance to market success. Capabilities and capability components not important to the achievement of company goals tend to be ignored and are often not exploited.

* Capability description often includes the following information: what we know how to do, how we control what we do, and the resources we do it with. Contractors concentrate on making their capabilities known to present customers and often fail to see needs outside the aerospace market, to which their capabilities could be addressed.

* Definition of capability is conditioned by the nature of a contractor's business--size of the firm, systems vs. components, research vs. production.

Implications for a Capabilities Center

Information characterizing contractors' capabilities of all types could be handled within a single general purpose file to serve the needs of multiple users. Differences in format and language of capability statements furnished by contractors do not necessarily render the information incompatible. Because of these differences, however, the input information would require additional analysis and processing; the data file, index structure and terminology controls must be larger and more complex, and special routines for retrieval would need to be developed.

Broad, multi-purpose capability files do not appear justifiable at the present time because such a center would involve costs, both to NASA and to NASA contractors, which outweigh the benefits to most users over the methods presently employed.

A more specialized NASA Contractor Capabilities Center designed primarily to support and enhance Technology Utilization activities is suggested as a more attractive alternate: a file of rare or unique capabilities.

An inventory of NASA contractors' capabilities representing novel, rare, new, or unique abilities to solve problems would both complement and augment Technology Utilization Division efforts in technology transfer. Such a "registry of rare capabilities" would aid NASA in five areas:

a. Monitoring of technical needs;
b. Identification of innovations;
c. Documentation of state-of-the-art surveys, as well as individual innovations;
d. Matching of innovations or capabilities with needs;
e. Assessment of benefits from technology transfer.

Technology Transfer Implications

NASA's contractors are continually engaged in developing, adapting, accepting, and utilizing new technologies. The procedures which they have adopted; their views of capabilities; their behavior with respect to capability development, application, and marketing; the constraints which act upon this process; plus related matters--all have relevance for the enhancement of existing technology transfer programs and the design of new approaches.

High technology utilization leverage could be obtained through programs providing three elements: (1) an identified non-space problem to which capabilities can be addressed; (2) a sufficient incentive to make the undertaking worthwhile; and (3) an environment facilitating face-to-face interchanges between the possessors of unsatisfied non-space needs and possessors of aerospace induced capabilities. NASA's Biomedical Application Team program is one current effort that follows this general approach. There is promise that NASA contractors can be encouraged to play more active and direct roles as transfer agents by programs based on "demand pull."

Only a fraction of space contractors' capabilities are reported to NASA under the provisions of the New Technology Reporting Clause. This occurs because few capabilities are developed solely for NASA and because capabilities are complex and are not viewed in a way that produces reportable "items." Thus, consideration should be given to programs that encourage transfer without going through existing technology reporting procedures.

For individual firms the cost of obtaining information about transfer opportunities often deters application. Economies of scale can be achieved by developing such information at a single source and then distributing it to all potentially interested parties.

We conclude that transfer programs concentrating on "demand pull" would effectively complement programs keyed to "technology push." We recommend that NASA, in cooperation with other public agencies, private associations, and foundations, consider the development and dissemination of "non-space need" (market opportunity) information as an inducement for transfer. This could be done in much the same way that technology information is now developed and disseminated.

Finally, it appears that formal technology utilization programs can benefit from more knowledge about the normal process whereby technology is transferred and applied. We recommend further research on the process, offer a research framework hypothesis, and suggest specific types of investigation.

II. INTRODUCTION

A. Background

In recent years NASA has levied many advanced requirements on American industries. The response in all fields--scientific, technological, manufacturing, and management--is a matter of record. The success of the response is attested to by the successful completion of a number of NASA programs and rapid progress in other, even more advanced, programs. Satisfaction of space exploration requirements has necessitated many state-of-the-art advances which have been incorporated into the skill inventories of NASA's contractors and subcontractors.

To realize the full potential of these new and augmented industrial capabilities, NASA has undertaken a number of steps to facilitate further their application within NASA's primary mission areas and their use in satisfying other public and private needs. This report is the product of one such step.

It presents the findings of a study that explored the feasibility of a Capabilities Center that would catalog and provide reference services for the specific technical capabilities possessed by NASA's contractors and their sub-contractors. NASA was particularly interested in the reference center's potential as a mechanism for furthering the application of space technology in other fields. However, the Center was to be designed to serve a broad range of NASA and other users. Included among the potential NASA users who have need of capability information were the procurement offices, the program offices, the NASA centers, and of course, the Technology Utilization Office. Other potential users included government agencies, the contractors themselves, non-aerospace industry which might make use of NASA contractor capabilities, as well as other private interests.

B. Methodology

The study plan employed a two-phase research program. The first phase was a pilot survey of selected contractors to define broadly the types of capabilities to be cataloged, the types of descriptive information required, and the major constraints which had to be given recognition in the design Center. Phase II was to progress to the specification of design criteria for the Center, including: the type or types of cataloging systems, the data to be provided with respect to each entry indexed, controls on access, the geographical location of the Center, and information on how the Center might mesh with existing reference sources.

Nine companies were surveyed during the course of Phase I. The sample was selected to provide a mixture of large and small firms; prime and sub-contractors; and component, hardware, software, systems; and R&D contractors. A wide geographical distribution of firms was also sought. The specific firms selected were: Arinc Research Corporation; Ball Brothers Research Corporation; Electro-Optical Systems, Inc.; Excelco Development Inc.; General Electric Company - Missiles and Space Systems Division; General Precision, Inc. - Systems Division; Honeywell, Inc. - Aeronautical Division; and Statham Instruments, Inc.

Each company was interviewed in depth. Topics discussed included--but were not limited to--the following:

1. The types of special capabilities that the contractor had developed or enhanced through NASA work.

2. The circumstances surrounding the achievement of these capabilities--i.e., why the capabilities were developed.

3. Other NASA and non-NASA uses to which these capabilities had been put.

4. Current sources or methods used in identifying the specialized capabilities of others and the attributes and limitations of these existing sources.

5. Opinions regarding the proposed Capabilities Center, including an assessment of the value to the contractors (both as suppliers of information and potential users of the output), of experience with other files and registers of capabilities, their willingness to participate, and problems or difficulties anticipated.

The interview findings disclosed a number of practices and tendencies on the part of contractors that might severely restrict the utility, practicality, and feasibility of the originally planned Capabilities Center. Many of these factors stemmed from the nature of "capability," as the contractors define the term. It turned out that contractors did not typically identify or name their capabilities in terms of technical tasks or processes required in the performance of contracts. Instead, they adopted an "outside" viewpoint--they named their capabilities in terms of the item or service that they finally delivered to the buyer. They also included in their capability statements a number of nontechnical, organizational, and control procedures which they believed were important in the suppliers selection process employed by buyers. Consequently, capability identification and expression was found to be an extremely difficult and complex process which presented both conceptual and information processing problems not originally considered. While NASA contractors were found to possess an impressive range of capabilities, some of the unexpected findings--e.g., about the origin of new capabilities, the ways in which contractors look at their own capabilities, and the question of whether capabilities are fully exploited--indicated that the original concept of a NASA Contractors Capabilities Center should be re-examined.

C. Phase II

As a result of the findings, questions raised, and new opportunities suggested by the pilot survey, NASA's project monitors requested that design planning for a Capabilities Center be postponed. Instead we were asked to take additional steps to test the validity and generality of the major hypotheses derived from the previous survey. This took the form of a limited number of additional interviews and a review and analysis of relevant literature. Potential NASA users of the Center were also contacted to provide their views on the utility and desirability of the Center. A final portion of the redirected study was aimed at an analysis of a number of findings which promised a basis for better understanding of the process whereby technology is utilized in new ways or applied to new problems. Such an examination might lead to new approaches to the transfer of NASA technology and/or improved effectiveness in existing Technology Utilization Programs.

The balance of this report sets forth our findings with respect to the ways in which contractors view their capabilities. We discuss both the implications of these views for the Capabilities Center, and the design of approaches to speed the transfer of technology.

The findings are presented in four basic sections. The first is a review and expansion of Phase I findings. It lays the foundation for the following sections. The second presents implications from our findings for a successful Capabilities Center. The third contains implications for Technology Utilization in general. Conclusions and recommendations are presented in the Final Section.

III. SUMMARY OF PHASE I FINDINGS

This section of the report presents a summary of the findings of Phase I. These findings form the basis for a later discussion of the implications concerning the design of a successful Capabilities Center and its potential usefulness, as well as suggestions relating to technology-utilization program modification. The discussion of each finding is based, in part, on the findings of Phase II research.

A. Contractors Do Have Identifiable Capabilities

The conclusion that contractors have developed impressive capabilities, and that these capabilities can be identified, is fundamental to all others, and was not unexpected. However, the fact that contractors have identifiable capabilities does not necessarily mean they are directly identifiable in a form useful in a Capabilities Center. In most instances the capabilities are not static but are continually being developed and extended. NASA programs and funding have played, and continue to play, important roles in this process. However, only rarely will contractors admit that their capabilities are directly or solely traceable to NASA. More typically, capabilities are said to have been brought into being through a combination of company, NASA, Air Force, and other government agency funding. To some extent, this may reflect concern on the part of the contractors with NASA patent policies, i.e., if the company can show that sources of funding other than NASA were important in the development of the capability, then it may be able to retain a proprietary position or patents associated therewith. However, we do not believe that NASA's patent policies are a major consideration in the reluctance of companies to specify a specific source of the capability. Instead, it appears that capability development is an on-going and integral part of being in the space industries. New capabilities are most frequently said to be the result of corporate response to a need implicit (or explicitly stated) in the requirements of advanced government programs. Capabilities are rarely developed to support any single requirement or to solve a specific technical problem encountered in the course of a program. In short, capabilities are usually developed in response to a recurring problem, or a problem that is generic to a number of programs which offers significant market opportunity.

Although more will be said on this point later, capabilities are typically composites. A capability is not a facility, or a piece of equipment, or a particular set of skilled personnel. Instead, capabilities are sets of resources (including the preceding plus many others) that are addressed to some particular end. As a result, it is possible to distinguish between latent capabilities and capabilities in being. For the latter type, the outside stimulus of an expressed or perceived customer need or simple competitive pressure has been applied to the company which in turn reacts by marshalling its resources (its latent capability bank) into a capability in being.

B. Capabilities Are Not Viewed in a Technical Frame of Reference

Contractors do not define their capabilities in terms of abilities to perform discrete technical tasks. Capabilities are not named in accordance with the specific technical actions required, nor are they described simply in terms of the mix of technical resources--people, equipment and facilities--required to perform the task. In addition, few capabilities are described in terms of technical functions; instead, the focus is on the commodities delivered as end items.

This lack of focus on the "technical" or methodological aspects of capability, particularly in view of the importance of technical task accomplishment in aerospace industry, may seem surprising. The relative lack of emphasis on the technical aspects of technical capabilities, however, is a product of normal business behavior. Even though the contractors sell highly sophisticated, advanced technology goods and services to NASA and the defense establishments, the performance of technical tasks is only one of several types of activities that must be accomplished skillfully if the firm is to be successful. A company's success in the aerospace industries, as in other industries, requires the satisfactory performance of a number of functions, including design, production, marketing, planning, and control, finance, and distribution. Elements of each of these are included by contractors identifying their capabilities. This is particularly true of adaptations they have made to satisfy the peculiar requirements of the aerospace market. Thus, companies are particularly aware of their skills in scheduling, planning of complex operations, procedures for maintaining rapport with the technical customer, and other skills supporting the delivery to the customer of their highly technical products or services.

Contractors often refused to stress technical factors in describing their capabilities. Their response, in effect, was: "You've got it all wrong. It's not that anything we can make we can sell--it's that anything we can sell, we can make. The important parts of our capabilities are all the things we do in order to maximize the ability to sell to our chosen markets. Only when we do these things first, are we able to utilize our technical skills."

C. Contractors See Capabilities in Market-Oriented, Company Goal-Conditioned Ways

Aerospace firms, like all private enterprise, are fundamentally interested in perpetuating themselves and making profit. This seems to be particularly true with large investor-owned firms. Management is responsible (and judged) for its ability to insure that the company stays in business and provides at least a reasonable return to the investor. This applies equally well to companies engaged in technologically prosaic industries or in high-technology space industries.

A company cannot be profitable unless it makes sales. Its capabilities are addressed to this end. An appliance manufacturer will not be successful unless it can supply and sell a product that satisfies consumer wants. The product and the means of manufacturing and distributing are all means to the end: the sale, and ultimately the profit. The same holds for the space industries. The product or service they provide and the technical skills or capabilities employed are again means to the end of achieving sales and finally profits.

Capability statements are conceived and expressed with these facts in mind and are an integral and important part of the marketing process. This situation causes the company to see its capabilities in a much different light than would be the case if these economic considerations were not present. Thus, capabilities are market-oriented and are perceived as being different from an internal-skills inventory of a company, which would focus on elements and functions rather than on the resulting marketable product. The internal-skills inventory is not a capability statement, but rather a statement of the pool of resources to be drawn upon to accomplish a technical task. The internal-skills inventory can be used to work up a production plan, which is one step closer to a capability: the plan represents a marshalling and organization of resources to accomplish a technical objective. But a production plan is only one sub-set of a capability and the technical objective is not the ultimate objective. A capability also includes contributions from all the other normal business functions--marketing, distribution, finance, management, support services, etc.,--formed to produce sales and provide profits.

Not all companies are motivated solely by economic factors. At least three of the companies we talked to were strongly impelled by non-economic forces, and saw their reason for being--and obtained their satisfactions from being--at the frontiers of science and technology. But even in these cases the economic realities placed powerful constraints on what they undertook and how they went about their work. Even these firms which were predisposed to view their capabilities in a limited technological way were forced to view and express their capabilities in a market-oriented way.

Within the broad context of a market-oriented view of capabilities, company goals affect the visibility of capabilities possessed by a firm, the importance attached to them, and the problems to which they are addressed. For example, one company saw itself as basically a scientific enterprise. It sought research and development contracts, sometimes followed by limited production of the resulting hardware. It did not seek volume production contracts. In fact, from time to time it had diverted to other organizations several products which had reached the volume production state. The company had strong potential manufacturing capabilities, but these were not exploited because such exploitation would have been in conflict with basic company goals. The manufacturing skills were regularly employed in the conduct of their operations--but they were viewed as supporting skills. Because the firm did not view itself as a manufacturing company, major market or goal changes would be required before these manufacturing skills could be developed into a major capability.

Another company viewed itself as a high-technology, component supplier, and avoided R&D contracts which might taint its patent position.

The differing goals of the two companies produced radically different views of the capabilities. In addition, the two companies aimed their marketing efforts at two different customer segments. The first maintained extensive contact with research buyers, and the second concentrated on hardware buyers.

D. Capabilities Are Mission-Directed and Organismic 1/

Contractors do not view their skills as capabilities until they are gathered together to satisfy some mission. In addition, capabilities are a combination of component elements with a value or utility greater than the sum of the parts. In our discussions with various contractors, we tried very hard to get the interviewees to reduce their capabilities to fundamental elements that are discrete, easily named, functional, and consequently comparatively easy to catalog or index. Contractor representatives inevitably resisted this kind of capability formulation. They consistently expressed their capability at a higher level than the process elements, facilities, knowledge, organization, etc. For example, we would attempt to get an optical instruments manufacturer to express his capabilities in terms of designing, generating, and figuring optical elements, precision machining, assembling, collimating, and testing. His response, however, would be that his company's capability was "stellar navigation devices." By so responding, contractors were telling us at least three things:

First, capabilities exist at a higher, more complex level than the component elements that must be combined to produce a capability.

Second, an objective must be specified before a capability can be assembled. This means that skills for which there are no known needs (markets) are not capabilities--because to the contractor the capabilities must be salable. Either the customer must state that he has an unsatisfied need, or the company must perceive that the customer has an unsatisfied need, before the contractor can assemble the capability. The putting-together of a capability depends upon where a contractor starts. Assembly can include all or some of the following: (a) focusing upon and mentally identifying a potential capability, (b) generating and naming a capability which speaks to the market need by relatively minor alterations of an existing capability and/or (c) actual mobilizing and organizing a new capability from a resource bank plus the acquisition of new capability elements from outside the company.

1/ For confirmation, see: Howard Reiss and Jack Balderston, "The Usefulness of Scientists," International Science and Technology, May 1966, pp. 38-44.

Third, the components or elements of capability are not limited to technical skills alone, but also include the skills necessary to get the business in the first place, and then to organize and control the application of the technical skills to the achievement of the market-defined mission.

E. Contractor's View of Capabilities Defines Behavior

Behavioral characteristics of contractors stem from their view of capability, and even more fundamentally from the forces that shape their views of capability. These behavioral characteristics have a number of significant implications for the Capabilities Center and for the design of technology-transfer programs.

1. Contractors have difficulty expressing their capabilities abstractly without a reference point. To some extent this is a result of the sheer abundance of talent possessed by many contractors. More important, the way they do business (i.e., assemble their talents to satisfy a specific need) does not require that they learn how to state capability abstractly. Finally, general listings of elemental skills which make up capability are not compatible with the organismic nature of capability. Dissecting a capability into its parts may make the capability unrecognizable and would certainly undervalue it. For example, Statham Instruments has a rare capability in Thin Film Transducer Technology. The major technical elements making up this capability are:

- Substrate finishing to optical surface quality,
- Multiple vacuum deposition--dielectric ceramic, strain gage alloy, and lead elements,
- Ultra-precise lead-wire welding,
- Integrated electronics,
- Accelerated aging and stabilization techniques,
- Materials know-how--alloys, seals, and dielectrics, and
- Performance of these operations at a microminiature scale.

Although somewhat sophisticated, none of these elements is unique. However, their combined application to transducers is: the transducer produced represents a radical departure from traditional strain gage design and production; and the performance in terms of precision and operating environment is dramatically improved.

The difficulties associated with abstract capability statements cause the contractors to view with alarm requirements imposed on them by various governmental customers for before-the-fact, nonproject related, overall capability statements. Several agencies now require such statements. The contractors feel that they are not used; that they are really not usable; that there is much duplication; and they certainly do not want this study to result in another system having the same faults.

2. Even with a reference point, capability expression is a difficult task. The complex nature of capability makes this the case. The fact that reference points (Requests for Proposals and the like) are often somewhat vague is a further complication. Contractors believe that they must read between the lines to identify what the buyer really wants and then form the capability statement accordingly. Further proof of the difficulty of the task is found in the variety of crutches used by contractors in discussing their capabilities. They rarely make a single statement such as, "Our capability is . . . ." Instead they will continue with, "By that I mean . . . ., and we have applied this capability to the following programs . . ., . . . , . . . , in the past." Description in terms of the output from a capability (the resulting product) is an even more common means of circumventing an explicit capability statement. Finally, the meaningful expression of capability seems to require that the presentation be made to a technically qualified audience.

3. Contractors have evolved a marketing procedure which is very personal, depends upon technical interfaces, and avoids explicit capability statement. In this process both buyer and seller are represented by technical people. The seller's representative continually cultivates the buyer's representative in an attempt to keep abreast of the buyer's requirements long before specific RFP's are issued. In fact, the interchange of information between the two is reputed to be a significant aid to the process whereby the buyer determines exactly what tasks he wants to undertake. All contractors indicated that this cultivation was absolutely necessary to their continued success. If they waited for the issuance of an RFP, they believe that their chances of getting the job are slim.

The interaction between technical representatives of the buyer and seller is said to work like this: Using their technical backgrounds, the two are able to discuss existing hardware characteristics and translate these into modifications and advances required to perform the new mission which the buyer has in mind. From this background the seller's man draws implicit conclusions as to the capabilities required to accomplish the job, or produce the new piece of hardware. Then, he draws examples from his company's past hardware work that demonstrate the company's capability to supply the desired item. The buyer's man then judges the company's capabilities by translating the tendered hardware examples back into capability.

Again, the translation is intuitive. Note that this process avoids the difficult task of explicitly formulating and presenting capability statements, and that this is accomplished through a close personal interface between members of the technical fraternity.

Before the contract is let, all the formal written steps are of course taken. But all contractors surveyed believe that this is largely after the fact; i.e., the buyer has largely made up his mind about who is best qualified to get the job based on previous discussions.

None of the contractors surveyed believed that this personal phase of selling (capability presentation) could be replaced by a computer-based Capability Center. However, all indicated that the existing process was expensive and wished that something could be done to assist the process and thus cut costs.

4. <u>Contractors express their capabilities in order of importance to market success</u>. This tendency is very important because it can often obscure true technical capabilities. TRW Systems finds its principal capability is to mobilize and manage a bank of resources (primarily expressed as people in a broad range of specialties) to yield an operating payload hardware system of almost any type the customer requests. All their wealth of technical skills are subordinate to this overall capability.

ARINC Research Corporation indicated that its most important single capability was its impartiality and lack of bias; more explicitly its ability to truly and objectively represent the interest of its customers. This is obviously a nontechnical feature, but given the type of work done by the company, it is of fundamental importance in getting business. ARINC Research operates for its governmental customers as a staff expert in systems effectiveness. When so contracting for its government customers, its position is analogous to that of the Aerospace Corporation except that the area of expertise is narrower. Violation of confidences tendered by either the customer or the company, whose product or processes were being examined from a reliability viewpoint by ARINC Research, would be disastrous to the future of ARINC Research. If confidence and integrity are not maintained, the company will not get to apply its recognized strong analytical technical capabilities.

Ball Brothers Research Corporation and another firm stress their capabilities in systems management and systems engineering because of customer influences but for a somewhat different reason than ARINC Research. In the case of these two companies, their capabilities in the above areas came about as "fixes" which were necessary to improve their market positions. Ball Brothers Research started out quite small, grew rapidly, and finally found that coherency of effort was jeopardized under the then existing organization. The company therefore reorganized on a program basis so as to provide a substantially better framework for systems management. The other firm, a traditional supplier of rather sophisticated components to the aircraft industry, found that it was losing sales as the aircraft industry evolved into the aerospace industry. The apparent reason was that the marketing game had changed as the demands of aerospace placed more emphasis on integrated systems. Thus, to sell components, the firm was forced to move into systems engineering. Both companies feel that these adaptations to the market have added significant--perhaps vital capabilities.

5. Contractors tend to ignore or fail to exploit capabilities and capability components that are not important to the achievement of company goals. Statham has a number of processing capabilities that are subordinate and necessary to its overall Thin Film Transducer Capability. However, it would be unlikely for the company to actively seek business in one of these areas unless the new business area was consistent with the company's goals or market missions.

Our visit to Electro-Optical Systems was made just after its acquisition by the Xerox Corporation--before Xerox goals and market philosophy had pervaded the organization. Company goals still mirrored the interests and motivations of EOS's founder, Dr. Abe Zarem--one of this nation's outstanding scientists. The company viewed its great strengths as being in basic scientific phenomenological research and subsequent development addressed to the problems associated with unmanned spacecraft. Time and again during the interview at EOS, examples were called out wherein items with market potential had been carried through the small lot production stage, and then either abandoned, or a manufacturing subsidiary created to exploit the more mass market. The reason given in each case was that EOS was not a manufacturing company; its strength lay elsewhere; and consequently it did not intend to dilute its effort by engaging in off-the-shelf manufacturing.

Now, two years later, the goals of EOS have been markedly altered through a combination of Xerox ownership and market pressure, i.e., the research market has contracted and the military hardware market has expanded. Major changes in the company's view of its capabilities and their application have followed. EOS retains its research excellence but this is not an end in itself. Today, emphasis is on the manufacture of operational hardware in high obsolescence mass market areas. Scientific research is conducted in support of this manufacturing function.

Honeywell is another example. This firm has explicitly carved out areas of primary interest to the company and established goals in each.

All company activities are geared to attaining these goals.[1] Such a policy exemplifies the excellent management and control for which Honeywell is well known and is obviously beneficial to existing customers (they can count on the maintenance and further development of the capabilities they buy from Honeywell), but it also inhibits the acceptance of unplanned for, tangential, walk-in-the-door business to which Honeywell's capabilities might be addressed.

As the preceding illustrations indicate, company goals exert a powerful influence on a company's view of its capabilities. In many cases this view severely inhibits the application of capabilities in new areas. However, this limitation is not so strong that it cannot be overcome, if sufficient market potential is demonstrated to warrant goal reevaluation. Such was the case with Statham in its move into medical instrumentation and electronics. Market forces were also important in the Electro-Optical Systems product line shift. But the companies do appear to be reluctant to respond to one-time, tangential business for their subordinate capabilities such as might be referred to them by the Center.

6. Contractors include nontechnical as well as technical factors in describing their capabilities. Examples of this tendency at ARINC and Ball Brothers were noted earlier. The reason is that nontechnical factors often control who gets the contract--particularly when the choice is among relatively technical equals. Thus, the survey showed that a relatively complete capability description would include the following types of information:

a. What we know how to do: This would be the technical heart of the capability. An example would be Statham's Thin Film Transducer Technology. In this portion of the description the general field is named. It would probably be followed by hardware proofs citing examples of past applications of the products produced by the capability.

b. How we control what we do: This information includes statements about management, company organization, systems know-how, quality assurance, documentation, and so on. All are nontechnical but all are important to getting and keeping business.

1/ For more on this approach and a description of the techniques employed see: Lawrence D. McGlauchlin, "Long Range Technical Planning," Harvard Business Review, July-August 1968, pp. 54-64.

c. Resources we do it with: People, facilities, equipment, and finances are general classes of resources called out in this part of the statement. They are the ultimate building blocks out of which both the technical and nontechnical aspects of capability are constructed.

The upshot is that there are a number of required market- and buyer-imposed factors that keep contractors from focusing upon their elemental or functional technical skills.

7. Contractors concentrate on making their capabilities known to existing customers. This is because true capability expression is difficult and expensive. Companies naturally address their efforts in this regard to existing customers where they already have their foot in the door in order to maximize the return. Also, they know the needs of existing customers and are organized to marshal their skills to serve these needs.

8. Contractors often fail to see needs that exist outside of aerospace to which their capabilities could be addressed. The reason is the concentration on existing customers. Thus, application of capabilities to problems outside the aerospace market usually arises because the person with the need stumbles across the company with the capability. This was essentially the case in the two most dramatic transfer instances found in the surveys.

Statham's move into medical instrumentation was initiated by medical researchers with a problem. The medical researchers were located at Wright Field and Statham had an operation there. As a result of this proximity, the doctors learned of Statham's capability and asked that it be applied to their problem. Ball Brothers' manufacture of computer memory-core planes for IBM began in much the same way. IBM moved into Boulder, Colorado, and sought local sub-contractors. Ball Brothers made their basic capabilities known to them, but it was IBM which initiated negotiations for the specific memory-core plane work.

9. Contractors probably fail to see or exploit opportunities for subordinate capability components in non-aerospace applications. Since contractors view their capabilities in an organismic and a mission-directed manner, they are not likely to perceive opportunities to apply isolated skills, and are less likely to actively seek out new applications for such skills. Further, since the component elements of capabilities are only of peripheral importance to company goal achievement, the firm is not likely to actively enter a new area even if an opportunity is identified.

10. The nature of a contractor's business operations conditions his definition of capability. NASA's contractors and their subcontractors are not a homogeneous group. There is no such thing as a typical aerospace firm. There are at least three types of differences among firms which condition the statement of capability.

a. Size: Generally speaking, smaller companies can formulate more explicit capability statements than large companies can.

b. Systems vs. components: Contractors primarily engaged in systems management and systems engineering experience more difficulty in defining their capabilities than do producers of components. The reason is that the systems company has fewer tangible benchmarks to employ as descriptors.

Another aspect of this problem is that many systems firms also do some component work. In fact, they may do the same type of component work as a specialized component subcontractor. But the systems firm probably will not view his component skills as a significant capability. Obviously, the subcontractor will see his component capability as highly significant. This characteristic is an impediment to complete disclosure of the universe of capabilities possessed by NASA's contractors.

c. Research and services vs. production: Identification of capabilities possessed by contractors primarily engaged in either of these activity areas encountered problems similar to those in the system vs. components case. Capabilities in research are in an entirely different class than those in production. Also, the languages used in the two areas of endeavor are markedly different. As a result, a single, uniform method of describing the capabilities of all NASA contractors is difficult to foresee.

IV. IMPLICATIONS OF THESE FINDINGS FOR A SUCCESSFUL CAPABILITIES CENTER

The project findings contain highly significant implications for (a) the desirability of a Capabilities Center and (b) the major characteristics and constraints that define a successful Center operation. In fact, when an analysis of the opinions gathered in the Phase II study was added to the interim findings of the pilot study, it became clear that the original concept of a multi-purpose, broadly inclusive nation-wide registry of contractor skills needed to be drastically revised.

Therefore, a major concern during the Phase II studies was to ascertain: (a) what functions a Capabilities Center could and should perform; (b) the practicality and cost of acquiring and processing the necessary data; and (c) the usefulness of the system outputs to various potential groups of users.

The initial concept of a Contractors Capabilities Center, as developed in conversations with NASA, and as described in the work statement and proposal for this project, envisioned a broad gage, multi-purpose, multiple-user information system. Specifically, this project was designed to explore the feasibility and desirability of a national Capabilities Center which:

* Would catalog and provide reference services for specific technical capabilities found among NASA contractors and their sub-contractors.

* Would provide direct benefits to NASA's procurement activities.

* Would aid in the growth and broader utilization of special capabilities developed for, or induced by, the space program.

* Could accelerate the solution of many existing problems in diverse fields.

* Could lead to an even more comprehensive indexing and referral system which would include capability inputs from DOD, AEC, SBA, Commerce, and others.

* Could provide ready access to capabilities appropriate to problem requirements of all government agencies and qualified private organizations.

* Would retrieve information required to conduct studies aimed at assessing the economic impact of the space program.

Some questions were left open: for example, whether prime and subcontractors should have access to Capabilities Center information, how they might wish to use such a system, and whether contractor requirements would represent a significant portion of the total activity in the proposed Capabilities Center. Information bearing on the relations of contractors with the proposed center was gathered in the pilot study, and the views of NASA procurement offices, Technology Utilization, and program offices were elicited and analyzed as part of the Phase II studies.

A. Information Compatibility

The most important implication of the study findings affecting the design and development of a Capabilities Center relates to the compatibility within a single system to support both marketing functions and non-marketing applications.

Analysis of the capability information used in the marketing, procurement, contracting, and sub-contracting processes shows that the content and form of the capability information is significantly different from capability information organized for purposes other than buying and selling. In addition, the vigorously expressed consenses of both NASA contractors and potential users of the Capabilities Center suggest that the two kinds of capabilities information are not compatible, and should not be combined in the same operational system.

Chart 1 presents an array of the principal groups of users or potential customers for the proposed Capabilities Center, together with the main ways in which they can use or provide the information handled in the system. In discussions and correspondence with the various using groups throughout this research study, it was repeatedly made clear that capabilities information and capabilities statements can be and are used for many different purposes. Furthermore, the information requirements of a particular using organization are not unique or peculiar to that group, but rather depend upon two related aspects of the intent of the user: (a) the particular purpose for which the capability information will be used, and (b) the implied role of the user when he seeks information about capabilities. For example, a NASA prime contractor deals with and processes capability information in three different roles:

1. As a seller of capabilities (both his own and those of other organizations);

2. As a buyer evaluating the capabilities of suppliers and subcontractors; and

CHART 1

PRINCIPAL USER GROUPS AND USES FOR CAPABILITY INFORMATION

Using Group	Role	Use to Be Made of Capability Information
NASA - Technology Utilization	Internal	Monitoring of technological skills Supporting documentation, evaluation and special studies
	External	Matching of available technology to problems Identifying areas of benefit, impact, justification
NASA - Procurement Offices	Protective	Building qualified bidders' list Avoiding criticism of procurement practices
	Constructive	Controlling costs Insuring adequate competition Discovering unknown talent
NASA - Program Offices	Conservative (Managerial)	Soliciting best qualified sources to perform jobs which are planned and budgeted
	Explorative	Uncovering new ideas which may expand and enhance missions
PRIME CONTRACTORS	Seller	Making own capabilities look outstanding but not so specialized as to shut them out Strengthening proposal by using subcontractors having reputation, visibility, and good ideas
	Buyer	Selecting qualified, tractable, dependable, and low-cost subcontractors and vendors
	Performer	Maintaining inventory of in-house skills and experience
SUBCONTRACTORS	Seller	Making own capabilities attractive to the prime contractor
	Performer	Locating possible fixes for troubles Selecting vendors
(DOD, AEC, etc.) OTHER GOVERNMENT AGENCIES (OSTS, SBA, etc.)	Seeker of source references	Broadening bidders' list to include NASA's trusted sources Finding sources of rare and unusual capabilities
	Seeker of relevant ideas	Identifying technical ideas potentially useful to groups served by agency

3. As a contract performer occasionally faced with the necessity of finding alternative ways to satisfy technical requirements (either by using other techniques in-house or by employing the skills of other groups).1/

As shown in Chart 1, a wide range of uses is currently made of capability information. We believe that similar capability inputs and outputs would be expected of a broad-gage, general-purpose centralized file of contractor capabilities.

It is important, therefore, to understand how the purpose behind asking for or furnishing capability information determines the content and form of capability information.

The most important single finding of the study is that capabilities are almost universally viewed as an intrinsic part of the marketing process.

Specifically, the view that capabilities are an essential part of the buying-selling process largely determines how any particular capability or skill will be identified, named, classified, documented, verified, displayed or communicated, evaluated and interpreted by the recipient, and eventually acted upon. The majority of conclusions in the Phase I report underscore this point in various ways. The substance and form in which a capability is described by contractors accurately mirrors various levels of the marketing process. Capabilities are described in certain ways because these statements are intended to perform definite functions in selling the technical capabilities of the organization. Contractors name and classify their capabilities in forms that reflect what their customers seek from them. And capabilities are usually expressed in anticipated order of importance to marketing success.

Primarily to assess the degree of compatibility of capabilities data, a more detailed analysis was made of the relationship between (a) the purposes for which capabilities information is expressed and (b) the form and content of that expression.

The purposes of use have been divided into three categories: uses strictly in marketing and procurement, uses where procurement is a secondary but ultimate objective, and uses not concerned with selling or buying.

1/ It has also been suggested from time to time that NASA contractors make use of capability information for the purpose of assessing their technological position in relation to other organizations, and for evaluating the attractiveness of investment in the further development of a new capability for eventual marketing as a specialty of the firm.

1. <u>Capabilities used exclusively in marketing and procurement</u>

- Building and maintaining a list of qualified bidders.
- Soliciting bids from best-qualified sources.
- Selecting vendors (by contractors).
- Broadening bidders' list by adding another agency's sources.
- Presenting capabilities in proposal or bid.
- Strengthening proposal by citing outstanding capabilities of sub-contractors.
- Selecting most desirable sub-contractor.
- Safeguarding procurement process from criticism.

For these purposes, statements of capabilities are a direct medium of communication between seller and buyer, and use a formal, highly stylized almost ritualistic language implying capability at the same time that it avoids specific description. Several simultaneous messages of communication are intended--the image and reputation of the seller, his market orientation, the general technical area of the capability, plus resources sufficient to insure satisfactory performance.

Expressions of capability are basically a metaphor that conveys information sufficient for its audience to evaluate the producer's capability without enumerating the elements and skills which are involved.

<u>Examples</u>:

Controls

Aerospace transducers

Complete capability from analysis through experimental production

Anti-submarine warfare

Solar pointing

Organization for effective systems management

Gust alleviation

Contract cost control program

On-board tape recorders

Navigation, guidance, and control

Station keeping

Gemini communication lasers

Reducing to numbers the complex factors associated with systems effectiveness

Integrated biomedical electronics

Satellite nuclear power systems

Replica optics

Gravity gradient stabilization

Ablative heat shields

Acoustic surveillance and detection

Mars microbiological experiments

Electric space propulsion

Configuration change control

During Phase II of this study we confirmed our hypothesis that the NASA procurement offices viewpoint is remarkably similar to that of contractors who are asked to name their capabilities. The words and tone are nearly identical. The rubric is the same. For instance, the following capabilities are called out in one NASA capabilities classification which--according to the contractors interviewed--represents the best organized and most realistic procurement listing:

Stellar and planetary atmospheres

Organization coordination

Airborne nuclear power plants

Cost-effectiveness methods

Betatrons

Anti-jam communications

Management of quality control

Ramjet engines and afterburners

Frequency interference control

Energy management

Escape, rescue, and survival

Planetary entry analysis

Performance standards

Rocket and missile vulnerability

Command and control equipment

2. <u>Procurement as secondary, but ultimate objective</u>

- Discovering unknown talent.
- Uncovering new ideas and approaches to expand or enhance missions.
- Locating possible fixes for production troubles.
- Assessing own position for make-or-buy decision.
- Identifying sources of rare, unique skills.
- Describing capabilities speculatively, without respect to a particular market or application.

The common factor in each of these uses is that an information problem of some complexity and sophistication must first be solved before any procurement decisions can be started.

Location of a rare or highly specialized ability is especially difficult when the concepts are loosely defined or when nomenclature is new and uncertain.

Searching for skills and ideas which can support a mission in new and novel ways is closely akin to the problem of application matching in technology transfer. The reverse problem--describing capability "speculatively," without knowledge of how it can be used in specific applications or markets--is equally difficult.

Thus, these uses typically require a high degree of differentiation at the conceptual or functional level, yet without much specificity regarding how the job is done. Compound adjectives and modifiers are used to suggest how the ability differs from the ordinary, garden-variety capability of the same name.

This class of capability statement reflects the uncertainty of buyer or seller as to the exact pigeon-hole by which the ability can be categorized, or named, or recognized. Analogy or precedent is often employed. Qualification or evaluation of the capability is a frequent component.

Examples:

Computerized 9th order failure mode and effects analysis

Solid state amplifiers capable of operating at liquid hydrogen temperature

Ultra-high strength weldable alloys

Highly realistic mission analysis

Marked reliability improvement over current state-of-the-art

Thirty megabit digital color TV system

Signal conditioning electronics for remote aerospace and telemetry measurement

Fabricated original H-bomb cases

Newest concepts in solid state transduction technique

First contact ion-engine capable of useful thrust

Knowledge of evaluation factors in selecting alloys for thin-shell pressure vessel applications under practical fabrication conditions

Peculiar circuits

Unfolding satellite booms and locking knuckles

Horizon sensors

Precise passive temperature control

Unique strain gage alloy

Electroforming plant is the most advanced in the country

Unique Magnetotropometer facility

Ultrasensitive sonic inspection facility

3-dimensional display and character recognition variable parameter television test set

3. Uses of capability information not concerned with buying or selling

- Maintaining in-house skills inventory.
- Monitoring of technological capabilities (by NASA).
- Supporting TU documentation and special studies.
- Matching available technology to problems.
- Identifying areas of benefit, impact, justification.
- Searching for technical ideas potentially useful to groups served by other government agencies.

Since these purposes all lie outside the direct buying-selling process, some difficulties will be encountered in trying to use capability statements (which are market oriented) for non-procurement ends. The problem-solving focus of non-procurement capability identification requires a reference description that includes specific sub-elements, organized by function performed, in addition to the name of the end item.

When capabilities are described for non-marketing purposes, there is a strong tendency to focus on specific elements: processes, components, and/or supporting disciplines. This kind of emphasis is especially evident in any attempt to describe a capability in terms of personnel having mastery in highly specialized disciplines, a description which implies a capability to solve problems in these fields.

These capabilities attempt to answer the query: "What can we do?" The format suggests HOW the solution will be achieved, rather than what will be delivered.

Examples:

Vacuum deposition of alloys without fractionation

Slotted airfoil boundary layer control

Diffusion bonding of honeycomb structures

Electrostatic image, passive intrusion surveillance

Protective coatings for refractory metals

Quantum physics

Prediction of stress failure under biaxial strain

Thermionic generator using solar concentrator

Replication process for mass producing quality optics using electroforming and plastic adhesive techniques

Accelerated thermal aging and stabilization of metal diaphragms

Transfer of energy within living cells

Welding leads onto vacuum deposited circuit elements without penetration to metal substrate

Quantification of human transfer functions

Character generation and display techniques

Large vacuum brazing furnaces

Contamination free, laminar flow optical assembly facility

Techniques for adherent precious metal plating

Fiber quartz drawing

Automatic, third-order lens design

Methodology to analyze requirements in detail and with structure using complete hierarchical sets

Substrate finishing to optical surface quality

The chief differences in the ways capabilities are described for these three types of end uses are summarized in abbreviated form in Chart 2.

The differences in format and language do not necessarily render the information incompatible with procurement capabilities. From the standpoint of information technology there is no reason why capabilities information of all three types could not be accommodated in the same file. But it must be understood that the terminology control document would have to be larger and more complex. The file structure or index would be increased perhaps 50 percent, and would require copious cross-referrals. Thus, the cost of designing a capabilities file to use all three kinds of information would be significantly increased.

The cost to NASA of acquiring comprehensive information on contractor capabilities would be relatively modest. The cost of processing and coding the file inputs would be appreciable. But the cost to the contractors who are required to furnish complete capability information may be prohibitive. Five out of the 11 organizations interviewed stated that the cost of providing such data was out of all proportion to the benefits.[1/]

Serious design problems are encountered when we seek to devise efficient file-searching strategies to serve two main types of inquiries. One file-search matches demonstrated capabilities-in-being which are named chiefly for procurement purposes. The second type of file-search requires associative matching of ideas or problems with potentially relevant skills.

Several information-coding techniques are capable of efficiently performing the first type of procurement search. However, comments furnished by NASA Procurement people during Phase II indicated quite clearly that this type of searching is presently performed adequately by using existing files and methods, and that a central system to do this type of matching is not needed badly enough to justify the effort.

1/ Studies by Edward Roberts echo this view--"These systems cause pain to those who must furnish the input data--you can discover this from a discussion with any government R&D contractor." Science and Technology, August 1968, p. 43.

CHART 2

FORM AND CONTENT OF CAPABILITIES

How Capabilities Are:	OBJECTIVE Procurement Only ← Increasing Mission Orientation	Procurement Secondary	Non-Procurement Increasing Problem Solving Orientation →
Identified	Broadly--as total ability to satisfy. With reference to a market. As composites, not elements. To include management and other non-technical resources.	Semi-specific. As sub-systems or elements, sometimes with reference to a market, sometimes not.	Specific elements. As process, service or product.
Named	As what the customer asks for. As deliverable end item.	Using adjectives, modifiers, and qualifiers or either end item or element.	As technical discipline. As product. As technique.
Classified	By markets served. By product class.	By function performed. Also by markets.	By function performed.
Differentiated	By contribution to customer satisfaction.	By HOW it differs, and by DEGREE of difference.	By advantages gained.
Documented	In customer language.	By performance characteristic.	By specifications.
Verified	By precedent of successful application. Naming satisfied customers.	By analogy and precedent.	By test results.
Communicated	At vendor's initiative; or when requested, in order of importance to marketing.	Speculatively, when angling for unknown market. On request from customer.	In response to inquiry.
Interpreted	Subjectively--as metaphor. As credentials of qualification to do related but possibly different job.	Subjectively--as potential to furnish a critical sub-element.	Objectively--as ability to achieve a novel solution to a problem.
Acted Upon	Formal decision regarding advance to next stage of procurement.	Informal negotiation to explore abilities. Leading eventually to formal procurement action.	No procurement action. Information furnished may be end sought.

On the other hand, none of the general inquirer methods which have been developed provides a straightforward solution to the matching and retrieval of problem statements and relevant capabilities.

In designing a capabilities file to perform searching of this more difficult type, one will want a system that can use computerized aids to human judgments of applicability, relevance, and appropriateness. The use of U.D.C. or other facet codes in conjunction with associative nets or relevance trees would go a long way toward providing a reactive tool to aid the matching of problem statements and potentially useful skills.

Some progress toward associative matching has already been achieved in the pilot designs of procurement selection programs such as TORQUE (Technology or Research Quantitative Utility Evaluation). This scheme involves relevance and applicability factors which serve to relate the degree of support or association between capabilities and mission technological requirements. Although much different associative links would be needed for a NASA capabilities file, some of the same concepts are applicable. The development of relevance networks, or arrowgraphs similar to those used by Euratom offer other approaches.

Any such system should be designed so that the inquirer can interact with the machineable file and adjust the search strategy, so as to be able to re-format his query in a dialogue that will flush out capabilities that would otherwise not have been adjudged as pertinent. After identifying a "shopping list" of tentatively relevant approaches for the inquirer, the computer system has finished its job. At this stage human judgment needs to be applied, and more detailed information is required than can readily be kept in machine-manipulatable form. Good old-fashioned reading, understanding, and creative imagination are needed now. But the effectiveness of a TU transfer agent could be tremendously augmented by a powerful reactive capabilities file.

B. Unique and Rare Capabilities

Many of the problems implicit in devising and maintaining a comprehensive and general purpose file of contractor capabilities can be overcome by shifting the focus to the scarce, new, distinctive or unique capabilities.

In ten out of eleven firms interviewed, management was able to identify a few capabilities which they considered outstanding or unique. It seems much easier to answer questions such as--"What can you do that no one else is able to do?" or "Have you learned to do something better than any other firm?"--than it is to identify all potentially relevant capabilities.

In addition to ease of identification, we found that unique capabilities tend to be named and described in a more technical view, and with a problem solving orientation. These characteristics are associated with the description of capabilities for purposes somewhat removed from the procurement situation (toward the right side of Chart 2).

The reason, we believe, is that newly born abilities have not yet become set in the mold of a corporate capability (i.e., "What our customers ask us for"); the contractors still tend to regard these accomplishments as "components" of some future marketable capability.

The functions performed and the means of accomplishment receive more attention than does the market served. This emphasis may result from the capability being new; managers may not yet know many of the ultimate applications that could be developed.

The very nature of highly distinctive capabilities offers one simple means for validating the capability as described: ask who else possesses comparable or nearly equal ability. Two firms suggested this straightforward way of checking. They indicated that firms at the forefront of new technology can usually name their closest competitors in some specialized area of skill or accomplishment. If two groups do not recognize each other as technical front-runners, it probably means that the capability of one is so new that knowledge of it has not spread, or that there may be reason to question the validity of one stated capability.

Newly developed capabilities which have been demonstrated to be unusually successful occupy a peculiar position with regard to contractor willingness to disclose information about the ability. In the speculative stage when the contractor is not sure how far the application of the capability can be carried, or into what markets, management was relatively open and eager to discuss their capability. After a corporate decision has been reached to pursue further development and apply the capability to some defined market, the cloak of secrecy is likely to decend. IBM offers a striking example of this behavior applied curiously enough, not to a product or a technical process, but to a relatively "soft" capability--the methodology for detailed technical mission analysis and economic justification. Management believes this capability to be so valuable that the group which has received awards and national recognition for its accomplishment, is severely limited in discussing the new and outstanding capability.

In most cases, however, contractors are completely willing to make known their unique capabilities. Visibility and understanding by others often lead to new and profitable applications.

V. IMPLICATIONS FOR TECHNOLOGY-UTILIZATION PROGRAMS

A. Contractor Views of Capability Provide Insights Into Technology Utilization

Although this research program was specifically targeted at the feasibility of a contractor Capabilities Center, our investigations disclosed a number of features associated with capabilities--their development, application, marketing, and acceptance--that have implications for a broad range of technology-utilization questions. The fact that a study of technical capabilities would bring to light findings relating to technology utilization should not have been unexpected. NASA's contractors are in the business of developing, adapting, accepting, and utilizing new technologies. The procedures they have adopted in the conduct of their business; their views of their capabilities; their behavior with respect to capability development, application, and marketing; the constraints which act upon this process; plus other related matters--all have relevance for technology utilization.

An examination of typical characteristics of the capability development and application process discloses features that have positive effects on technology diffusion and features that impede such diffusion. Explicit recognition of these factors in the design and operation of technology utilization programs will provide greater leverage per unit of effort than might otherwise be obtained.

The specific insights and implications called out in the following discussion were developed from our interviews, and are generally supported by the literature on the subject.

B. Insights Can Be Used to Enhance Existing Technology Utilization Programs and to Design New Approaches

1. Problem or Application Identification: Our analysis indicates that the greatest technology-utilization leverage can be obtained by the identification of non-space problems to which capabilities or space developed technologies can be addressed. Just about every characteristic associated with the capability formation and buying process supports this view. Given a NASA problem statement in the form of a specific Request for Proposal or even a broad mission statement like--"Place three men in space for ten days, support them, and recover them"--contractors do an excellent job of assessing the technical requirements, forming the necessary capability from their pool of resources, and then organizing and managing the capability to achieve the stated objective.

Our findings indicate that a capability will not be formed until the need for it is perceived by the contractor possessing the requisite skills. And, a capability cannot be applied until it has a buyer. The potential buyer must recognize that he has a need, and that a capability can be applied to satisfy the need. On the other hand, the seller must also recognize the need, and recognize that he has or can form an appropriate capability.

As a buyer of technologies, NASA has exploited these characteristics of the capability-application process. NASA has analyzed its space missions to determine their technical requirements and then widely disseminated these needs to potential contractors, who in turn respond by forming the necessary capabilities, which they apply upon contract award.

This same general approach has great utility in promoting the application of NASA-induced technology to non-space applications. In fact, the Biomedical Applications Teams already follow this approach. First, medical problems are identified. Then, routes to solutions are sought from the body of NASA-developed technology. The BAT concept also provides for adaptation of the technologies to the new medical use. Extension of this approach to (or intensification of existing activities in) other pressing problem areas (e.g., air and water pollution, crime control, transportation, urban reconstruction, etc.) holds high promise.1/

2. Incentive: Although problem identification is a necessary precondition for capability formation, the critical event that must take place before capability application is the provision of incentive to do so. Incentive can take many forms. Important among these are scientific curiosity, engineering tenacity when confronted with an unsolved problem, and money. The first two forms of incentive are very important, but the supply is relatively fixed in the short run by the number of people available with these motivations. There is little that the Office of Technology Utilization can do directly to enlarge the number of these people available. But NASA can exploit the money incentive--more properly, NASA can indicate the market potential available from the solution of identified non-space problems. Given a defined need and an associated attractive market, aerospace resources (technologies) do get applied to non-space problems. This occurs in much the same way and for the same reasons that these resources were earlier applied to NASA problems.

1/ Several such efforts of this type are now under way. For example, one involves the cooperative efforts of NASA (Office of Technology Utilization), Department of Interior (Federal Water Pollution Control Administration), and MRI (Biomedical Applications Team).

At least two of the firms we interviewed made significant moves into non-space markets. These moves were made using modifications of capabilities developed to meet NASA/DOD demands. Technology was transferred, despite the fact that both firms saw themselves as almost exclusively space and defense contractors. They responded to the new markets when the non-space opportunities were communicated to them in the form of technical requirements or needs, and when the market potential was demonstrated to be worth the bother. Because the firms were focused on their existing customers, the impetus for the transfers came from the non-aerospace buyer in both cases, and the initial encounters were almost accidental. The experience of these two firms does offer proof that aerospace firms can and will adapt their capabilities (transfer technology) when presented with an attractive opportunity.[1] Obviously, not every firm will be able to adapt its capabilities to satisfy every non-space need, but if NASA were to make available information on non-space needs to aerospace firms (and others) in a systematic and formal way, the environment for technology transfer would be enhanced. Given non-space market need and market potential information, rational business behavior on the part of contractors should--at a minimum--make transfer opportunity assessment a routine rather than exceptional experience.

3. <u>Technology Possessor/Technology User Rapport</u>: Effective capability expression and communication require a high degree of familiarity and interaction between buyer and seller. All contractors interviewed believed that "technical intimacy"--but not necessarily personal intimacy--is required if they are to market their capabilities.[2] To satisfy this requirement contractors focus their marketing efforts on existing customers to the potential exclusion of other capability-application opportunities. Indeed, the way contractors view their capabilities is a direct outgrowth of the needs of existing customers. Latent capabilities that might be addressed to the needs of new customers are rarely recognized by contractors.

1/ "The key step, especially for an innovation that spins off to non-military, non-NASA sectors of the economy, is industry's realization of the opportunity potential. No matter how powerful the other factors, if industry does not see any benefits over and beyond the government applications, the innovation will see limited use and a narrow market." Herbert S. Kleiman, "A Case Study of Innovation," <u>Business Horizons</u> (Winter, 1966) pp. 63-70.

2/ For more on this point see: Edward B. Roberts, "The Myths of Research Management," <u>Science and Technology</u>, No. 80, (August 1968), pp. 40-46.

The implication for TU from this is that the inducement of contractors to apply their skills in non-space fields requires not only information about market identification and market magnitude, but also potential non-space customer identification and contact. NASA can take a number of steps to lower the non-space customer identification and buyer-seller familiarity barriers. One such step would be working conferences addressed to some particular non-space problem (some aspect of the air pollution control problem, for example) at which representatives of aerospace firms would discuss with potential buyers--government and private--the problem and solution approaches. NASA's role could take several forms: it might be limited to encouraging such experiments, it could include conference format suggestions, or it might include joint sponsorship with relevant mission agencies or private associations. In any event, such encounters would also do much to reduce the barriers to transfer posed by the different "languages" spoken in aerospace and other industries. Our findings and TU's experience indicate that "language" is a significant impediment to transfer.

4. The Office of Technology Utilization Works with the Tip of the Capabilities Iceberg: Even the small sampling of NASA contractors interviewed in this study disclosed an impressive number of new, important, and useful capabilities concerned with new techniques, new products, new management concepts, manufacturing controls, materials know-how, and all the other factors which go to make up "space technology." Observation and comparison convinced the investigators that many of the capabilities encountered were significantly advanced over counterpart skills and capabilities found in non-aerospace industry. But relatively few of these contractor capabilities are made known to the Office of Technology Utilization. There are several reasons why this is so, and these will be discussed more fully. But first, the implications for NASA's technology utilization activities should be discussed. NASA should give consideration to whether some presently unreported contractor-developed capabilities should be identified and documented for TU and whether there are appropriate and effective ways to do so. In addition, it appears that some of these capabilities can never be documented effectively, yet are still potentially transferable. Consideration should be given to TU actions that would stimulate transfer without going through the steps of documentation and reporting to NASA.

The reasons why capabilities are not reported have relevance for the design of new capture methods and transfer stimulation actions. Only a small fraction of the capabilities were developed solely in the performance of NASA contracts. More typically, capabilities come into being as a result of a combination of NASA, DOD, and company sponsorship. Since most capabilities are not directly traceable to NASA funding, they are not reported under the New Technology Reporting Clause. Perhaps more important, contractors just do not look at their capabilities in a way that would produce reportable "items." Instead, they see them as composites of talents and resources required to deliver the product to the customer. Everything is viewed in the context of the job at hand. As a result, new, novel, and unusual technical solutions are often overlooked because "that's the way any good engineer would do it if he were working on this problem." Proprietary interests also limit reporting to NASA. It is our opinion that proprietary interests rarely intervene in the reporting process as a result of malicious intent. Instead, it is a normal desire to exploit--on one's own--a discovery with market promise. When this situation occurs, a transfer has occurred, even though it did not happen through formal TU mechanisms and was not reported to NASA as a transfer achieved.

The final reporting impediment stems from the fact that many capabilities amount to nothing more than a particular company's being farther along the "learning curve" than anyone else. Capabilities of this type are basically a body of experience with a high "art" component and are extremely difficult to document. They are almost impossible to transfer to another group, but they can be transferred (applied) to another problem by the group which developed and possesses the know-how.

5. The Cost of Information: The cost of obtaining information determines in part whether newly developed capabilities will be exploited. The extent and rate of transfer of capabilities to new uses or new markets likewise may be limited by the cost of information.

Six of the companies interviewed had developed interesting new technical capabilities, but had not yet been able to make a corporate determination whether they should pursue further exploitation of these abilities and attempt to find new markets and new applications for the skills. Unless ways could soon be found to turn capabilities into profits, it is likely that the capability would die.

Our findings indicate that profit potential can and often does attract the application of capabilities to new uses. However, even the possession of a potentially profitable capability will not insure that application or transfer will be seriously considered unless the firm knows with some confidence that this potential profit exists, knows the technical requirements of the new application, knows whom to contact, and knows a number of other things relevant to capability application to a new use in a new market context. This requires information--a lot of information and several different kinds of information.

In the report of the Phase I study we concluded:

* Contractors tend to ignore or fail to exploit capabilities and capability components which are not important to the achievement of company goals.

* Contractors often fail to see needs which exist outside of aerospace to which their capabilities could be addressed.

* New capabilities are transferred--applied to other needs, or sold to other markets. But the economic rules governing transfer of technology are complex. Factors other than the purely rational maximizing of expected profits are found to influence these management decisions.

Further study suggests that these seeming anomalies may be resolved as rational economic behavior when the cost of information needed to transfer new capabilities is considered. In some cases the cost of acquiring information sufficient to decide whether to develop and exploit a new ability, is simply more than the firm is prepared to pay.

Within recent years several ideas have been added to the emerging "Theory of the Firm" with regard to management decisions. One is the gradual agreement that many non-pecuniary elements figure into and influence managerial decision-making with regard to product development, marketing and R&D investments.1/

A more important development is recognition that the information required for making of choices is not a free good, but has a cost of acquisition that may not be worth paying.2/ In view of the cost of obtaining information that will allow making sounder decisions about whether to pursue a new capability or to abandon it, it is not surprising that some of these important decisions are made on the basis of fragmentary information, personal or corporate preferences; or as Johnson points out--"on the basis of information provided in persuasive capsule form by parties interested in influencing the outcome of decisions."

The fact that management decisions regarding the development and transfer of new capabilities are made in this way is generally regarded, in the neo-classical tradition of economic theory, as a reflection of the irrationality of man in the economic system. When the cost of acquiring sufficient information to decide better whether to transfer capability or abandon it is considered, such rule-of-thumb practices begin to appear both rational and economic.

1/ See Dow and Cullison, "Oligopoly, Intergroup Conflict, and the Growth of the Firm," American Journal Economics and Sociology, Vol. 24, July 1965, pp. 273-290. Also see Boulding, The Present Position of Theory of the Firm, p. 4, and Penrose, Theory of the Growth of the Firm, p. 13.

2/ For a brief but excellent discussion of information costs and policy implications see: Harry G. Johnson, "Economics and Public Policy: I. The Economic Approach to Social Questions," The Public Interest, (Summer, 1968), p. 76.

Two important implications for NASA's technology utilization programs are that--"The production and distribution of information relevant to consumption choices is a necessary part of the economic system, not merely a wasteful excessence of it,"1/; and that the natural economizing process of the marketplace will insure that such information is accepted and acted on even though the information is not complete or exhaustive, and the form is far short of that required by classical scholarship.

This high cost of information about capability application opportunities explains--in part--why NASA contractors concentrate on aerospace markets to the virtual exclusion of other possible market applications of their capabilities. Contractors focus on learning about the needs of existing customers (NASA and DOD), on forming information packages about how their capabilities can meet these needs, and then on communicating this information to NASA and DOD. By so doing, contractors maximize the benefits they can obtain from the limited resources that they can devote to capability opportunity assessment.

Turning now to technology transfer (selling a new capability to a new customer in a new market or buying from a new supplier from a different industry), we find that the cost of the information necessary to justify a transfer attempt is at least as high--probably higher--than the information costs of operating in known market niches, and the foreseeable benefits are lower. Thus, the cost of information about needs and requirements is a significant barrier to technology transfer. More often than not, individual firms simply refuse to undertake the required costs. The result is that many potential transfer opportunities never even reach a point of decision.

If the TU Office were to supply more of the information required to reach decisions on non-space transfer opportunities, then the costs of exploring other possible applications would be reduced and the potential for transfer would be enhanced. In this context our findings indicate that information regarding the commercial (market) feasibility of using some new technique or other advance is part and parcel of the capability formation and application process. By analogy, the development and dissemination of information on non-space market needs and opportunities is a valid and crucial Technology Utilization function.

NASA cannot and should not undertake unilateral development and dissemination of non-space need (opportunity) information. Cooperative efforts with government agencies responsible for specific need areas (water pollution and crime control, for example) or interested industry associations are necessary. Missionary activities to stimulate such joint efforts are a legitimate NASA function--acting alone.

1/ Johnson Op. cit.

Obviously, the TU Office cannot supply complete market information on all non-space needs to all firms, but it could (in cooperation with others) disseminate selected market information on selected non-space needs that have high technology solution requirements and whose solution would be clearly in NASA's and the public interest.

6. NASA Contractors as Transfer Agents: Much of the current TU dissemination program is based upon technical data reported to the Technology Utilization Office by organizations internal to NASA or by contractors under the New Technology Reporting Clause. This information is then disseminated to a broad audience of potential technology acceptors who, in turn, may apply the new technology toward the solution of a non-space problem within the context of a conventional marketing framework. This process involves at least four major parties, i.e., the contractor who originally developed the technology, NASA, the non-aerospace acceptor of the technology, and the ultimate non-aerospace buyer of the fruits of the new technology. In addition, the process has a number of steps which must be performed, important among which are: the perception that the technology is worthy of reporting, the reporting of the technology to NASA, the screening of the report by NASA, the dissemination by NASA, the acceptance of the technology by the recipient, the adaptation of the technology to the new use, the marketing of the new technology or its fruits, and finally, the decision to buy by the ultimate user.

The transfer of technology requires that there be change. But, because change is resisted, the less change required the better. If the number of parties currently involved in the transfer of technology can be reduced, then the possibilities for transfer should be enhanced. The same is true for the number of steps involved in the transfer process; if they can be reduced, transfer potential should increase. Both the number of steps and the number of parties involved can be reduced if the Technology Utilization program is expanded to emphasize transfer from the possessors of the technology (NASA contractors) directly to non-aerospace buyers. What this amounts to is a program to induce NASA contractors to adapt and apply their capabilities toward the solution of non-space problems. In such a scheme, both NASA and the non-aerospace acceptor of the technology would drop out of direct participation in the transfer process. In addition, the following steps in the existing procedure would be eliminated or significantly reduced: reporting, screening, dissemination, and acceptance.

A program emphasizing contractor application of their capabilities in new non-aerospace areas has a number of other potential advantages. The perception step becomes a main thrust function rather than a subordinate side issue. Motivation for this step now is negative, i.e., the contracts call for new technologies to be reported. The incentive for doing so is simply that it is required to get main thrust business with NASA. On the other hand, if contractors were encouraged to apply their capabilities in new markets, the perception step would become an integral part of the business operation. It could be a significant source of new product ideas and process improvements. Similar benefits accrue to the adaptation step. Given a problem statement or market-need statement, the possessor of the resources is in the best position to adapt these resources to conform with the requirements of the new non-aerospace market needs. In addition, the full weight of the contractor's potential capabilities can be brought to bear on the problem rather than just some element of the capability which is reportable under the new technology clause.

7. <u>Difficulty of Transferring Technology by Documents</u>: Almost every characteristic and behavior trait associated with capabilities argues against the effectiveness of transferring technology by some sort of document. The emphasis on personal communication between technical representatives of sellers and buyers is a case in point. This selling technique evolved at least in part because of the difficulties of capability expression. A certain amount of give and take and empathy is required of the two parties. This is extremely difficult to reproduce in a written document.

Buyers and sellers in the aerospace field have at least two things going for them that are not available in a technology-transfer case (seller in an aerospace industry and buyer in non-aerospace field). They have a community of interest, i.e., aerospace, and speak the same or similar languages, i.e., trade jargon. These factors assist the capability marketing and evaluation process in a number of subtle but important ways. In the case of technology transfer from aerospace to non-aerospace, the buyers and sellers each have a different interest area and speak different dialects. Some bridging of these gaps must be accomplished before effective communication of needs and capabilities can begin. This is a formidable hurdle to get over in a two-way discussion. Surmounting this hurdle in a written document (a one-way communication device) is even more difficult.

Most documents prepared to transfer technology are limited in scope to descriptions of sub-elements of capabilities. There are several valid reasons for this scope limitation; among them are the facts that (a) comprehensive capabilities are difficult to express--briefly and effectively--in written form and (b) capability statements are prepared with some specific objective in mind. These characteristics of capability expression are in direct conflict with the objectives of the person preparing a transfer document (Tech Brief, for example). The document writer wants his presentation to be brief--so it will be read by recipients--and he wants it to have appeal for a broad audience. The incompatibility between the writer's objectives and the requirements of comprehensive capability expression is resolved most often by limiting the scope of transfer documents to capability sub-elements.

Because significant problems (for example, air-pollution control) in all fields are complex, solutions will take the form of a tailored set of technologies specifically addressed to the problem at hand in much the same way that aerospace capabilities are combined to solve aerospace problems. Transfer documents limited to descriptions of capability elements do not provide solutions for significant problems--only for parts of solutions. Accordingly, such documents can only be expected to achieve small incremental transfers even if they are accepted. The achievement of more profound impact requires that the potential acceptor of the tendered element must perceive that it can be combined with the other elements he already possesses to form the set of technologies (capability) required to solve a larger problem. This is a major barrier to significant transfers.

A final limit to transfer by document stems from the predisposition of NASA contractors to seek technical solutions from their suppliers or experts through some form of non-written communication. Our interviews with contractors disclosed that this was invariably the first step undertaken when a problem was encountered. Only if this failed did contractors move to various types of literature inquiry. Assuming that firms in non-aerospace space fields behave the same way, then this impediment to transfer by document exists in non-aerospace industry, too.[1]

C. Framework for Systematic Investigation Can Be Developed From Insights

The findings of our investigation and our analysis of insights drawn from findings lead us to believe that transfer programs that concentrate on "demand pull" can be significantly more effective than programs keyed to "technology push." This is based on our assertion that industry--in particular the aerospace industry--is better equipped to seek out relevant technology than it is to identify new problems to which technologies can be addressed. In addition, technology advance, per se, is not rewarded in our market system. Instead, the rewards come from the satisfaction of market demand. Accordingly, firms seek out and apply technology only after a demand has been identified.

1/ This assumption is verified by a recent Denver Research Report; see: John S. Gilmore, et al., The Channels of Technology Acquisition in Commercial Firms and the NASA Dissemination Program, NASA Contractor Report-NASA CR-790, National Aeronautics and Space Administration, Washington, D.C., June, 1967.

This view is not unique with us. Schumpeter,[1] for example, wrote along these lines 30 years ago. More recently, Jacob Schmookler[2] is among the leaders of a growing band of researchers stressing the dominance of "demand pull." Dick Carpenter in his recent study "Policy Planning and Technology Transfer," after reviewing the writings of Schumpeter and Schmookler, makes the following comment:

> "These studies lead to an economic theory which suggests that deficiencies in economic growth via technological change are more related to inadequate identification of demands and choices among conflicting wants and needs. The long-held impression that science stimulates invention is relegated to the secondary importance by this analysis."[3]

In the same report, Battelle Memorial Institute follows this statement up in its comment on the strength and weaknesses of Federal Transfer Programs:

> "Dissemination based on solution identification followed by attempts to locate problems, tends to inundate a recipient and render him somewhat insensitive. This type of dissemination is the result of an outgrowth of technology from mission-oriented agencies. The weakness results from failure to recognize that effective transfer can be accomplished only by reversal of the present process, namely to seek out problems and then solve them from available technology or match technology to appropriate problems or needs."[4]

Nelson, Peck, and Kalacheck also emphasize demand in their analysis of technological advance:

> "Two broad factors are at work. First, there are differences and changes in the rewards from particular kinds of technological advance--demand factors that stimulate or repress efforts aimed at achieving them. Second, there are differences in changes in a stock of relevant components and materials, and of knowledge, and in

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1/ Joseph A. Schumpeter, "Theory of Economic Development," Harvard Economic Studies, XLVI, Cambridge, Massachusetts, 1934, Harvard University Press.

2/ Jacob Schmookler, "Invention and Economic Growth," Cambridge, Massachusetts, Harvard University Press, 1966.

3/ "Policy Planning for Technology for Technology Transfer," a report of the Subcommittee on Science and Technology to the Committee on Small Business, United States Senate, Washington, U. S. Government Printing Office, 1967, p. 57.

4/ Ibid., p. 174.

the number of people who possess the relevant knowledge--supply factors which permit or restrict certain kinds of advances."1/

Thus it seems that our findings are in basic agreement with those of other researchers. The problem remains, however, as to how to design programs aimed at accelerating "demand pull" in general, and in particular how to obtain the most leverage from such programs. Accordingly, we suggest that NASA consider a series of pilot or experimental programs designed to enlarge practical knowledge about means for exploiting the role of demand in technology transfer.* To facilitate this study, we propose the following hypothesized description of the technology utilization process.

D. Hypothesis--The Technology Utilization Process

Investigation of the role of demand in technology utilization requires that studies also give recognition to other elements in the process. If this is not done, it would be extremely difficult to isolate

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1/ Richard R. Nelson, Merton J. Peck, and Edward D. Kalacheck, "Technology Economic Growth and Public Policy." Washington, D. C., The Brookings Institute, 1967, p. 28.

* Our findings disclose at least three possible types of Technology Utilization programs. All operate to accelerate the "natural technology diffusion process," but each differs in the point at which leverage is applied and the direction of the force exerted. The first approach is the now familiar Technology Push, in which reported new NASA technology is channeled to potential non-space users through such devices as Tech Brief announcements. The second is Demand Pull linked directly with the search of technology. The Biomedical Applications Team programs are the prime operating example. A medical problem or need is identified, the technical solution requirements are specified, and space technology is searched for a solution. The third approach uses Pure Demand Pull. Like the preceding, this starts with problem identification and technical solution requirement specification. Next, the market potential is estimated and this total information package is disseminated to industry. With the need properly defined and the market opportunity delineated, private industry will be motivated to apply the most appropriate technology to solution of the problem. Industry is, thus, responsible for the application of its skills to the problem (market opportunity). There is no attempt by the project team to achieve direct linkages between problems and the reported body of NASA technology. It is this last approach that we suggest be explored more fully.

the impact of demand forces. Our hypothesis draws heavily on the work of Buttner and Cheaney[1/] and to a lesser extent the work of Churchill and Ozinne.[2/]

We see three major elements in the technology utilization process. They are: needs, technology, and organizational factors. These elements act to shape the direction and rate of technology utilization. In turn, these elements are subject to some degree of manipulation and alteration on the part of organizations such as NASA concerned with the acceleration of the process.

In our analysis we see needs--actual demand, latent demand, and the stimulus--as the dominant controlling element in the short run. For example, the need for air pollution control, in existence for some time, has only recently been articulated. There is actual demand now for devices addressed to this need, and latent demand for a number of other as yet undeveloped or unadapted devices or techniques for reducing air pollution.

Several need-related requirements must be met if we are to exercise control and direction over technological advance. Needs must be recognized. They must have attractive market potential. They must be translatable into technical solution requirements. And, this information must be communicated to industrial firms with latent capabilities which may be organized to solve the problems associated with air pollution.

The second element operative in the technology utilization process is technology, i.e., the supply of skills, resources, etc. that can be applied to need satisfaction. In the case of technology transfer, the basic premise is that the technologies now being used for one purpose can also be used for another. We believe that this reapplication of the technologies requires that they be adapted and restructured to meet the particular requirements of the new use. This process is analogous to the existing process which NASA contractors go through in reforming their capabilities in response to a new NASA project opportunity. The adaptation of the technologies requires that they be linked to the new need, and that they be regrouped to satisfy the new need.

1/ H. Buttner and E. S. Cheaney, "Models of Technological Change," presented at the Annual Technology and Management Conference, Lake Placid, New York, May 22-25, 1967.

2/ G. A. Churchill and U. B. Ozinne, "Adoption and Diffusion Research: A Potential Tool for Improving Technology Transfer," The National Conference on Technology Utilization and Economic Growth, July 30-August 4, 1967, Aerospace Research Applications Center, Indiana University.

Organizational factors--the third element--are concerned with company characteristics, goals, organizational structure, procedures, and related factors that define the institutions operating in the technology-utilization process. They are characteristics of the companies possessing the relevant technology (technology seller) and companies serving the relevant market (technology buyers) that act to impede or to accelerate technology diffusion and application. Some of the factors relating to the technology seller are: the firm must perceive the market opportunity; the firm must adapt to the requirements of serving the new market, i.e., discard organizational and procedural characteristics it acquired to serve the NASA market and adopt new characteristics required to serve the new non-aerospace market; the firm must revise its view of itself and its objectives; and to accomplish all these things, the firm should be provided with incentive to do so.

Organizational factors related to the technology buyer are essentially the reverse of those associated with the technology seller. The technology buyer must perceive the technologies required in serving its market, particularly with respect to emerging market needs and new technological ways of satisfying these needs. It must adapt procedures, organizations, and so on to accommodate the new technologies. It also must revise its view of itself and its goals. And it must have the incentive to undertake these steps, i.e., significant new market potential.

It is our view that this hypothesis provides a starting point for an examination of the roles of these three elements and their subelements in the technology utilization process. Tests of the hypothesis should provide a structured understanding of the process, identify those points in the process where greatest leverage can be obtained by technology utilization stimulating programs, and provide experience with various practical techniques for exerting leverage.

VI. CONCLUSIONS AND RECOMMENDATIONS

A. Recommendations Concerning Implications for Technology Utilization

As a result of our findings concerning the nature of capabilities and our analysis of the associated implications for Technology Utilization, we make the following recommendations:

1. Efforts to develop clearer understandings of the technology-transfer process, which the Office of Technology Utilization is attempting to act upon, should be continued. We suggest that a structured framework for such studies is available from our hypothesized description of the

transfer process (p. 39) plus the conceptual systems model of technological innovation recently developed by Ellis Mottur.1/

2. Efforts to identify interesting, new, unique capabilities possessed by NASA contractors are in order. When identified, some of these capabilities should be subjected to study to establish how they came into being. The scope of these investigations should include the timing, investment, and decision-making factors associated with the development and exploitation of the capabilities. An objective of these studies should be to determine ways to expand the small fraction of capabilities now reported to TU for dissemination. Critical incident analysis would be an excellent methodology for these investigations.

3. Most important, the "demand pull" approach to Technology Utilization should receive great emphasis. Existing programs following this approach should be augmented, and new programs should be put into effect. In general, the approach requires the identification of non-space problems (transfer opportunities), market-potential estimation, and dissemination of this information to both potential users and possessors of aerospace-developed capabilities.2/ (See pages 30 through 36 for specific action suggestions.)

The Office of Technology Utilization should take steps to involve other mission agencies, industry associations, and foundations in a series of programs to implement this recommendation. These steps would be in addition to the Office's current technology identification and dissemination functions. The analytical techniques developed by Dr. Peter Castrucio for the ORL Experimental Program provide a model methodology for the conduct of the market-identification function.3/ To the extent possible the market (non-space transfer opportunity) information should be disseminated through existing channels.

1/ Ellis Mottur, <u>The Processes of Technological Innovation: A Conceptual Systems Model,</u> a study sponsored by the National Bureau of Standards and U.S. Arms Control and Disarmament Agency (forthcoming).

2/ Dr. Donald M. MacArthur has also called for and outlined a program of this type. See: "Utilization of Federal Laboratories," a report of the Subcommittee on Science, Research and Development of the Committee on Science and Astronautics, U.S. House of Representatives, Ninetieth Congress, Second Session, Washington, GPO, 1968, p. 60-61.

3/ IBM, ORL Experimental Program, NASA Contractor Report NASA CR-70348, February, 1966.

4. Finally, case studies of NASA contractors who have attempted to transfer their capabilities to the civilian sector can provide knowledge about the specific types of barriers encountered, and can additionally identify leverage points for TU action. The current transfer efforts associated with the Rockwell-Standard/North American Aviation merger provide an excellent specific case-study opportunity.[1/]

B. Conclusions and Recommendations for a NASA Capabilities Center

Concerning establishment of a Capabilities Center the investigators conclude:

1. Broad purpose Multi-Client Capabilities Files present difficulties and costs which outweigh the present need for such centralized systems.

2. The nature and format of capabilities information used (a) for non-procurement purposes and (b) to locate rare or scarce skills, while differing in form and content, could be made compatible in an associative file.

3. Attempting to combine in the same file the relatively well standardized capabilities that are stated, classified, and coded for procurement purposes with more specialized descriptions of unusual or unique capabilities would greatly enlarge the file size, and introduce conflicts in searching procedures.

4. Any NASA contractor-capability file created to serve Technology Utilization should be designed and developed for that audience and its purposes of use alone; not for program offices or other agencies, and assuredly not for procurement use. Usage of such a file by Technology Utilization would be primarily oriented toward monitoring the emergence, and the spreading of aerospace technology, and toward association of technology and needs.

5. To be practical, a Technology Utilization Division file of capabilities should be kept small and highly specialized. This constraint is suggested in part because of the experimental nature of the index coding, file structure, and associative searching methods which would be needed. Even more compelling, however, is the need of the TU division to be concerned with perhaps the top one percent of technological capabilities--that on the leading edge of change.

1/ See: "Piping Technology Toward New Goals," Business Week, July 27, 1968, pp. 108-112.

6. The most attractive and potentially useful form of contractor capabilities file appears to be one concerned exclusively with novel, rare, new, or unique abilities to solve problems. A selective file indexing in depth, perhaps no more than 3,000 capabilities of from 500 to 1,000 NASA contractors, is envisioned.

7. Building a file of unique, rare, or new capabilities would require types of information not now available in inventories of conventional skills or procurement files. However, it is worth noting that at the stage of newly evolved capability-in-being, most contractors are willing to supply the necessary information <u>on request</u>. This is especially true where the organization possessing a new capability is not sure how or whether its further exploitation fits their company goals and markets.

8. Raw information furnished by contractors should be processed to provide the following file inputs and outputs:

a. Specific skills by name

b. Related abilities by functional or related classes

c. Indicators of rarity or uniqueness

d. Indicators of newness or date of first use

e. Association or clumping by problem solved

f. Association by markets served or applications

g. Indicators of usefulness, value, benefit

h. Organization possessing such skills

i. Internal checks for validity or verification

Aggregative outputs would include the number of different skills inventoried, the number of classes, and the number of organizations represented, together with the number of rare skills they possess.

The information should be capable of differentiation with respect to time. Thus, a valuable output will be measures of growth rate and diffusion of technology (plus, hopefully, indications of benefit, impact, and value).

Some of the ways by which such a specialized capabilities file could assist in the work of TU are shown in Chart 3.

CHART 3

HOW REGISTRY OF RARE CAPABILITIES WOULD AID TU

TU Functions	Nature of Information Needed
Monitoring of Technological Capabilities	1. Individual skills by name and by class 2. Number of different skills inventoried 3. Indication of rarity or uniqueness 4. Identity of organizations having each skill 5. Numbers of organizations represented (information differentiated with respect to time)
Support Technology Studies and Documentation	1. Skills associated or clumped together 2. Measures of growth rate or diffusion 3. Is technology at stage appropriate for documentation, analysis, or transfer effort?
Applications Matching	1. Basic functions performed 2. Problem solved by capability 3. Analogous skills, functions, and problems 4. Identity of groups highly qualified at skill
Document Benefits Impact, Justification	1. Indicators of importance or usefulness 2. Indicators of benefit or impact 3. Indicators of news interest (should be quantified by numbers, dollars, or emotional value)

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