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Quo Vadimus? Coming to Grips With The Information World

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QUO VADIMUS? - COMING TO GRIPS WITH THE INFORMATION WORLD

"The world's economy has shifted from one built on materials to one governed by information. In the past, those who controlled materials like gold and oil governed all. In the information age, those who wield information will shape the world."

— *Signal Magazine*

As we near the end of the Twentieth Century, we find ourselves living in a new environment, a new age -- an information society, an information age -- which offers new opportunities for organizational and individual excellence. New relationships and new opportunities are resulting from the increased availability of information and the stimulation and expanding opportunities it brings. There will be new individual and organizational relationships, new methods of doing our work, and new environments in which we will carry out our work. The managers of information resources will be a new breed of technical generalists and information specialists with a thorough knowledge of the organization and its function, and sensitive to the changing needs of its people and clients.

In this new information-oriented culture, the U.S. aerospace industry, especially the commercial aviation sector, is also undergoing profound change as a result of the circumstances created by a combination of domestic actions (such as deregulation) and external trends and events (such as emerging foreign competition). The future will show an increase in U.S. collaboration with foreign producers, resulting in a more international manufacturing environment, and will foster an increasing flow of U.S. aerospace trade. Simultaneously, international industrial alliances will result in more rapid diffusion of technology, increasing pressure on the U.S. aerospace industry to push forward with new technological developments.

There are certain characteristics that make the U.S. aerospace industry unique: it leads all other industries in expenditures for research and development (R&D); it benefits heavily as a technological borrower from developments in other industries such as metallurgy, materials, chemicals, and petroleum; it is characterized by the high degree of systemic complexity embodied in its products; and it has been the beneficiary of federally funded R&D for nearly a century.

An integral part of the aerospace R&D process is the scientific and technical information (STI) associated with it. STI is both a raw material (input) and a product (output) of this process. The systems that support STI are part of the scientific and technical (S&T) infrastructure. The data or existing knowledge bases are a raw material necessary for the production of new findings and developments. Strong STI programs are critical to a strong national S&T base.

BACKGROUND

STI has received attention as early as 1963, when the Weinberg Report[1] documented the following conclusions, which are as valid now as they were then:

> "Transfer of information is an inseparable part of research and development. All those concerned with research and development -- individual scientists and engineers, industrial and academic research establishments, technical societies, government agencies -- must accept responsibility for the transfer of information in the same degree and spirit that they accept responsibility for research and development itself."

> "New science and technology rests firmly on the base of information generated in the past; thus the effectiveness of future work in universities, government laboratories and industry depends on the efficiency of present information transfer."

The report clearly saw STI as a critical part of the S&T infrastructure of the United States. And yet the challenges to U.S. leadership in science and technology remain, and the STI infrastructure has not been defined.

Many other reports and studies have been issued since then. The findings in these reports and studies which address the importance and value of information in the R&D process are remarkably consistent. They show that access to a wide variety of information sources is critical for innovation and problem solving. The studies also clearly indicate that the cost of information includes far more than the costs involved in publication and database access charges. The time spent for searching for information, verifying information obtained from others, and waiting for information is also a cost factor. Any improvement in this process results in significant savings.

Few will dispute the importance of the need to transfer information about our current knowledge to create new knowledge. You can ask whether you are doing good research and development efforts if you don't have good data and information. If you do have good information resources, could they be better exploited so that you can do even better R&D? Everyone has a responsibility to share results with others.

WHAT IS STI?

STI, scientific and technical information, is the collected set of facts resulting from scientific, technical and related engineering research and development efforts. It includes information from both basic and applied research in the entire range of scientific disciplines - physical, social, medical, terrestrial, and biological. STI is vital in establishing, maintaining, and improving a strong national science and technology base, as well as improving national productivity and competitiveness. New science and technology rests firmly on the base of information generated in the past.

Timely accurate and relevant STI is critical to the R&D process. It is an incredibly valuable resource that directly affects the cost of performing a technical task, the quality of the results, and productivity. Further, STI has value which may be exploited more widely than the purpose for which is was originally collected. It can serve as a critical link between R&D and the achievement of other national goals such as improving the education of U.S. scientists and engineers, the strengthening of the technology base, and fostering international cooperation on global problems. Even further, the diffusion of knowledge resulting from federally funded aerospace research and development is indispensable in maintaining the vitality and international competitiveness of the U.S. aerospace industry.

STI comes in many forms and has many uses and audiences which may or may not be part of the R&D infrastructure. STI is used at the bench, in the managers office, and at corporate level. It is used for planning, research, development, production, for bidding on contracts and grants, for writing papers and presentations, etc. STI comes in many forms; it may be textual, graphical, audio, video, raw telemetry data, structured evaluated numeric date, or a combination of all. A recent Office of Technology Assessment (OTA) report stated "STI is important not only to scientists and engineers, but to political, business, and other leaders who must make decisions related to S&T, and to the citizens who must live with the consequences of these decisions."

In order to cope with the complexities and unique problems inherent in this information resource, the NASA Scientific and Technical Information Program (STI Program) was established.

WHAT IS THE NASA STI PROGRAM?

The NASA STI Program was established to provide information management and services. STI Program management is concerned with the operation, promotion and utilization of established information services. These services provide for collection, cataloging, storing and retrieving information items. In essence, the NASA STI Program was established to improve the scope and effectiveness of collecting, processing, disseminating and applying STI.

The overriding function and goal of the NASA STI Program is to ensure that accurate and timely STI is generated and entered into an appropriate information service and is made available in a useable form to those who have a need for it. Hence, the STI Program is concerned not only with knowledge production, but with knowledge transfer and utilization as a component of the R&D process.

The NASA STI Program was founded in the belief that transfer of information is necessary for all research, development, engineering and technical programs and efforts. All those concerned with research, production, engineering, and technical efforts -- individual scientists, engineers, technicians, program managers, and administrators -- must accept responsibility for the transfer of information in the same degree and spirit that they accept responsibility for research, production and engineering itself.

The NASA STI Program recognizes that a strong science and technology base is a national necessity in a competitive world, and that adequate information services, support, and communications are prerequisite. We recognize the necessity of information exchange, and interchange technology and information with the public and private sector, nationally and internationally. This interchange is essential to the progress and viability of NASA. Technologies developed for civilian applications have potential for application in aeronautics and space, and technologies developed in aeronautics and space programs have potential for application in the civil sector.

Hence, the NASA STI Program was established and developed to provide information support and services in order to assist the S&T and R&D community to:

- improve mission effectiveness;

- improve the scope and effectiveness of collecting, producing, disseminating, and applying STI;

- support the information needs of managers, scientists, engineers, and technicians;

- increase productivity and effectiveness of research, production, engineering, and other technical efforts;

- improve our capabilities through research and application of new technologies;

- maximize use of R&D resources;

- overcome incomplete and inaccurate databases; and

- facilitate domestic technology transfer and transition.

DISCUSSION

In order to understand the STI management issues, it is critical to understand the role of the STI Program and the information centers in the context of the R&D process. Federally-funded R&D is carried out in a decentralized manner, accomplished by thousands of principal investigators performing their tasks at hundreds of locations. NASA and other Federal organizations such as Defense, Energy, etc. established STI programs to ensure that the results of R&D are managed in an effort to obtain the best return on investment, both from an economic and from an S&T standpoint.

Unfortunately, during the past few years, the focus of the NASA STI Program management office has changed from a close relationship with R&D program managers to administrative concerns: battling budget cuts, coping with personnel cuts and losses, acquiring new equipment, etc. The relationships between R&D managers and STI managers has also grown apart; more and more they work as separate communities, with the STI community serving a passive role by responding to service requests of the R&D community.

This trend must cease, and the STI Program must refocus and concentrate on how better to support the R&D community, as well as how to support scientific and technical productivity. This apparent gap between R&D managers and the STI managers must be filled; information specialists must be actively involved in all stages of R&D. This participation must not be a passive "Don't call us we'll call you", but the result of active membership on the R&D team.

There is ample evidence of the contributions of STI in high-technology programs and products. Innovation and internal as well as external technology transfer are essential to the development of any R&D organization. The contributions of scientific and technical information throughout a project, from exploring ideas through research, development, production and service to the product have been defined. There is a direct link between information and success in high-technology products.

Using a two-step process to illustrate technological development, it is easy to see how STI is a vital factor in the process. The first stage is an investment in people. In this stage, which is sometimes called the "competence building" stage, and which actually continues through a person's working life, knowledge is accumulated. This stage includes: reading widely in an individual's specialty and in associated specialties in a variety of publications; performing a variety of assignments at different levels, publishing papers and making presentations, and maintaining a wide variety of contacts outside an individual's work group. These are the keys to later success.

The second stage, the "problem solving" stage, is where the acquired competence, knowledge, and experience are translated into good judgment and wise decisions that result in successful projects. This is also the stage where specific problems that arise during a project are solved. A product or service is selected for production, the engineering or other aspects of the design are determined, the product is produced and tested, failures are corrected, and the product is improved and later serviced.

During these processes, key individuals facilitate, guide, and manage the product to success. These same people are essential to all stages of a product's life. They possess the same characteristics described in the competence-building stage. It is clear what they do and what effect they have on good results.

There are several trends emerging which have a significant impact on the conduct of science, research and development and the corollary management activities, and which dictate that generic issues of STI be addressed. The trends include the use of information technology, the growth of interdisciplinary research, and an increase in international collaboration.

Seemingly every day studies addressing a wide range of information needs and concerns are published as reports, journal articles or newspaper columns. One of the most significant recent reports is the report of the 1989 Committee on Science, Engineering, and Public Policy, "Information Technology and the Conduct of Research: The Users View." The report points out that information technology, which has dramatically changed the conduct of research, has brought forth a need to better understand and manage its exploitation. Computerized instruments gather data many orders of magnitude greater than previous methods. Telecommunication capabilities can link researchers to computing facilities with vast capabilities and with data sources not constrained by geographical location. Data are available, not only in computerized databases, but also from sensing and other data gathering instruments. New analytical approaches are possible through graphics, color enhancement, animation, and other visualization techniques. With this ever growing capability, there is a need to help teach researchers to better use it, to develop better ways to store, retrieve data and to maintain its integrity, and to determine how to assure intellectual property rights in an electronic network.

Information technology is having a significant impact on the conduct of science and engineering efforts. Computerized instruments gather vastly greater amounts of data than previously possible. New approaches to research questions are possible through computerized analyses of massive databases and visualization techniques. Communications networks link scientists to each other, to distributed databases, and to remote instruments and computing resources. All of these capabilities overwhelm traditional data management techniques and create pressures on accepted information practices.

Many of the significant research challenges today are interdisciplinary in nature, which requires expanding the circle of collaborators, as well as the range of information sources. A network of communications links will soon develop worldwide, to link personal computers, work stations, data bases, peripherals, and information utilities. Information systems will become transparent, and will facilitate the flow of information and meaning among people. Consequently, we will be able to focus on content not technology. Responsive expert advice, information, and solutions will be at our fingertips; we will find ourselves receiving more stimulation and excitement from the systems than the energy we put into them. We will become more purposeful, growing, and professional than we are now.

Notwithstanding these communications networks and large databases, the different methodologies, vocabularies, and cultures of individual disciplines create obstacles to efficient information exchange. Systems need to be designed to accommodate users who were not immediately involved in the original research. Merging existing data collections from different fields to perform analyses creates new problems. It becomes extremely difficult to compare data that were derived using different techniques or approaches. Contributing to this problem is the lack of standards for data exchange formats which hamper the building of these multidisciplinary databases. The bottom line is that we must be prepared to import external information to support the internal R&D process, assure real-time delivery of information to support the transfer and transition of technology within the R&D community, and be able to export some results to remain competitive in the R&D arena, as well as to provide visibility to the NASA organization.

These problems are further compounded by the growing internationalization of science. STI is being produced, enhanced, and stored around the globe. Single countries in some cases are acknowledged leaders in select scientific and technical disciplines. Many of the major research efforts involve worldwide data collection. Not only are a variety of disciplines involved, but scientists from around the world are participating in these efforts. The users in these projects are distant geographically as well. Global economies dictate that every effort be made to reduce unnecessary product and service development cost. Communications networks facilitate the exchange of ideas and access to remote databases, but there is still much progress that needs to be made in making systems more transparent and in developing common protocols.

Hence, the pace of data collection, the growth of international approaches to research, and the tendency to cross traditional disciplinary boundaries all cast a new perspective on earlier STI issues, and raise new challenges for effectively providing critical information to the end user.

The issues to be addressed and resolved are numerous, including the transparency of access to vastly expanded and distributed electronic resources; merging data from numerous sources; greater data validation; closer cooperation between the user community of scientists, engineers, and managers and the information system designers; the long-term viability of electronic data; and expanded resource commitments to support technologically advanced information systems; archiving large scientific databases; what STI should be retained, where datasets should reside; what formats should be used, how can they be physically maintained; and how to reduce dependence on specific hardware and software.

Notwithstanding the above issues, it will also be necessary to better understand the knowledge transfer process. It will be necessary to establish a research agenda to address these and other issues related to STI. Not only must information managers, but policy makers involved in the science and technology programs as well, need to understand the relationship of STI to the R&D process: knowledge transfer is an inseparable part of R&D, and knowledge transfer must be an integral part of not only the NASA STI Program, but of the entire Federal science and technology programs. Innovation is a complex process composed of multiple and interrelated systems. A better understanding of knowledge diffusion by policy makers, R&D managers, scientists, engineers, and information specialists should result in better defining policy and programs that will enhance the productivity of the R&D community, and in turn enhance U.S. competitiveness.

Then too, there are policy issues to resolve: questions of intellectual property rights, publication procedures, data security, and confidentiality, as well as resolving questions about system integrity and reliability.

As STI concerns move beyond the parochial interest of particular disciplines, as linkages occur with the networking community, and as the trends toward interdisciplinary research on a global scale become more pervasive, an expanded R&D user community is developing. The user community must voice legitimate concerns about both technical and policy issues associated with STI. The user community must identify common concerns about STI access and in building systems that will accommodate the needs of future government scientific and technical initiative.

We are in the dynamics of technological pull versus administrative lag. Administrative lag retards the development and use of the new information systems and technologies. The industrial age from which we are departing needed us to be interchangeable cogs in a machine, turned-off and emotionless, mechanical, routine, controllable, and consistent. The new information age into which we are entering needs us to be growing, experimental, creative, enthusiastic, risking, and taking initiative.

CONCLUSIONS/RECOMMENDATIONS

STI must be considered as an R&D resource, essential to the continued success and innovation of the NASA R&D community. Not to be overlooked is the fact that STI has costs: costs in collection, internal and external communications, processing and storage, archiving and disposal, and in skilled staff used in all of the activities above. It is also noteworthy to mention that although STI is used mainly by the scientists and engineers of the R&D community, it does have value and is required at the policy level, as well as at the managerial level.

STI management means more than simply developing more sophisticated information transfers systems; rather, it means providing the means to exploit both internal (NASA corporate) and pertinent external (other governmental/ industrial/ foreign) information to meet the requirements of the R&D community.

Practical steps can be taken to improve the quality, timeliness, and accuracy of information which will have an impact on the R&D efforts of NASA. By recognizing problems and taking appropriate action to correct them, we can reduce information handling costs. Given the size of NASA expenditure on information handling, even small improvements in the efficient use of information will result in very large potential savings within the NASA STI Program.

Effective use of information adds value to all the activities of the R&D community. It means improved quality of information for more effective planning; more effective and efficient discharge of functions and higher quality of service; more accurate, more cost-effective information; reduced expenditure on the collection, communication and storage of unnecessary data; and a better focused information system investment.

However, it is only in close concert with the R&D community that we can make the most effective use of information. It is only in concert with the R&D community that we can identify and specify the needs for information (including its content, quality, and timeliness); identify the most appropriate sources of information to meet these needs; identify the most appropriate mechanism for the delivery of this information; and establish procedures to allow data from many sources to be brought together to provide information at the point of need. In short, it is only with the help and cooperation of the R&D community that the NASA STI Program can provide information services which are easily accessible, and allow users to find the information they need with the minimum difficulty and minimum intervention by skilled specialists.

The starting point for information management must be an understanding of the users' business, its aims and objectives, and how these are translated into the functions it performs. It is then possible to derive or work out the total information needed to carry out this mission. It is important to note that the product which results from processing the required information is very important, and should employ language familiar to the users of the information.

Through dialogue and support of the R&D community the differences between information need and provision can be investigated, and this investigation will determine where it is necessary to make up the deficiencies or dispose of the surpluses. The choice of delivery systems depends largely on who needs the information, how quickly, how frequently, and what they do with it. Exploitation of the information stock also depends on knowing what is available, and on being able to identify whether it offers a contribution to the requirements. The tasks are all continuous, requiring constant or periodic review, which is best done during R&D planning stages.

STI management must become a part of the accepted culture of the R&D community, but it cannot become so unless adopted and accepted by it. A start should be made now to integrate the NASA STI Program into the R&D infrastructure, including funding and operational control. Within the R&D infrastructure, we must obtain management commitment, review and produce policy reflecting our new organizational status, allocate responsibilities, and set to work on implementing the true requirements of the R&D community.

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1. **Science, Government and Information: The Responsibilities of the Technical Community and the Government in the Transfer of Information**, A Report of the President's Science Advisory Committee (Weinberg Report), The White House, January 10, 1963.

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16. Abstract

The new information-oriented culture in which we find ourselves has created new relationships, new stimulating and expanding opportunities, new methods of doing our work, and new environments in which we carry out our work. An integral part of the NASA aerospace research and development (R&D) process is the scientific and technical information (STI) associated with it; it is both a raw material (input) and a product (output) of this process. Within this process, the NASA STI Program is tasked to provide information management and services, to ensure that accurate and timely STI is generated and entered into an appropriate information service and made available in a useable form to those who have a need for it; in essence, a means to exploit both internal (NASA corporate) and pertinent external (other governmental/industrial/foreign) information to meet the requirements of the R&D community. To understand the STI Program management issues, it is critical to understand the role of the STI Program in the context of the R&D process. STI management must become a part of the accepted culture of the R&D community, but it cannot become so unless adopted and accepted by it. A start should be made now to integrate the NASA STI Program into the R&D infrastructure, including funding and operational control. Within this infrastructure, we must obtain management commitment, review and produce policy reflecting the organizational status, allocate responsibilities, and set to work on implementing the true requirements of the R&D community.

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