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TECHNOLOGY TRANSFER IN THE NASA AMES ADVANCED LIFE SUPPORT DIVISION

A Summary of Representative Activities

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FOREWORD

This white paper summarizes a representative set of technology transfer activities which are currently underway in the Advanced Life Support Division of NASA Ames Research Center. Five specific NASA-funded research or technology development projects are synopsized which are resulting in transfer of technology in one or more of four main "arenas:" (1) Intra-NASA, (2) Intra-Federal, (3) NASA-Aerospace Industry, and (4) Aerospace Industry-Broader Economy. Each project is summarized as a case history, specific issues are identified, and recommendations are formulated based on the lessons learned as a result of each project. More detailed information on each of the five cases is appended separately.

This collection of materials is offered to the participants of the 1992 NASA OAST workshop entitled "Civil Space Technology Development: A Workshop on Technology Transfer and Effectiveness," in order to stimulate discussion around some concrete examples, and to offer recommendations and lessons learned that might serve as a starting point for improving technology transfer as practiced by NASA.

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APPENDICES

1.0 INTRODUCTION

This paper is intended as a summary of several technology transfer activities in the field of Advanced Life Support research and technology development. The activities summarized herein are taking place in the Advanced Life Support Division (ALSD) at NASA Ames Research Center (ARC). The information presented is intended to be an illustrative, rather than an exhaustive, review of various activities underway in the division. Recent ALSD technology transfer activities are summarized in the body of the paper, and supporting documentation is appended. The pertinent history, issues, and appropriate recommendations are summarized for each case discussed in the paper. In addition, a set of "lessons learned" from the composite of the technology transfer activities of the ALSD is presented, with the lessons grouped according to the four "arenas" of technology transfer that have been identified by the NASA Office of Aeronautics and Space Technology (OAST) (ref. 1):

- Intra-NASA transfer (from NASA research and technology development (R&TD) programs to NASA flight programs/projects);
- Intra-Federal transfer (between NASA and other federal laboratories/agencies);
- NASA - Aerospace Industry transfer (between NASA and its traditional aerospace industry contractors); and
- Aerospace - Broader Economy transfer (between aerospace government/contractor organizations and organizations in other sectors of the economy).

Note that in all of these arenas, technology can be transferred in both directions, although for Intra-NASA transfer, the usual mode is from the research center to the flight development center. At least one ALSD activity from each of the four arenas is discussed in this paper.

2.0 BACKGROUND

Shortly after the formation of the Division in 1989, Division management consciously sought to both analyze and pro-actively implement technology transfer in several arenas: internal to NASA; external to the private sector; external to other agencies, states, and institutions; and external to appropriate international settings.

In 1990, in response to a request from the Executive Director of the National Space Council, the ALSD published a preliminary survey of opportunities in commercial technology transfer, "Potential Spin-offs of Advanced Life Support Technologies," (Appendix A). This document identified several high impact areas for possible advanced life support technology transfer. Included among these are the following:

- Reduction of plastic solid waste in landfills.
- Superior yields in global agriculture.
- Software to manage hazardous materials and waste.
- Protective clothing and life support units for fire fighting and toxic waste management.
- Residential and commercial water clean-up and recycling.
- Sensor technology for "tight building" syndrome.
- Revolutionary technology for aquatic exploration and commercial undersea operations.

2.1 The Rationale for Advanced Life Support Research and Technology Development

The impetus for advanced life support R&TD is imbedded in the requirements for extended duration manned space exploration, as embodied in the President's proposed Space Exploration Initiative (SEI). Advanced life support, consisting of surface habitat/space transfer vehicle core life support systems and extravehicular mobility units, has been identified as an enabling technology for SEI by several recent studies (ref. 2-4, others). Advanced regenerative, or closed-loop, life support technology drastically reduces the amount of consumables (oxygen, water, food, etc.) required for human support, thereby minimizing the otherwise enormous cost of resupply. Specific advances in the state of the art of this technology have been identified which will enhance crew productivity, ensure crew safety, augment food supply with freshly-grown food, and bolster crew morale during long, arduous missions or planetary stays.

Advanced life support R&TD produces, by definition, technology for maintenance of human health. Air and water regeneration, waste disposal, and plant-based bioregeneration/food production are all key areas of research. New processes for accomplishing these functions in space may be readily adaptable to performing these functions on earth. Thus, development of advanced life support technology has the inherent capability to generate terrestrial benefits.

Certainly other NASA technologies also have "spin-off" potential, but terrestrial applications of this technology would seem to be among the more easily understood in terms of direct benefit to individuals and the resolution of problems associated with human activity in an environment or habitat which is recognized to possess finite resources and/or non-infinite buffer volumes in which to discharge pollutants.

In addition to advancing technologies which benefit the public good, advanced life support technology is also capable of stimulating commercial activity, as the Foster Grant patent license case demonstrates (see Appendix E). The potential economic value of this technology, combined with the human relevance of the technology, also generates interest among the public, which may be translatable into political support during crucial budgetary times for civil space related programs.

The following cases illustrate tangible national and global benefits. To fully realize these, however, requires a systematic attempt to do so, while maintaining a focus on the principal mission of developing and delivering the technology. Serendipitous and "passive" transfer can and does occur (e.g., Foster Grant License Agreement, Appendix E), but managed or "active" technology transfer activities and projects, the authors contend, is likely to increase the occurrence, and hopefully, the success of the transfer. This is the primary motivation for the proposal to formalize and improve the Intra-NASA technology transfer process, which is summarized in Section 3.1 below (see also Appendix B for the Technology Transfer Process Improvement Task proposal).

2.2 The Rationale for Managed Technology Transfer

The restructuring of the global economy over the past twenty years has created new realities which the U.S. civil space program must contend with. It is persuasively argued that economic security has replaced national security as the driving force of American politics and policy (ref. 5). In this highly competitive global economy, public investment is now debated on the merits of the contribution a high technology project can make to "national competitiveness." The scales of competitiveness weigh, among other things, the potential transferability of technologies resulting from the funded program into other sectors of the national economy. Technology transfer is thus one of the major issues which R&TD principal investigators and managers in NASA and other federal labs must address (ref. 6).

The trend toward managed transfer is also spurred by the budgetary climate in Congress. Competing claims for education, environmental, and social programs are literally (through the placement of NASA's budget in the HUD-and-Independent-Agencies appropriations bill) and rhetorically pitted against the civil space program. As the rhetoric has increased in intensity in recent years, the specter of the major reductions in aerospace budgets during the post-Apollo years comes readily to mind. Given this situation, it is reasonable to assert that NASA's ability to produce technology for both space and terrestrial applications may be a key to survival in the coming years.

However, as an American Society of Mechanical Engineers publication notes (ref. 7):

> "...a director of licensing for a "Fortune 100" multinational corporation observed that they long ago concluded that dissemination (of information) did not produce results. He maintained that the only sure way to transfer (license) company developed technologies was to market, or sell, them in the same way any other commercial product is sold. Federal agency programs have not gone, or even plan to go, that far. Indeed, chances are that most federal agencies do not now have even a fair in-house capability to determine the potential commercial values of their own technologies."

This fundamental impediment to technology transfer, as well as others which are identified in the issues section of each case study below, must be overcome in order for NASA-sponsored research and technology development programs to produce maximum benefit for the U.S. economy.

3.0 CASE STUDIES

3.1 The Technology Transfer Process Improvement Task (TIPIT) Proposal (Appendix B)

3.1.1 Case History

The success of the Space Exploration Initiative (SEI) will depend on the development of several key enabling technologies, such as advanced life support (ref. 3). In programs, such as Apollo, the need for, and inherent risk in, developing new technologies was driven by required performance and schedule. The political necessity of mission success and the need to prudently manage risk resulted in large funding requirements. Often multiple, competing technologies were carried to flight readiness before down selection to the best candidate. Post-Apollo redirection in the nation's priorities, along with today's highly constrained discretionary federal budget situation, have resulted in reduced NASA budgets for research and technology development. Resources are no longer available to develop all the high priority new technologies that will be needed for the SEI, let alone funding two or more alternative technologies for a given function as was done during Apollo. Technology projects which are funded must be efficiently run, and they must address the key issues which the ultimate customer, i.e., the flight program, identifies. These realties require a fundamental re-examination of how effective the existing Intra-NASA technology development and transfer process is, and how it could become more cost-effective and customer-responsive without sacrificing ultimate system performance or safety.

The Advanced Life Support Division at NASA ARC, together with the Planet Surface Systems Office (PSSO) at NASA Johnson Space Center (JSC), are proposing the Technology Transfer Process Improvement Task (TTPIT). This task will address how NASA could improve technology transfer from the research lab to the flight program (Intra-NASA technology transfer). Since a research center (ARC) and a flight center (JSC) are represented on the TTPIT, the points of view of both technology developer (i.e., the "supplier") and technology user (i.e., the "customer") will be fairly represented. It is hoped that this teaming arrangement will result in the definition of an improved, more formalized Intra-NASA technology transfer process that can be readily incorporated into NASA programs.

The authors wish to acknowledge the contribution of William Morgan and David Petri of the PSSO for inspiring the TTPIT concept, and contributing to its development to date.

3.1.2 Issues

There are two primary issues that must be dealt with if the TTPIT is to become a reality. The first is the constrained budget environment itself. If funds are not available to support all the required high priority R&TD projects OAST has identified in its Integrated Technology Plan (ref. 3), then how can enough money be found to fund a project to improve the generic *process* by which technology is developed and transferred? The response to such a rhetorical question is obvious. A very small amount of funding (on the order of a tenth of one percent of the current annual OAST civil space technology budget, for two to three years) is estimated to be required to effectively analyze and develop an enhanced set of technology transfer mechanisms for the agency, with the team participants identified at ARC/ALSD and JSC/PSSO. The potential payoff is large if the project proves to be successful, and the investment is relatively small.

The second issue has to do with acceptance of the ultimate TTPIT products by the research project principal investigators and technologists and the flight project engineers and managers who will be responsible for improving how technology is transferred within the agency. Technology transfer from research to flight centers is currently handled on an informal, almost ad hoc, basis. Successful examples usually involve a Principal Inves-tigator (PI) or technologist who was motivated to "go on the road" or otherwise "sell" his technology concept(s) to a flight project customer. Other cases involving serendipity, or other such random factors, abound. One might ask how receptive the independent researcher will be to a directive to follow a prescribed technology development life cycle (see below, and Appendix B) and participate in a formalized Technology Readiness Review that customers from the flight project office would also attend. Clearly, the proposed TTPIT products will have to be sold to these personnel as part of getting them accepted, just as new technologies have to be sold to their customers today.

3.1.3 Recommendations

1. Analyze the existing Intra-NASA technology transfer process. The current OAST-sponsored Workshop is the first step in this analysis.

2. Rigorously define the Technology Readiness Level (TRL) and the activities and products associated with achieving a TRL rating.

3. Examine the approach to technology transfer in use at other government agencies, such as the Department of Defense, the Environmental Protection Agency, the Department of Transportation, and the Department of Energy.

4. Define and formalize the Technology Transfer Life Cycle (integrating both technology development and technology transfer).

5. Formalize the information flow (types and content) between technology suppliers and flight program customers that will provide for an effective decision making environment.

6. Advocate for adoption of a formalized technology development and transfer process, incorporating the TTPIT products, by NASA, using appropriate means, such as training courses, publications, workshops, etc.

3.2 International Cooperation and Technology Transfer of Closed Environment Life Support Systems to Antarctic Habitats (Appendix C)

3.2.1 Case History

The National Science Foundation (NSF) and NASA have had a long history of cooperative projects in the Antarctica. With respect to this tradition of collaboration, the NSF and NASA have prepared and approved a Memorandum of Agreement (MOA) to further formalize their mutually beneficial interests in Antarctic research activities applicable to space research and exploration (see Appendix C). As an example, under this MOA, NASA will be able to utilize the unique Antarctic environment to test prototype hardware systems and protocols in a setting analogous to Martian environmental conditions, while NSF will benefit from the transfer of space technology in many areas, including: improved power systems, telerobotics, automated systems, and life support technologies. In the case of life support systems, NSF will benefit from an improved quality of life for its stationed personnel, a reduction in resupply demand, and protection of the Antarctic environment by the implementation of NASA-developed Closed Environment Life Support Systems (CELSS).

The ALSD intends to participate in this collaboration by developing an operational CELSS. In close conjunction with the NSF, a plan is currently being developed to provide systems for food crop production and waste processing for the Amundsen-Scott South Polar Research Station (South Pole Station). This project is known as the CELSS Antarctic Analog Project (CAAP) and is composed of two phases. The first phase will deliver a crop production unit to the South Pole during the winter of 1993-1994. The second phase will provide to the NSF an integrated waste processing/crop production unit in the anticipated time frame of the winter of 1996-1997.

3.2.2 Issues

There are no specific issues as this time.

3.2.3 Recommendations

1. Specific, readily identifiable technology transfers should be tracked as a key component of the CAAP. In addition to enabling science via collaborative transfer of data, concepts, and technology, the emplacement of a CELSS unit in Antarctica is the first such application of this technology in an operational (versus a pure research) environment where it will be depended on to provide human support. It is expected that data gathered from this project will provide valuable information as to the usefulness and viability of CELSS technology in other remote, harsh environments. Thus, the contribution that technology transfer can make to this high priority project is of sufficient interest to warrant careful documentation.

3.3 Memorandum of Agreement for the NASA/Ames - McDonnell Douglas Research Associate Exchange Program (Appendix D)

3.3.1 Case History

Upon creation of ALSD in March 1990, the Systems Evaluation and Integration (SE&I) Branch was chartered to build a system engineering capability for the Division. Since the branch was built essentially from scratch with a limited pre-existing funding base, several methods for expanding the branch's scope of activities and access to system engineering tools were pursued that would not require NASA Headquarters funding. Two of these methods are documented in Appendix D. The first, a Memorandum of Agreement (MOA) between ARC and McDonnell Douglas Space Systems Company (MDSSC), established a cooperative Research Associate Exchange Program. To date, a MDSSC research engineer has served a nine month tour of duty at ARC assigned to the SE&I Branch of the ALSD working as an integrated member of the branch team under the lead of a civil servant project manager. In a reciprocal exchange, that civil servant project manager has just begun a similar assignment in residence at MDSSC in Huntington Beach, and will work under the lead of a senior MDSSC research scientist. In addition to providing an excellent vehicle for two-way technology transfer between NASA and MDSSC, this arrangement also provides an outstanding professional development experience for the personnel involved.

The second method employed a standard Non-Disclosure Agreement (NDA) between NASA ARC and MDSSC to allow ARC personnel exclusive use of several proprietary computer codes developed by MDSSC using Internal Research and Development (IRAD) funding. Intellectual property and proprietary ownership considerations require that this exchange of software be "temporary" in the sense of having a specified duration, and require that NASA personnel exercise due caution to prevent the proprietary code from being transmitted to any organization who would gain a competitive benefit at the expense of MDSSC by possessing it. NASA retains the right to publish analysis produced with the code provided the confidentiality is not compromised. To date, use of the code modules obtained from MDSSC under the NDA shown in Appendix D are estimated to have saved ARC over $200K and 1-2 years in code development effort.

3.3.2 Issues

The only issue of any consequence was the time it took to draft, review, coordinate, and revise the MOA through both ARC and MDSSC management. From conception of the idea for an ARC/MDSSC researcher exchange, to final sign-off by the ARC Center Director, took almost ten months. However, this is not an unreasonable amount of time considering this MOA was the first one involving exchange of personnel that ARC had entered into in almost ten years (according to ARC External Relations Office files). It is hoped that in the future such agreements, at ARC and other NASA centers, could be formulated and approved more quickly by using this MOA as a model and precedent.

3.3.3 Recommendations

1. NASA should employ personnel exchange programs as a centerpiece of its technology transfer activities. Personnel exchanges are perhaps the optimum form of technology transfer, since transfer of the information that underpins the "technology" is assured to happen. Such exchanges are applicable to all four arenas identified earlier.

2. Utilize the ARC/MDSSC Research Associate Exchange Program MOA shown in Appendix D as a model for formulating similar agreements at other NASA centers and federal laboratories, as appropriate.

3.4 Exclusive License Agreement for the Foster Grant "Space Tech" Eyeglass Lens (Appendix E)

3.4.1 Case History

In 1978, Foster Grant learned of an ARC patent with commercial application to their product. Utilizing an exclusive license agreement, both NASA and the researcher receive royalties from the manufacture of lenses which bear the patented polymer coating. Several million units have been produced and sold thus far.

3.4.2 Issues

The NASA patent holder reports that the royalties received are significantly lower than the industry standard, because they were negotiated on the basis of one cent ($.01) per unit, as opposed to a percentage of the revenue stream. The patent holder also reports that there are no educational materials about patent applications, or the implications of royalties resulting from research conducted under NASA auspices, that the typical NASA researcher could benefit from reading. In 1990, Foster Grant dissolved and was bought out by a new company. The patent holder discovered this only coincidentally. In short, the tracking of royalty agreements is difficult due to limited support from the NASA institution.

3.4.3 Recommendations:

1. Provide commercial analysis services to determine the fair market value of NASA-developed technology, and the most advantageous basis for royalties negotiated with commercial organizations. The goal should be to provide increased financial incentives for researchers to consider the commercial potential of their research activities, with the ultimate goal of maximizing the benefit to the broader U.S. economy of the public's investment in their research.

2. Develop educational materials and training mechanisms for NASA researchers regarding commercial aspects of patents and royalties.

3. Increase the level of Intellectual Property support available to the NASA PI. An increased level of support from the NASA Patent Counsel should be provided in order to more closely track royalty agreements.

3.5 NASA and the National Solid Wastes Management Association (NSWMA) (Appendix F)

3.5.1 Case History

In 1989, industry representatives, who are also former high level NASA managers, proposed a series of information exchanges between NASA and the NSWMA, to discuss relevant technologies which could be applied to waste disposal systems and solid waste sites in the United States and abroad. Discussions were facilitated by the Washington group J.M. Beggs Associates, funded independently by the NASA Office of Commercialization at NASA Headquarters. A series of workshops were held to identify several potential joint projects that would transfer technology in both directions between NASA and the solid wastes management industry (see

Appendix F). The Environmental Protection Agency is also a participant in the dialog, enabling potential Intra-Federal transfer as well. Current discussions are focused on the first phase of a three phase project to develop an a chemical sensor using advanced life support technology that could be installed in a ground water monitoring well adjacent to a municipal solid waste landfill. If successful, the monitor could greatly reduce the expense of the required thirty year post-closure landfill monitoring period by minimizing the need to draw water samples out of each of several wells and take them to an analytical chemistry laboratory for expensive, specialized analysis of the 47 different constituents required.

3.5.2 Issues

Currently, technology transfer from NASA to the commercial sector is managed out of a separate organization (the Commercialization or Technology Utilization Office) from the research and technology directorates at each Center. This can at times compromise clear accountability and authority over individual commercial technology transfer projects. Responsibility to manage such projects should be integrated into the technology provider's organization.

3.5.3 Recommendations

1. The management of most commercial technology transfer projects should be integrated into the NASA field center organization which is providing the technology. Criteria should be developed, in conjunction with the R&TD organizations, to allow identification of those projects which should be managed out of the Technology Utilization offices.

2. Dialog with appropriate commercial trade associations should be expanded. The trade association can be a valuable organization to engage in technology transfer discussions and activities, as its leadership has a global view of both it's industry's needs and the individual capabilities of it's member firms. Trade associations also allow for access to top management decision makers.

4.0 LESSONS LEARNED

In addition to the above cited recommendations, the following lessons learned are offered. Note that most of the experience the ARC/ALSD has gained since its creation in 1990 has been in external transfer projects. Thus, the following issues largely relate to transfer external to the agency.

4.1 Generic Issues

A few generic lessons have been identified which span all technology transfer arenas. These include:

1. Incentive Structure.

   The primary incentive structure within the research groups at the project level is rewards for producing research results and research papers. The incentives are not aimed at encouraging and rewarding technology transfer. Rather, the assumption is made that technology transfer occurs "naturally," through personal relationships and the organization. Likewise managers, while generally aware that a "track record" of technology transfer will benefit the perception of the program, are not provided with formal incentives or specialized training in order to effect the transfer of technology.

2. Institutional Support.

   Technology transfer activities are not considered an integral part of the program/project, but rather are managed as a separate institutional activity in the NASA technology utilization/commercialization office. Dedicated personnel and ongoing programmatic support for technology transfer are not a part of the project life cycle, nor are the costs associated with technology transfer planned for. Travel budgets, for example, are oriented towards completing projects, rather than permitting the face-to-face exchanges necessary for effective transfer technology.

3. Application-Specific Research

   R&TD projects are rarely allowed to allocate even a small fraction of programmatic funds to modifications in the research which permit or support transfer applications. Generally, technology which is originally developed for a specific mission, especially civil space flight programs, usually must be modified for transfer to other applications.

Transfer of the knowledge to other users requires modification of the application at some point in the process, either by the original developer or by the "transferee."

4. Contractor's role and entitlement.

Under current NASA policy, if a contractor requests "right of first refusal" to title or exclusive licenses on NASA funded technology, their request generally will be granted. Any further "transfer" is then dependent on the company, as NASA retains only a research license. This broad entitlement practice should be re-examined in light of the unduly restrictive effect it has on technology transfer.

4.2 Intra-NASA Transfer

1. Organizational Support

There is an absence of formal institutional mechanisms to facilitate intra-agency transfer, over and above the person-to-person contact that is the fundamental basis of transfer. The supporting mechanisms should include incentives, personnel exchange programs, and targeted funding to permit transfer.

2. Incentives Conflicts

The NASA space flight programs are operating against development deadlines that require them to have technology ready at the start of Phase C/D in the project cycle. The research programs, by culture and structure, are not incentivized to produce technology to deadlines. Also, the drive to build up the institution and maintain the workforce complement has led flight centers to become extensively involved in R&TD programs. This trend has led to direct competition between research and flight centers for the same R&TD funds, which has resulted in a major impediment to technology transfer. The recent Roles and Missions directive from the NASA Administrator is a response to this perceived problem of activity overlap.

4.3 Intra-Federal Transfer

1. Federal Contacts and Incentives

Incentives need to be established to promote the transfer of knowledge and technology between federal agencies. Once again, no formal mechanisms currently exist to facilitate this, as the NASA-NSWMA case cited above illustrates. In this case, contact between

NASA and the EPA, in the specific area of solid waste, was facilitated by the NSWMA, a trade industry association. It should be noted that there had been previous contacts between ARC/ALSD personnel and EPA personnel, but it was on an informal researcher-to-researcher basis.

4.4 NASA-Private Sector Transfers

1. Legal Support

Transfers to the private sector often require legal support. General Counsel support is very limited, and patent counsel support is almost exclusively dedicated to the filing of new patents and assurance of NASA research licensing on privately titled intellectual property. Increased availability of legal counsel resources for working technology transfer issues would serve to remove some of the impediments in the NASA-broader economy arena of transfer.

2. Business Support

Business and commercial support is not available to researchers. Researchers are generally ill-equipped to influence licensing negotiations to protect their financial interests or understand the consequences of commercial "deals." Little or no resources exist to educate the research population about commercial licensing. The development of formal training courses on commercial licensing and technology transfer issues and mechanisms is highly recommended. Training courses on several aspects of technology transfer could prove very helpful and should be developed.

3. Parallel Private Sector Needs

In many cases, there is not an obvious parallel private sector need for NASA civil space technology, in the same way there is for NASA aeronautics technology and research. The most obvious parallel needs for space technology are in power/propulsion, life support, and information systems applications. It is easier to find an interested user for an improved blood pressure monitor than it is to find one for an improved robotics software code for work in a microgravity environment.

4. Cost of Transfer

In addition to face-to-face communication of experts within whom knowledge resides, technology exchanges often require moving equipment, documents, software, etc. Thus, it can be expensive, under the current system, to arrange for transfer to the private sector. Transfers occur, therefore, when there is a perceptible benefit to the transferee. Finding these returns to be justification enough to make the effort is a judgment call which a manager must make, relative to other demands.

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