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Paper Session II-C - Technology Transfer and The Office of Advanced Concepts and Technology

John C. Mankins
Office of Advanced Concepts and Technology, National Aeronautics and Space Administration

Johnathon Root
Office of Advanced Concepts and Technology, National Aeronautics and Space Administration

Carissa B. Cristensen
Princeton Synergetics, Inc., Princeton, New Jersey

Robert G. Steen
Princeton Synergetics, Inc., Princeton, New Jersey

TECHNOLOGY TRANSFER AND THE OFFICE OF ADVANCED CONCEPTS AND TECHNOLOGY

John C. Mankins and Jonathan Root
Office of Advanced Concepts and Technology, National Aeronautics and Space Administration
&
Carissa Bryce Christensen and Robert G. Steen
Princeton Synergetics, Inc., Princeton, New Jersey

ABSTRACT

NASA has a continuing mission to develop and transfer advanced technologies for the benefit of government space programs, the aerospace industry and the nation's economy. In October, 1992, the NASA Administrator created a new Office of Advanced Concepts and Technology (OACT) that is comprised of both the former NASA Office of Commercial Programs (OCP) and the Space Technology Directorate of the Office of Aeronautics and Space Technology (OAST). The purposes of this new office include the development of innovative new technologies and concepts, and the rapid and effective transfer of technology into and from NASA as well as other organizations participating in the U.S. civil space program.

In this paper, the character and interrelationships of OACT programs and plans will be summarized, including overarching strategic planning (e.g. the Integrated Technology Plan, ITP); space technology development efforts (for example, the NASA base and focused space research and technology programs); special technology innovation efforts (such as the Small Business Innovative Research, SBIR, program); and, efforts to promote commercial space development (e.g. the Centers for Commercial Development of Space, CCDSs).

Particular emphasis will be given to technology transfer programs and efforts to improve technology transfer (such as the on-going development of the national technology transfer network). This paper will describe both existing technology transfer programs and current planning, as well as assessment and analysis activities aimed at enabling OACT to refine and energize NASA's approaches to technology transfer. It will also evaluate recent recommendations made by internal and external review teams and others concerning technology transfer for the civil space program. These include a 1992 workshop on Technology Transfer and the Civil Space Program, as well as the results of two internal NASA-wide teams. Finally, the paper will identify options for the future of civil space technology transfer improvements.

Overview

Technology development and the subsequent timely application of technology by industry are increasingly recognized as fundamental to the economic success of the United States. NASA has a continuing mission to develop and transfer advanced technologies for the benefit of not just government space programs, but also the aerospace industry and the nation's economy. The success of this mission depends in large part on coordination of space technology development and effective transfer among government institutions, industry, and academia.

Technology transfer encompasses many pathways and participants. There are many barriers to its success. A useful method of organizing civil space technology transfer activities, for purposes of planning and analysis, is to consider four transfer sectors:

- Technology Transfer Within NASA. This sector encompasses coordination of technology development and transfer between NASA research and technology programs and NASA flight programs and their field center project offices, resulting in successful integration of NASA developed technology into NASA programs.
- Technology Transfer Within Government. This sector encompasses coordination and selected transfer between NASA and other U.S. government agencies, with NASA both providing technology to other agencies, and harvesting technologies from them.
- Technology Transfer Between the U.S. Government and the Aerospace Industry. This sector encompasses transfer and dissemination of timely technology development information between NASA and the aerospace industry, with information flowing in both directions.
- Technology With the General Economy. This sector encompasses technology transfer from the civil space program and the aerospace industry to the broader U.S. economy.

Technology development and transfer are key responsibilities of NASA's Office of Advanced Concepts and Technology (OACT), which was created in the Fall, 1992. This paper discusses major OACT programs addressing all of these transfer sectors. The paper's focus is on the technology transfer aspects of OACT's programs, reflecting the increased emphasis being accorded by NASA to technology transfer as a key mission. The paper also considers external and internal recommendations for improving technology transfer in NASA, providing a chronology of events (such as workshops, internal reviews, and reports) related to technology transfer improvement during the past 3 years. Finally, the paper synthesizes the results of these analyses into a description of the future directions of NASA's technology transfer activities and the role of OACT.

OACT Technology Transfer-Related Programs

The appropriate starting point for an analysis of NASA/OACT technology transfer activities is a summary of OACT's technology development and technology transfer programs. These include basic technology development as well as technology development aimed at specific technology users, and a broad range of programs designed to deliver NASA-developed technologies to other users in government, industry, and academia.

NASA Base and Focused Research and Technology Programs OACT conducts basic space technology research and development (R&D) in discipline areas such as aerothermodynamics, advanced materials, power and propulsion, automation and robotics, information sciences, and others. In addition, there are space technology research programs focused on five key areas: space transportation, communication, science (instruments), planetary surface (exploration), space platforms and operations. Finally, OACT conducts in-space technology research and validation programs that fund the development of support hardware and software (e.g., the In-Space Technology Experiment Program, IN-STEP). These programs constitute a principal source for technology to be transferred in all four sectors.

Small Business Innovative Research Program The NASA Small Business Innovative Research (SBIR) Program, managed by OACT, aims at enhancing the success of small business in developing and marketing new technology to NASA. It is part of a multi-agency technology development program. Federal R&D agencies commit a small percentage of their research budgets to the SBIR program, in order to involve small businesses in working to meet their technology needs. The SBIR program enables small businesses to obtain government funding to pursue research with potential commercial applications. Businesses submit proposals for such research, and awards are made in three phases. Typical award levels vary from agency to agency. At NASA, Phase I awards are generally about $50,000 for six months of feasibility assessment research. Phase II awards (for which only Phase I award recipients are eligible) are for a maximum of $300,000 and 24 months. Phase III of the SBIR program does not involve SBIR funding; Phase III is the commercial application of the research by the firm, in which non-federal capital is expected to be used. The SBIR program promotes technology transfer from small businesses (aerospace and non-aerospace) into NASA and other agencies.

Technology Transfer Network At the direction of Congress, NASA OACT created the National Technology Transfer Network. The Network is comprised of the National Technology Transfer Center (NTTC) and six Regional Technology Transfer Centers (RTTCs). The NTTC's principal mission is to assist all Federal agencies in executing the Federal-wide technology transfer mandate as a means of enhancing U.S. competitiveness. The NTTC serves as the national hub for the Network, providing core capabilities and cross-cutting services. The NTTC is currently establishing key capabilities and services to act as the national clearinghouse for Federal technology transfer, linking U.S. firms with Federal agencies and laboratories, the RTTCs, and state and local agencies, and to provide training and education services to government and industry for to develop technology transfer skills. In addition, the NTTC conducts national outreach and promotional activities.

The six RTTCs replaced NASA's longstanding network of Industrial Applications Centers, and reflect NASA's initiative to upgrade and restructure its technology transfer system to serve U.S. business and industry better. The RTTCs work closely with a wide range of Federal, state, and local programs in their regions to provide information (computerized searches of Federal technology databases and other technology sources), technical services (assessments of technology requirements, analysis of technology applications, and engineering reports) and commercialization services (technology brokering, business analyses, and venture capital sourcing).

OACT also has a responsibility to promote the creation of new space industries. The Centers for the Commercial Development of Space (CCDSs) focus on this goal. The CCDSs bring together industry, academia and government to share resources and undertake research in space-related technology areas, and to develop marketable products. The CCDS network consists of 18 not-for-profit Centers formed by commercial firms, academic and research institutions, and non-NASA government organizations. NASA provides financial grants to the Centers, typically in amounts from $500,000 to $1,000,000 per year, for an initial period of 5 years. This period has in some cases been extended. The CCDS program requires that the Centers have increasing non-NASA financial and in-kind contributions; a program goal is for CCDSs to achieve self-sufficiency.

Review of Recent Events

Although NASA has a history of technology transfer success, the Agency has in the last three years undertaken analysis and planning activities aimed at developing a reinvigorated technology transfer strategy. These efforts have included (in chronological order) responding to external assessments of NASA (in part with the development of an Integrated Technology Plan), conducting a workshop focused on improving the technology transfer process (involving industry, academic, and government technologists), and directions by the NASA Administrator, including internal reviews of NASA's technology transfer and technology integration capabilities. These efforts are described below.

Integrated Technology Plan In 1991, the Space Technology Directorate of NASA's Office of Aeronautics and Space Technology developed an *Integrated Technology Plan* (ITP) for the civil space program. Understanding and beginning to improve the process of civil space technology transfer was one of the goals of the ITP (with a particular focus on two transfer sectors -- transfer within NASA and transfer with the aerospace industry).

The ITP responded to the 1990 report of the Advisory Committee on the Future of the U.S. Space Program, chaired by Mr. Norman Augustine, addressing the Committee's Recommendation 8. The Committee singled out particular aspects in the process of creating new technologies as crucial to the success of the NASA's technology program: first, the determination of what technologies should be developed (i.e., the identification of needs and priorities); second, development and demonstration of these technologies; and, finally, successful transfer of the technology to users.

Of these, technology transfer requires significant attention to assure success. In its report, the Committee noted that:

> *The serious technological challenge for NASA at the present time does not relate to issues of invention or creativity, but rather to the difficult sequence of taking an invention and turning it into an engineering component, testing its suitability in space; and then incorporating it into a spacecraft system. In its early years, NASA managed this "technology insertion" phase particularly well. But there is a widely-held opinion that although NASA continues to do excellent research, both in its centers and in its affiliated universities, the results of this work are not being efficiently transferred into application--a fault, it must be said, that is shared with the U.S. industry at large. A prime responsibility of the NASA technology development activity must be to bridge the gap between technology concepts and application to space practice.*

Technology Transfer and the Civil Space Program Understanding and beginning to improve civil space technology transfer across all sectors was a central goal of the March 1992 Workshop on Technology Transfer and the Civil Space Program that was sponsored by the Space Technology Directorate of NASA's Office of Aeronautics and Space Technology. This workshop represented a groundbreaking approach for NASA's technology program -- meeting with technology transfer practitioners from government, industry, and academia, seeking to understand better what makes transfer succeed. The principal findings of the workshop were:

- Technology transfer, including supporting U.S. commercial competitiveness, needs to be a mission of NASA and civil space participants from all sectors. This implies a need for both near-term action and a long-term commitment to technology transfer efforts.
- A commitment must be made to plan technology transfer into space R&T efforts, including potential resources, measurement systems, senior management focus, customer involvement, and personnel training.

Secondary workshop findings were that:

- Technology transfer requires meaningful customer involvement early and through the technology development process -- including all types of "customer" (e.g. industry).
- There is a requirement to provide real incentives/rewards to motivate technology transfer (at all levels of the organization and within all sectors).
- There is a need to focus management attention at all levels on removing technology transfer impediments, including personnel, organizational, legal, and procurement practices. Organizations must aggressively pursue improved communications related to technology transfer (among all sectors).
- There is a need for clear policies (and appropriate mechanisms) to implement "bridging" efforts, including demonstrations, flight experiments, and required facility development.

In addition to the findings listed above, the workshop also developed a series of "options for action" that were urged on the participants. These included the review of the results of the workshop by participants with their management; consideration of a future forum and/or meeting on technology transfer of the same (and possibly additional) organizations; consideration of the creation of technology transfer teams within participating organizations; consideration of the creation of a working "network" spanning the sectors involved in technology transfer to facilitate continuing coordination; review of the workshop results with the NASA/OACT Space Systems and Technology Advisory Committee (SSTAC) and other advisory groups (including the NASA Advisory Committee (NAC), the National Research Council (NRC), and others); and, formal, external review of workshop results (including groups specializing in policy expertise).

A special issue of the journal *Space Commerce* based on the Workshop is available. The aim of the journal issue was to provide practical approaches to technology transfer that practitioners have found to be effective.

The analysis in the journal addresses the four technology transfer sectors used for the Workshop: transfer from NASA to NASA, transfer between NASA and other parts of the U.S. government, transfer between NASA and the aerospace industry, and transfer between NASA and the general economy. It also discusses the strategies and mechanisms that can be brought to bear to achieve technology transfer in each sector. In addition, many of the recommendations and approaches in this analysis can be generalized to technology transfer in arenas beyond the civil space program.

Finally, government and industry perspectives on technology transfer are provided by Mr. Courtney Stadd, Acting Deputy Associate Administrator for NASA OACT; Mrs. Deborah Wince-Smith, Assistant Secretary for Technology Policy of the Department of Commerce; Mr. James Romero, Deputy Director of Phillips Laboratory; Dr. Fenton Carey, Director of the Office of Space of the Department of Energy; the Society and Aerospace Technology Technical Committee of the American Institute of Aeronautics and Astronautics (AIAA); and, Dr. George Millburn, Executive Vice President of the National Center for Advanced Technologies (NCAT).

Internal Review Team Recommendations Technology transfer within NASA and to external users was recently reviewed by two internal teams created by NASA Administrator Daniel Goldin. Transfer with external organizations was assessed by the Technology Transfer Team, led by J. Creedon of Langley Research Center, and transfer within NASA was assessed by the Technology Integration Team, led by J. Wayne Littles of Marshall Space Flight Center.

The findings of each of these Teams are summarized below.

TECHNOLOGY TRANSFER TEAM: The Technology Transfer Team's principal finding was that, first and foremost, technology transfer is a fundamental mission of NASA. The Team observed that NASA has a good reputation for technology transfer and is looked upon as a good example for federal technology transfer activities. The Team concluded that NASA has not always, however, lived up to its potential. There have not been enough technology transfer successes compared to the potential, and past successes have been largely anecdotal. The Team found no comprehensive written documentation describing even the existing formal technology transfer processes and activities, and also felt that the current processes were too slow to meet industry's needs.

The Team also identified the reasons behind its findings. These observations included that NASA is hampered in its technology transfer activities by the lack of a clear statement of policy that technology transfer is a fundamental mission of the Agency and that secondary targeted (i.e., planned) and non-targeted (i.e., serendipitous) transfers are fully valued, important NASA missions; that NASA employees, managers, contractors, and grantees often do not feel that technology transfer is part of their job; and that applications programs (which reduce technical risk to industry and thus encourage the use of new technology) tend to be quite expensive.

The Team based its analysis on the transfer sector framework established at the March, 1992 Workshop. In that context, the Team produced four main findings. The first was that NASA is accountable to transfer its special capabilities and technology. The second was that success in technology transfer requires deliberate dedicated effort. The third was that technology transfer occurs mainly in the context of an appropriate person-to-person relationship between the providers and recipients. The final basis for recommendations was that experience suggests that technology transfer is most successful when recipients *want* technology for their needs, and that effective proactive outreach creates this desire. Thus, the Team concluded, a marketing model for technology transfer has greater potential for success.

The Team developed ten detailed recommendations to enable NASA to significantly improve its performance in technology transfer. The recommendations aim to change the culture of the Agency, protect employee's interests in intellectual property rights, track transfer performance, empower process action teams to improve flawed processes, and foster secondary technology targeted technology transfer. The recommendations were:

1. Each center must manage to the recommended metrics or define and manage to a more effective set.
2. Headquarters must implement a unified plan to support technology transfer.
3. NASA should specifically mention technology transfer in the Vision-Mission-Values statement.

4. The Administrator should send a directive conveying a clear, unambiguous message that technology transfer activities are fully valued, important parts of NASA missions, and that the center directors are accountable to manage their programs accordingly.
5. Administrator should continue strong technology transfer support and measure overall Agency performance.
6. Each center should include technology transfer in its mission statement.
7. Each center should provide technology transfer training for all employees.
8. Assess, promote, and reward employees according to metrics/contributions.
9. Form and empower at least the following process action or process development teams: Tech Briefs; patent applications and licensing; software distribution and transfer; conversion of non-targeted to secondary targeted transfer; conversion/integration of primary targeted to secondary targeted transfer; execution of secondary targeted programs; define relationship of centers to CCDSs; employee motivation and incentive for technology transfer activities.
10. Secondary technology transfer activities should be proactively sought. The budget allocated to each center for its use in secondary targeted transfer programs should grow and be taken "off the top" as is SBIR.

The Team's summary points were that continuing improvements must be made in NASA's technology transfer performance for NASA to best serve the country, that NASA's culture must change to achieve continuous improvement in technology transfer, and that implementing the ten recommendations made by the Team constitutes an important first step in improving NASA's technology transfer performance.

TECHNOLOGY INTEGRATION TEAM: The Technology Integration Team reviewed data from Headquarters offices, technologists, program offices, industry, and other teams, and identified five major findings related to issues of integrating state-of-the-art technology into NASA programs. Addressing primarily the NASA to NASA transfer sector, the Team found that NASA does not function as an integrated system in identification, development, and insertion of technology. The Team also found that NASA emphasizes initial low cost rather than life-cycle cost and emphasizes controlling up-front project costs rather than reducing total project cost; that the Phased Project Development Process, as practiced, does not properly include technology definition and development; that there are insufficient resources for technology insertion into NASA programs; and that the Agency lacks a consistent vision and strategy to which technology research and development can be directed for successful integration into NASA programs.

The Team developed five recommendations responding to these findings:

1. The Agency should establish a process to enable its many organizations to work as a system in identifying, developing, and integrating technology into its programs. Agency investments in base research, focused technology programs, and advanced technology development must be based on Agency prioritized needs and potential benefits. (A restructured and expanded version of the OACT Integrated Technology Plan (ITP), discussed above, was identified as the appropriate focal process for Agency technology investment decisions.)
2. The Agency should shift its emphasis from controlling initial development costs to maximizing cost effectiveness over the life of its programs. Life cycle costs should be an integral part of the phased development process. In addition, the Agency's technology development programs should address life cycle cost as well as performance factors.
3. The Agency should implement a phased development process which includes the early identification of requirements, early identification of technology options in collaboration with technologies, and maturation and selection of technologies prior to phase C/D.
4. The Agency investment in technology (approximately 3%) should be doubled during the next three years with two-thirds of the increase devoted to advanced technology development and one-third to R&T.
5. The Agency should develop a nationally accepted vision and strategy in sufficient depth to provide guidance for identification and development of required technologies. The development, use, and transfer of a technology should be a mission to the Agency.

Synthesis of Results and Future Directions

NASA continues to refine and re-energize the broad foundation of programs that NASA's decades of technology development and technology transfer have created. As a major first step, in Fall, 1992, the NASA Administrator created OACT. The Office will use approaches that represent a blend of programs initially established under the auspices of its component organizations, the Office of Commercial Programs and the Office of Aeronautics and Space Technology, as well as new programs created to meet the new mission of OACT. OACT will undertake work in four key areas:

- perform detailed systems engineering analysis of advanced concepts, to improve NASA ability to plan and to allocate resources,
- act as a "front door" for businesses and universities that want NASA's help and expertise in developing new ideas and technologies,
- transfer technology into the commercial sector through a wide range of mechanisms like technical papers, cooperative agreements, NASA-generated software, Regional Technology Transfer Centers, and working with others in NASA labs and facilities, and
- commercialize space, by working with industry in a continual and systematic way.

A unifying focus of these programs is the need to get technology into applications. Customers for OACT and other NASA technologies include NASA program offices (such as Space Shuttle and Space Station), other government agencies, the aerospace industry, and non-aerospace industries, and even the general public.

A family of new technology transfer activities is being defined, with close attention to the results of the Technology Transfer Team (which addressed transfer within government, with the aerospace industry, and with the broader economy) and the Technology Integration Team (which addressed transfer within NASA). As one response to the Technology Transfer and Technology Integration Team reports, Administrator Goldin issued an internal NASA directive that made technology transfer a top priority for the Agency.

To revitalize NASA's technology transfer and commercialization programs, the Agency is taking a number of steps. It intends to redouble its efforts to catalyze small businesses. NASA is establishing a technology incubator at two field centers to stimulate and accelerate the creation of new small businesses. The incubator will couple technology innovations in NASA programs with the skills and resources needed to establish new business ventures. In addition, NASA is acting to facilitate transfer at the local level, through improved alliances with state and local governments through an expanded network of Technology Transfer and Business Assistance Centers. The National and Regional Technology Transfer Centers will be the backbone for this effort. Valuable transfer resources will be enhanced. The Center for Space Microelectronics Technology at the Jet Propulsion Laboratory will be significantly strengthened and augmented to emphasize commercial applications.

NASA will continue to build on its commitment to empower NASA employees, including creating an Industry Partners Program (IPP) to provide an Announcement of Opportunity to NASA researchers to work with an industry partner with matching funds.

The Agency is also considering options for a new NASA Policy, directing the development of technologies with dual-use potential through the creation of Government-Industry Consortia on the SEMATECH or CCDS models. NASA will also be taking a fresh look at the approach it uses to "harvest" technologies developed outside of NASA and its team of contractors and universities. It is considering the creation of a family of Critical Technology Application Centers for rapid prototyping of new applications of commercially-developed technologies for space use. In addition, OACT is currently working with the Small Business Administration on an innovative new element of the SBIR concept: the Small Business Technology Transfer Pilot Program.

Finally, NASA is planning a vigorous Technology Outreach Program, including workshops, symposia, and NASA Select programming, to strengthen nation-wide coordination of technology advancement. This effort will build on the highly successful Technology 2002 Conference. It will include workshops for specific technology market segments and working more closely with trade associations.

Conclusion

Linking all of these efforts, and reflected in all of the recommendations of the internal teams and the workshop participants discussed above, is the need to <u>measure success</u> in transferring technology across all four key sectors. OACT is working to develop appropriate measures -- or, in the language of Total Quality Management, metrics -- for its technology development and technology transfer programs. Initial efforts at developing metrics began at the same time that the new OACT organization was occurring through the work of a number of process action teams. Assessments of existing metrics used by OACT technology programs, other NASA programs, and other federal technology programs are being conducted.

Assessing program effectiveness and efficiency aids planning, leads to program improvement, and prevents waste. NASA is keenly aware of the need for feedback and evaluation, and will continue to work to both develop appropriate measures, or metrics, and to create an institutional culture in which program assessment is a fundamental part of every effort.

may be even more commercially exiting is that the center's controlled laboratory zeolites are about thirty times larger than those currently commercially purchased.

Center for Macromolecular Crystallography - University of Alabama, Birmingham (UAB)

The UAB Center also has two major technologies underway. They have been investigating Protein Crystal Growth for over five years on 11 Shuttle flights including the most recent USML mission which featured the Center's Deputy Director, Dr. Larry DeLucas as Payload Specialist. The microgravity environment has lead in many cases to larger and better structured protein crystals than have been grown on earth. This will aid in the determination of the molecular structure of the protein which will in turn accelerate the ground based design of drugs for treatment of many of man's diseases including cancer, leukemia, and AIDS. This activity has involved most of the major pharmaceutical industries and many academic institutions. Additional flights are scheduled this year on Shuttle middeck, COMET, and both SPACEHAB flights. The center also provides a state-of-the-art ground based analytical facility to support the biomedical industry and has spun off a company Biocryst which is highly active in the drug design area.

Another activity is the investigation into large scale production of protein pharmaceutical which has flown four times on Shuttle. This involves the actual production of space-based crystallin pharmaceutical. The most recent flight last fall was a highly successful payload in conjunction with Shearing-Plough utilizing Alpha-2b interferon in the newly developed Protein Crystallizaion Facility which is designed to produce large batches of crystals.

Bioserve Space Technologies - University of Colorado

Bioserve is currently involved in several technologies. They have successfully completed two Bioserve ITA Materials Dispersion Apparatus (BIMDA) payloads on Shuttle and obtained over 400 samples in experiments ranging from biomedical applications to bioseparation and purification technologies. More recently on the USML-1 mission and the STS-54 mission, they successfully flew the Generic Bioprocessing Facility, a multi-purpose facility that can support over 130 separate experiments ranging from the molecular level to small organisms. Experiments flown on USML-1 included the use of collagen fibers which could create a variety of new pharmaceutical. Experiments were also performed on lymphocytes and white blood cells which could lead to improved treatment of various diseases. Microorganisms were also investigated as a means to design waste management systems. Currently under development is a payload in conjunction with Cetus/Chiron on SPACEHAB-2 utilizing animals to look at accelerated biomedical modeling which could lead to new drugs relating to aging research. They are also developing apparatus' for the COMET-1 payload which will support 30 day animal and plant experiments.

Center for Cell Research - Pennsylvania State University

The Penn State Center is currently involved in physiological testing using animals which could lead to the development of pharmaceutical for degenerative and chronic diseases. The first proprietary commercial flight experiment in this area was in conjunction with Genentech in late 1990 and a second flight on the STS-52 mission with Merck. This payload will also fly on the upcoming SPACEHAB-1 mission with new biomedical affiliates. These missions were all supported by the Ames Research Center who supplied the mission management.

The Center also has an biomodule technology under development which looks at various biomedical mixing in zero-g. This concept has been verified on suborbital flights and will also flown on the upcoming COMET-1 flight with industrial sponsors.

Consortium for Materials Development in Space - University of Alabama, Huntsville (UAH)

The consortium is involved in various projects including sintered and alloyed Materials. The focus is to develop powdered metal and ceramic sintering technologies in microgravity that ultimately will result in metal products, machine parts, etc., with greater strength and durability. Several concept flights have been flown on suborbital rockets and the ECLIPSE furnace developed by Wyle Laboratories will provide hotter temperatures for a wide variety of materials to be produced on orbit on SPACEHAB flights and ultimately will be available for Space Station. NASA has also purchased an opaque copy of the Boeing Chemical Vapor Transport Experiment Facility for the consortium's (and other CCDS's) utilization on SPACEHAB and Space Station Freedom. This will be flown on the SPACEHAB-2 mission.

The UAH Center also has an on-going project in improved space materials, coatings, and foams which has flown on several suborbital rockets and in the shuttle cargo bay. Additional flights are scheduled this year on both Shuttle and COMET. This includes electrodeposition to produce high quality metals and alloys.

In addition, the Center has a materials dispersion activity which will fly on Shuttle and COMET and utilizes the CMIX hardware which has been developed by Instrumentation Technology Associates (ITA) through an agreement which allows ITA to market a portion of the hardware commercially through five flights. The first flight flew successfully last fall and the second is scheduled for March, 1993.

Space Vacuum Epitaxy Center - University of Houston

This Center has, in conjunction with their affiliate, Space Industries Incorporated (SII) developed a Wake Shield Facility which will provide a vacuum in space condition much greater than the best facilities on earth to perform chemical and molecular beam epitaxial growth. Materials processed in this ultra-vacuum are expected to grow virtually defect-free. There are unlimited applications of this process in the semi-conductor and super-conductor development which could result in faster computers, and improved electronics. The Wake Shield Facility is scheduled to launch first in November, 1993 on the Shuttle. It will be released shortly after launch, fly in formation near the Shuttle, and then recovered before reentry. Future flights of this facility will feature a robotic substrate servicing system developed by the robotic CCDS, the Space Automation and Robotics Center (SPARCS) which will automate manufacturing techniques on the Wake Shield Facility by an order of magnitude. This will be first flown on the third flight of the Wake Shield in 1995. The Wake Shield Facility also has the capability to accommodate other microgravity payloads on the carrier and the back side of the facility which provides an excellent free-flying microgravity environment.

Consortium for Commercial Crystal Growth - Clarkson University

This Consortium is concentrating on float zone crystal growth which has multiple applications in IR detectors, optical signal processors, radiation-hard electronics, high frequency communications devices, and faster integrated circuits. To carry out this activity, the Center currently is working with Rockwell International with a liquid encapsulated melt zone experiment scheduled for SPACEHAB-1. This will lead to a more sophisticated approach on later SPACEHAB flights and Space Station Freedom utilizing the Commercial Float Zone Furnace developed and integrated by the Canadian Space Agency under a NASA/Canadian agreement.

Wisconsin Center for Space Automation and Robotics - University of Wisconsin

This Center is involved in the development of close ecological life support systems and has developed a unit to supply nutrients and provide humidity control to plant growth in microgravity which flew on the USML-1 mission and is scheduled on the early SPACEHAB flights. This will have applications on future long duration space flights and also has earth based applications for new technology for clean rooms and health care facilities.

Center for Materials for Space Structures - Case Western University

This Center is involved in new methods for simulating and analyzing the effects of the space environment on materials which will result in better materials for space flight applications. They have flown in the Space Shuttle cargo bay last year and are scheduled on STS-51 this summer and in November on the deployed Wake Shield Facility.

Langley Research Center

Langley is working with Paragon Optical in a gas-permeable polymer technology which has applications in improved, long term, contact lenses. This will fly on two SPACEHAB missions beginning with SPACEHAB-1 in April, 1993.

FUTURE MICROGRAVITY FLIGHT ACTIVITIES (1994-1996)

Advanced Materials Center - Battelle

The Battelle Center has begun to investigate commercial mixed oxide catalysts in the microgravity environment which could result in more efficient catalysts for the ceramic, pharmaceutical, agriculture, and petrochemical industries. This will be flown on a later SPACEHAB flight in 1995 as a precursor to applications on Space Station Freedom.

Center for Cell Research - Penn State University

The Center for Cell Research has begun to develop new hardware to investigate bioseparations using electrophoresis which has significant applications in the purification of pharmaceutical, kidney dialysis, etc. This will be flown first on SPACEHAB in 1994 and 1995 as a precursor to future Space Station flights.

Consortium for Commercial Crystal Growth - Clarkson University

The Clarkson Consortium will continue their work in float zone crystal growth with a more sophisticated approach on later SPACEHAB flights utilizing the Commercial Float Zone Furnace developed and integrated by the Canadian Space Agency for flights on SPACEHAB-3 and later flights on SPACEHAB and Freedom.

Goddard Space Flight Center

Goddard is working with both the SPARC and Clarkson Centers in the development of a robotic materials furnace which will be able to process multiple materials during a mission in the Shuttle cargo bay in 1994. This payload has both future applications as a materials facility and a robotic capability for other space applications.

OUT/YEAR MICROGRAVITY PROGRAM - (SPACE STATION FREEDOM)

The Space Station Freedom program provides the long duration laboratory component in NASA's balanced space commercial program and offers an opportunity to provide more on-orbit, long duration, microgravity applied research for the commercial community. The programs carried out will in general be the next phase to the programs flown on previous Shuttle, SPACEHAB, and ELV programs; thus, most of the technology initiatives carried out will have an excellent heritage which should keep development costs at a minimum. A large percentage of the payloads will remain government sponsored although many of them will be in the development or pilot stage. The extent of reimbursable requirements will depend primarily on the transportation cost and the length of the integration cycle, the minimization of which is extremely important to the commercial community.

NASA has established a Commercial Space Station Freedom Planning Team to assist in the commercial utilization planning and the identification of the commercial Space Station Freedom requirements through the development of a commercial payload mission model. In an effort to directly involve the commercial community, this team is made up of representatives of the CCDS's, NASA's Joint Endeavor Partners, and other industrial organizations working with NASA along with appropriate NASA Headquarters and field center commercial organizations. The NASA sponsored draft commercial mission model has been developed (Figure 4) and is currently allocated 28 percent of the U.S. portion of the Space Station resources. The early Space Station commercial payloads under development by NASA include follow-on payloads in Protein Crystal Growth, Zeolite Crystal Growth, Commercial Float Zone, Sintered and Alloyed Materials, Bioprocessing, Physiological Systems, Plant Growth Modules, Commercial Mixed Oxides, Biomedical Isomorphism, Electrophoresis, and Space Exposure experiments. Some downstream infrastructural initiatives have been proposed including the servicing of the Wake Shield Facility and the ability to utilize the COMET recovery capability to provide quick return of samples.

CONCLUSIONS

The NASA sponsored microgravity space program has increased considerably in the past several years and is scheduled to be a major part of NASA's flight program for the next several years. The CCDS's along with some of the NASA field centers and their commercial affiliates are engaged in technologies that are beginning to produce exiting results which should result in the development of new products and markets in the future. The commercial microgravity flight program is in place and this past year saw nearly a four fold increase in the flight program. The commercial Space Station Freedom program is being developed with the commercial community. A commercial mission model is under development and payload development has begun. The potential benefits from NASA's commercial space program are quickly becoming evident and the future for commercial microgravity in space is limitless.

Current CCDS Commercial Flight Technologies

Auburn
- Solar Furnace Satellite
- Crystal Growth of Electronic Materials
- Computational Modeling of Casting Processes

Battelle
- Solution Crystal Growth
- Polymer Composites
- Zeolite Crystal Growth
- Investigations into Polymer Membranes

Bioserve
- Plant Growth Apparatus
- Blood Rheology Experiment
- Generic Bioprocessing Module
- Autonomous Biomedical Test Apparatus

Case Western
- Materials Exposure - Basic, Advanced, & Applied

Clarkson
- Low-Temp Solidification
- Liquid Encapsulated Melt Zone
- Directional Solidification - CdTe
- Chemical Vapor Transport - CdTe
- Commercial Solution Growth Facility

CSTAR
- Cryogenic Fluid Management
- Electric, Chemical Propulsion
- Industrial Laser System Applications

Florida Atlantic
- Transmission Techniques

Ohio State
- Remote Sensing & Mapping

Penn State
- Biomodule
- Telemedicine
- Bioseparations
- Bone Densitometry
- Physiological Systems Experiment
- Light Stimulator & Photon Detector
- Commercial Electrophoresis System

SpARC
- Autonomous Rendezvous & Docking
- Automated Microgravity Materials Processing

SRSC
- Remote Sensing & Applications

SVEC
- Chemical, Molecular Beam Epitaxy Growth

Texas A&M
- Micro Heat Pipe Evaluation
- Frozen Startup of Heat Pipe
- Microwave Power Transmission

University of Alabama-Birmingham
- Protein Crystal Growth

University of Alabama-Huntsville
- Polymer Foam
- Atomic Oxygen
- Electrodeposition
- 3-D Accelerometer
- Immiscible Polymers
- Nuclear Track Detectors
- Space Experiment Facility
- Non-Linear Optical Materials
- Sintered & Alloyed Materials
- High-Temp Superconductors
- Materials Dispersion Apparatus

University of Maryland
- Hybrid Networks

WCSAR
- Astroculture™
- Bioregenerative Water System

Figure 1

OACT Microgravity Flight Program

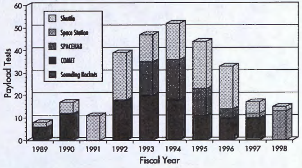
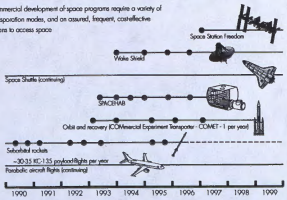


Figure 2

Commercial Transportation Modes

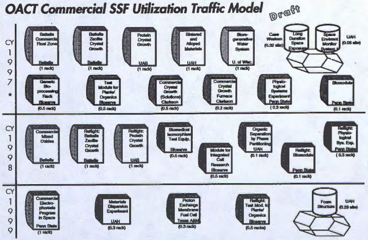
Commercial development of space programs require a variety of transporation modes, and on assured, frequent, cost-effective means to access space



* Many carrier and interface configurations not highlighted here

Figure 3

OACT Commercial SSF Utilization Traffic Model



* Includes payloads on Mission Build Flight 6, currently scheduled for launch in December 1996.

Figure 4

CE-9091 01/27/93