National Aeronautics and Space Administration

NASA
TECHNOLOGY APPLICATIONS TEAM
APPLICATIONS OF AEROSPACE TECHNOLOGY

ANNUAL REPORT
(October 1988 - September 1989)

for

National Aeronautics and Space Administration
Office of Commercial Programs
Washington, DC 20546

/RTI
Research Triangle Institute

TECHNOLOGY APPLICATIONS TEAM

APPLICATIONS OF AEROSPACE TECHNOLOGY

ANNUAL REPORT
(October 1988 - September 1989)

RTI/4321/04-F
NASA Contract No. NASW-4367

Technical Monitor: Mr. Ray Gilbert

NASA Headquarters
Mail Code CU
Washington, DC
20546

Research Triangle Institute
P.O. Box 12194
Research Triangle Park, NC
27709

Table of Contents

NEW PROBLEM STATEMENTS (CONTINUED)

COORDINATION OF ONGOING PROJECTS (CONTINUED)

1.0 INTRODUCTION

This report covers the activities of the Research Triangle Institute (RTI) Technology Applications Team for the period 1 October 1988 through 30 September 1989. The work reported herein was supported by the National Aeronautics and Space Administration (NASA), Contract No. NASW-4367. Mr. Ray L. Gilbert, NASA Headquarters, was the technical monitor. The work was performed in the RTI Center for Technology Applications under the direction of Dr. D. J. Rouse. Other participants in the program were Dr. John Cleland, Mr. Stephen Lehrman, Mr. Stephen Mangum, Mr. Robert Wallace, Mr. Daniel Winfield, and Ms. Nancy Court. RTI consultants participating during the reporting period were Mr. Reed Barnett, Dr. Francesco Iannetti and William Mead. The following student summer interns assisted the RTI Team during the reporting period: Mr. Jeff Antley, senior year undergraduate in Aerospace Engineering at N.C. State University; Ms. Catherine Canada, second year medical student at the University of North Carolina School of Medicine and; and Mr. Perry Cornelius, graduate student in Electrical Engineering (Robotics) at Duke University.

Highlights of the RTI Applications Team activities over the past year are presented in Section 2.0. The Team's progress in fulfilling the requirements of the contract is summarized in Section 3.0. Section 4.0 summarizes the status of the four add-on tasks. New problem statements prepared by the Team in the reporting period are presented in Section 5.0. The Team's transfer activities for ongoing projects with the NASA Centers are presented in Section 6.0. Travel for the reporting period is described in Section 7.0. The RTI Team staff and consultants and their project responsibilities are listed in Appendix A and Appendix B presents a glossary of terms used in the report.

The authors gratefully acknowledge the contributions of many individuals to the RTI Technology Applications Team program. The time and effort contributed by managers, engineers, and scientists throughout NASA were essential to program success. Most important to the program has been a productive working relationship with the NASA Field Center Technology Utilization (TU) Offices. The RTI Team continues to strive for improved effectiveness as a resource to these offices. Industry managers, technical staff, medical researchers, and clinicians have been cooperative and open in their participation. The RTI Team looks forward to continuing expansion of its interaction with U.S. industry to facilitate the transfer of aerospace technology to the private sector.

2.0 HIGHLIGHTS

2.1 PROJECTS

During the past year, the RTI Team has been especially successful in two critical aspects of the Applications Engineering Program:

1) commercializing products of Application Projects and

2) leveraging NASA funds for projects by developing cofunding from industry and other agencies.

These exciting results are presented in the following highlights for the reporting period.

Advanced Interventional Systems of California has commercialized the excimer laser for clearing plaque in the arteries of patients with coronary artery disease. This technique could spare nearly a quarter of a million Americans a year the trauma of open-heart surgery. The system has been used on humans since November 1988. This product is the result of an applications engineering project initiated by the RTI Technology Applications Team. An article on the device was published in *Business Week*, December 19, 1988.

Fulmer Dyson, Inc. has agreed to license and commercialize the ultrasound burn depth analysis technology developed at Langley Research Center. NASA's technology has been integrated as a front end to Fulmer's ultrasound system, and the resulting unit performs as expected. Fulmer Dyson will also explore the instruments use in diagnosing melanoma and other dermatological conditions.

In response to a commercialization prospectus prepared by RTI, **Interspec, Inc. has submitted a phased commercialization plan to NASA-Langley for the Intracranial Pressure Monitor**. Clinical studies are set to begin at the Medical College of Virginia. In addition, the Team identified interest at NASA-Ames for non-invasive ICP measurement in space medicine research. Subsequently, NASA-Ames has expressed interest in obtaining an instrument from Langley for animal studies.

Two exciting automation and robotics projects have been funded during FY'89. The **Flexible Agricultural Robotics Manipulator System (FARMS)** applications project is making progress in the development of sensors and a customized end effector for a roboticized greenhouse operation. The **University of Georgia, Olgevee Enterprises, Martin Marietta and Marshall Space Flight Center** are jointly engaged in developing one of the first robot systems to be used for agriculture purposes. Progress and interaction to date have been excellent. The other project involves the **University of Kansas, Kraft Telerobotics and Langley Research Center** who are working together to improve a dual robot arm controller. NASA funds are being leveraged by cofunding from the State of Kansas and Kraft ($200,000). Langley developments related to force

torque sensing, vision systems and other aspects of robot feedback control are being applied by both U. of K. and Kraft. It is anticipated that this project will additionally benefit from NASA developments related to the Flight Telerobotics Servicer Program underway to support the Space Station.

A **multisensor urodynamic pressure catheter** developed at Langley Research Center has been successful in clinical tests at the Medical College of Virginia. The device promises to greatly simplify urodynamic testing procedures and facilitate the diagnosis of causes of urinary incontinence. Data have been analyzed, and a scientific article is being prepared. In response to a commercialization prospectus prepared by RTI, Surgitek, Inc. is interested in commercial applications.

NASA's **collaboration with the Wilmer Eye Institute on low vision** has been formalized in a signed Agreement defining the project objectives and specific roles. An initial reimbursable payment of $150,000 has been made by Wilmer Eye Institute.

The RTI Team assisted the Lewis Research Center Electro-Physics Branch by preparing a questionnaire to industry on commercial applications for diamond-like carbon coatings. Forty-two applications were suggested and scored by LeRC. The top rated application, suggested by **Air Products and Chemicals**, is to produce **scratch resistant coatings for ophthalmic lenses**. The Team participated in two review meetings at LeRC and NASA Headquarters in which a plan for collaboration and cofunding between NASA and Air Products was developed.

The **NASA/American Cancer Society** collaboration continues to be productive. The Applications Team recently reviewed eight new project concepts for ACS, and three of these remain under consideration for technology transfer projects. Earlier in the year, **ACS voted to cofund a project to enhance MRI for Ovarian Cancer Detection**. Initiation of this new start is pending FY90 funding from NASA.

NASA held a second workshop on Multichannel Flow Cytometry in May to finalize input for an RFP to build the device. This RFP will be released by the end of 1989. Also, ACS will hold a conference specifically on cancer applications in November, 1989.

International Paper Company is reviewing a suggestion by Dr. Nathan Jacobson of Lewis Research Center for a corrosion coating for smelt spouts on pulp mill recovery boilers. A meeting at Lewis is being planned to discuss the use of aerospace materials (metal matrix composites, ceramics, coatings) to eliminate the water cooling jacket around the smelt spouts.

The Kennedy Space Center **liquid airpack** was presented at the **International Association of Fire Chiefs** annual meeting in Indianapolis, IN. The RTI Team organized and participated in demonstrations of the airpack for fire fighting professionals. Four manufacturers were identified and contacted. Over two hundred fire fighters discussed the airpack with RTI and sixty-five survey questionnaires were completed. The RTI Team discussed

the liquid airpack with Congressman Curt Weldon, Chairman of the Congressional Fire Caucus.

The **Arnold Systems Oscillating Cascade Project** met a major milestone with wind tunnel tests at the NASA Langley Research Center. The novel wind energy conversion device is fully instrumented and tested in a low speed wind tunnel with configurations simulating the accelerated wind conditions of urban environments or natural obstructions. .Efficiencies were observed and optimizing parameters determined. Arnold Systems is now having a linear generator (modelled on NASA designs) fabricated and is involved with capitalizing commercial development. NASA LaRC personnel and contractors and the RTI Applications Team were involved with the design and conducting of the wind tunnel tests.

The Team concluded a highly successful project to review the Space Shuttle Thermal Protection System (TPS) and make information on all TPS developments available to the commercial sector. In completion of this task the Team prepared a report that was published as **NASA contractor report #4227, "Thermal Protection System of the Space Shuttle."** This report is being distributed through the Applications Team and the Center TU Offices. Several TU Offices have indicated mailings of all available copies and it is anticipated that more will be distributed in the near future. The document has led to dozens of calls to the RTI Team from industry representatives interested in new insulation, sealing, ceramic repair, and installation techniques.

The RTI Team concluded its active support to the **Rotating Reactor Optimization Task** being supported by the Office of Commercial Programs through the Marshall Space Flight Center. The RTI Team has provided engineering assistance defining the modeling and verification of the motion of particles in a rotating fluid. The optimized condition related to rotating reactors, and the implications for microgravity simulation experiments. One draft publication has been completed by the Team and another is anticipated to be submitted for publication in a technical journal.

The Applications Team was instrumental in initiating a new project involved with encapsulated cells for hormone deficiencies. Dr. Taylor Wang, a former NASA mission specialist, and a team of experts are extending techniques first developed at the NASA Jet Propulsion Laboratory to a new method for **transplantation of microencapsulated living cells in humans to combat diabetes**. This revolutionary work is underway at Vanderbilt University and UCLA and will be monitored by Life Science scientists at the NASA Marshall Space Flight Center.

The Applications Team arranged and attended a number of meetings between **Gallaudet Research Institute**, and NASA Headquarters Technology Utilization Office and Marshall Space Flight Center to initiate a project called the **Automobile Emergency Vehicle Alert System**. NASA communications technology is being applied to devise a system which will alert hearing impaired drivers of the approach of emergency vehicles (e.g., fire, police,

and emergency medical services). The system is being devised to indicate proximity and direction of emergency vehicles so that the hearing impaired driver can take proper action. The Team will enlist the support of the Federal Communications Commission, police and other emergency vehicle services.

The **ROBOSIM Robotics Simulation Project** is also making great headway through the coordinated activities of Vanderbilt University and Marshall Space Flight Center. The original NASA-developed simulators are being extended for industrial and academic use. New techniques for path planning, collision and avoidance, downgrading to widely affordable hardware systems have brought the project to within a year of fruition. The Applications Team has volunteered Research Triangle Institute as a beta test site for ROBOSIM.

The RTI Team began to develop a potentially exciting interaction between **Spire Corporation** and the Langley Research Center to develop a new, affordable **electroluminescent flat-panel display**. An emerging area of color flat-panel displays represents a multi-billion dollar market ranging from cockpit displays to high definition television. Dr. James Robertson, whose work at Langley resulted in his nomination for NASA Inventor of the Year, will be involved with directing work toward commercialization of flat-panel displays when an applications project is initiated. Spire Corporation has submitted a white paper for development work to the LaRC Technology Utilization Office at the RTI Team's request.

In follow-up to a contact with Dr. Frost of Baylor College of Medicine made by RTI, a new start has been proposed by JSC to use neural net and expert system techniques to help **automate EEG spikes detection** to aid in epilepsy diagnosis and therapy.

Marshall Space Flight Center has submitted a response to an RTI problem statement entitled **"Pressure Sensing System for the Human-Seat Interface."** They propose using resistive coatings on polymer films for the sensing system, and Tekscan, Inc. is interested in commercial applications.

RTI coordinated two meetings at Goddard Space Flight Center to explore technology transfer possibilities for two RTI-generated problem statements: **"Improved Augmentative Communication Device"** (with Adaptive Communication Systems, Inc.) and **"Adaptive Gripping Device for Impaired Hands"** with Reading Rehabilitation Hospital.

2.2 OUTREACH

The RTI Technology Applications Team continued its outreach activities with industry, associations, State/industry technology initiatives, and Federal agencies involved with the development and commercialization of new technology. The following are highlights of the RTI Team's outreach activities in the reporting period:

The RTI TATeam met with the **Princeton Plasma Physics Laboratory (PPPL), Princeton University, David Sarnoff Research Center**, and **New Jersey Commission on Science and Technology** to discuss the commercial applications for Dr. William Langer's (PPPL) neutral atomic oxygen beam generator. Under contract from NASA Marshall Space Flight Center, this device is being used to study the erosion of spacecraft material by atomic oxygen. Potential commercial applications discussed were semiconductor device fabrication and polymeric materials surface modification. The result of the meeting has been a new project cofunded by SEMATECH and the Department of Energy.

Dan Winfield and Janet Dunham of RTI and George Finelli of NASA- Langley met with the **Medical Device Industry Computer Software Committee**. They presented information on the NASA TU program and on NASA's research programs in developing highly reliable software and hardware systems.

The RTI Team met with the staff of **International Paper Company's Corporate Research Center** in Tuxedo Park, NY. The purpose of the meeting was to present the NASA Technology Utilization Program and discuss generic problems of the pulp and paper industry suitable for Application Engineering Projects. As a result a potential project with Lewis Research Center is under development.

The RTI Team purchased a portable display and prepared accompanying pictures and text describing successful spinoffs. This display was used as the NASA booth at the annual meeting of the International Association of Fire Chiefs.

RTI organized a small workshop entitled **"Mobility and Seating for the Elderly and Severely Disabled."** The workshop, sponsored by the Interagency Working Group on Technology and Aging, was held December 14-15, 1988 and chaired by Dr. Cliff Brubaker, Director, Rehabilitation Engineering Center, University of Virginia.

The Applications Team initiated a new outreach program with the **National Easter Seal Society** to identify technology applications to assist the disabled. The Team is working with three Easter Seal Affiliates in Rhode Island, Texas and Iowa to analyze specific problems in rehabilitation of children, in head injury rehabilitation, and in rural/farm rehabilitation.

The RTI Team arranged and participated in a meeting between DuPont Electronics and the Materials Division at Lewis Research Center to discuss the application of NASA materials technology to manufacturing of electrical connectors.

The RTI Team coordinated a meeting between Steve Riddlebaugh and Dick Soltis (Lewis Research Center), Phil Meier (Castle Metal Finishing), and Ralph Ferraro and Roger Taylor (EPRI Power Electronics Application Center) at the **American Electroplaters and Surface Finishers** convention SUR/FIN 89. The purpose of the meeting was to discuss transferring NASA power management and distribution technology to the electroplating industry.

The RTI Team made a presentation on the Applications Engineering program at a meeting of the **Florida STAC State Affiliates** held in Tampa, FL.

The RTI TATeam met with Mr. Robert Cohen and Mr. John Hall of **SCANA Corporation**, Dr. Robert Henderson of the **South Carolina Research Authority**, and Mr. Paul Brockman of LFW Associates. The purpose of the meeting was to discuss opportunities for SCANA Corporation to participate in developing Applications Engineering Projects particularly in the areas of power and communications.

The Team made two presentations at a national aging conference called **Explorations: Technological Innovations for an Aging Population**. A good deal of interest was generated by the general NASA session which presented various aspects of the TU program. RTI also presented as part of the Wanderer Locator project team within a special interest session.

The Applications Team has cooperated with NASA Headquarters Technology Utilization and Space Biosphere Ventures to develop a workshop in late October of FY'90 for assessing **technology transfer opportunities related to closed life support and ecological systems**. NASA researchers, industry representatives and executives from other federal agencies have been invited by the Team to discuss opportunities and mechanisms for new applications projects in these areas. To this effort, the Team has also developed a problem statement for carbon dioxide removal from enclosed environmental systems. The Team is also assisting with a project plan describing Stennis Space Center's support to Space Biosphere Ventures in the area of environmental control utilizing growing plants in filtration systems. The Team has also initiated discussions with a company called Environmental Growth Systems who would like to access expertise being developed by NASA Ames Research Center under the Closed Ecological Life Systems Program (CELSS).

The Marshall Space Flight Center Technology Utilization Office has requested the Team to become closely involved with the **NASA/MSFC Technology Transfer Initiative with the states of Alabama, Tennessee and Georgia**. John Cleland presented the objectives, methods and some successful applications projects with the TU program at the NASA/MSFC Technology Transfer Orientation for Alabama, Tennessee state leaders. The Team has followed through with such interested participants as the University of Tennessee Space Institute in Tullahoma and the Alabama Small Business Development Consortium. The Team prepared a related problem statement on the control of benzene, toluene and zylene transfer to tank cars for the Drummond Company near Birmingham.

Preliminary responses have been received from both MSFC and Kennedy Space Center. The Team has also followed through on inquiries through the Georgia Tech Research Station (interested in improvements to very high temperature torches for rock quarrying) and to a clothing retail outlet interested in improved security devices.

The RTI Team presented the NASA Technology Utilization Program to **DuPont Electronics**. RTI and DuPont drafted a preliminary problem statement regarding electrical connector dies.

RTI began an active, focused outreach program for the JSC TUO under add-on task four. The outreach will concentrate on two industries: petrochemical and biomedical. RTI discussed new project ideas with the **Houston Area Research Center, International Biomedical, Inc.** and the **Limbs of Love Foundation**. We also received 11 biomedical project ideas from **Texas A&M University**.

RTI attended the 1988 **Neural Prosthesis Workshop** conducted by the National Institute on Neurological and Communicative Disorders and Stroke on October 26-27. In follow-up, we are investigating the possibility of using diamond-like coatings (NASA LeRC) as hermetic barriers for implanted microelectrodes.

RTI attended the **NIH-Industry Collaboration Forum** on October 25, 1988 to evaluate how NIH is implementing the intent of the Federal Technology Transfer Act. The Forum consisted of numerous poster exhibits of various NIH projects and capabilities which may be of interest to industry.

RTI made arrangements for a NASA TU display to be provided for a **U.S. Space Foundation Conference** in Colorado Springs, November 19, 1988. The display was so popular that Robin Daley of the Space Foundation has requested that the display remain on loan at the Foundation Headquarters for an extended period.

RTI made a presentation entitled "Space Spinoffs to Medicine" at a seminar for employees of the **Central Intelligence Agency** in Langley, VA. The Team has received several subsequent requests for information on NASA technology.

The Team continues its support to the joint **NASA and U.S. Navy technology transfer effort** by cooperating with the Southern Technology Applications Center to address a corrosion protection problem with the Orion P-3 aircraft landing gear. A problem statement was written and circulated to the NASA Field Centers. Two Field Centers, LeRC and KSC, are responding to the problem statement.

The RTI Team arranged for Dr. Roosevelt Fernandes of **Southern California Edison Company** to discuss commercial uses for the **JPL Mobile Satellite Program** with Mr. Ray Arnold and Mr. Dean Olmstead, NASA HQ, Code EC.

RTI met with a Task Force at the **Reading Rehabilitation Hospital** to discuss new problem ideas in rehabilitation. The hospital staff had come up with over 200 possible problem

topics, and we developed a procedure to narrow this list and select the highest priority projects.

RTI made a presentation on the NASA Technology Application Program to the Mid-Atlantic Regional Meeting of the **National Rehabilitation Association** in Charleston, WV.

John Cleland from the RTI Team traveled with the Director of NASA Technology Utilization and other to various facilities in the **State of Maine** to review technology transfer interests and needs. Organizations visited included the University of Maine, State Science and Technology Commission, the Maine Science & Technology Board, the Bigelow Laboratory for Ocean Sciences, the Production Technology Center at the University of Southern Maine, the Gorham Advanced Materials Institute, Bowdoin College, and National Semiconductor's Research Laboratories. Two problem statements have been developed through the Bigelow Laboratory and a project plan is underway to commercialize an advanced remote sensing device for chlorophyll and temperature measurements to assist fisheries' conditions off the east coast of the United States. Consultations are going on with experts at Goddard Space Flight Center and Wallops.

RTI met with representatives from the **U.S. Department of Agriculture** to discuss the utilization of NASA technologies in a joint effort with the Kellogg Foundation to improve risk management in rural areas.

RTI met with the manager of the **Port Operations Program of the Maritime Administration** to discuss possible use of Marshall Space Flight Center turbopump technology in oil spill clean-up.

2.3 ASSISTANCE TO NASA CENTERS AND HEADQUARTERS

An important component of the RTI Team program is the assistance provided to NASA Centers and Headquarters. As seen in RTI's travel log, Section 7.0, the RTI Team members visit many NASA Centers each year and some Centers on several occasions to discuss new and ongoing applications engineering projects. Examples of these activities during the reporting period are described below:

The RTI Applications Team assisted HQs in the preparation of papers and presentations for the **40th International Astronautical Congress of the IAF**. Papers, slide presentations, and handout material were prepared on NASA Spinoffs to Energy and the Environment, NASA Spinoffs to Public Service, NASA Spinoffs to Bioengineering and Medicine, and Technology Transfer in the NASA Technology Utilization Program: An Overview. RTI presented two of these papers at the meeting.

At the request of NASA HQ, RTI assisted the **Department of Commerce** in preparation for a **U.S. Trade Mission** to Taipei, Taiwan in December. The RTI Team contacted 20 companies with successful NASA spinoff products to explore their interest in participating in the Trade Mission.

RTI contacted NASA speakers for the NASA General Session and presented a paper at the **Technology and Aging Conference** held in Orlando, FL, January 30 - February 1, 1989.

RTI assisted NASA HQ and Centers in responding to a number of **Congressional inquiries** during the past year. RTI supported NASA HQs in gathering information and reporting to Congress regarding the use of NASA cooling garment technology for a dermatology problem. RTI assisted Ames Research Center in developing a response to a congressional inquiry relating to various air purification and clean room technologies that might be employed to provide a clean living environment for a woman with severe allergies.

At the request of the Office of Commercial Programs, the Applications Team participated in the task group reviewing and formulating a report which proposes establishment of a **National Technology Transfer Center**. This report was mandated by the conferees of the Committee on Appropriations on the FY 1989 HUD-Independent Agencies Bill and the resulting report was submitted to the Congress on February 1, 1989. RTI attended all Task Team meetings and provided recommendations.

At the request of NASA HQ, the RTI Team participated in a meeting with Mr. James Rogers of the U.S. Navy to discuss **joint NASA and U.S. Navy** technology transfer projects.

The RTI Team met with Ray Gilbert and the **U.S. Corps of Engineers** to discuss the transfer of NASA technology to the Corps of Engineers for applications engineering projects in Oklahoma. As a result of this meeting, the Team was employed to prepare a

concept paper describing ideas for joint NASA/U.S. Army Corps of Engineers Technology Transfer projects.

At the request of **Mr. Don Friedman of GSFC**, the Team participated in several meetings to evaluate new project opportunities with: The University of Maryland Medical School on melanoma screening, with the Veterans Administration on possible rehabilitation projects, and with Dan Klinglesmith of GSFC on retinal imaging.

The overview report prepared by the RTI Team on **"Thermal Protection System of the Space Shuttle"** was accepted and printed as an official NASA publication in the reporting period. This publication, NASA Contractor Report 4227, was distributed to all NASA Centers, to NASA Headquarters, and to the large number of inquirers interested in applying TPS materials to commercial applications. The report is also available through the National Technical Information service and through the NASA Scientific and Technical Information Facility.

During the year the TATeam assists HQ & Centers with various administrative/project management tasks. For instance, members of the Applications Team contacted all NASA Center TU Offices to provide Team assistance in responding to the **POP call** in February-March. RTI also updated project reports on the Technology Utilization Network System (TUNS) on a routine basis.

RTI hosted a visit by **Mr. James T. Rose** and the Team made a presentation on the Application Engineering Program and the status of applications engineering projects on the Intelligent Physics Tutor, Semiconductor Material Fabrication using Neutral Atomic Oxygen and Plasma Beams (Princeton Plasma Physics Laboratory), Excimer Laser Angioplasty and others. RTI President, Mr. George Herbert, met with Mr. Rose to discuss the Application Team program at the Institute.

The Team assisted OCP in preparation for presentations to the Subcommittee on Space Science and Applications, Committee on Science in Space and Technology, U.S. House of Representatives.

As part of an in-reach effort to develop better contacts with NASA Life Sciences, RTI hosted visits by representatives from **Lockheed** (support contractor to the HQ Code EB) and **Krug Int'l.** (support contractor to JSC Medical Science Division).

The Team supported the MSFC initiative with the **States of Alabama and Tennessee** by preparing a problem statement for the Drummond Company, an Alabama coke product company. The problem is being reviewed both at MSFC and at KSC for potential solutions to Drummond's need to transfer toxic liquids without vapor loss.

RTI assisted the JSC TU Office in preparing the nomination of Shayla Davidson for a **Federal Laboratory Consortium award** for her work on the Wanderer Locator project. Ms. Davidson received the award at the Spring FLC meeting in Chicago.

In response to a request from NASA HQ, RTI prepared graphs delineating correlations between number of New Technology Reports produced annually versus R&D budget and manpower levels and the Technology Utilization budget.

To assist NASA OCP in preparation for key meetings with members of Congress and other public and private officials inquiring about the NASA TU program, the Applications Team utilized a newly developed **database which cross references information on TU projects by States**. Significant TU program activity in each State can be monitored by the Team including data on key players, companies and relevant legislation (if any) which relates to TU projects.

At the request of the Office of Commercial Programs, the Applications Team participated in a task group reviewing and formulating a report which proposes establishment of a **National Technology Transfer Center**. This report was mandated by Congressional Committee and was submitted in February of 1989. RTI has provided support to the content, formatting and writing of the report with both written copy and comments during the several group meetings held during FY'89.

A productive effort has been undertaken to develop slides and related captions for the presentation of **Technology Utilization Projects' successes to U.S. companies**. An extensive file has been developed with the help of NASA Centers Technology Utilization Office. The slide's compendium has also been utilized for presentation of the NASA's TU program at the International Aeronautics Federation Symposium on Space Activities and Society in October 1989.

The Team responded to a request by NASA HQ to formulate innovative ways of performing **technology transfer for education**.

The RTI Team sent **twelve Spinoff referrals** to STIF.

At the request of Mr. Don Friedman of GSFC, the Team is performing a market evaluation and identification of manufacturers potentially interested in commercializing the **Airborne Oceanographic Lidar** (AOL) for topographic mapping.

3.0 BASIC CONTRACT STATUS

This section summarizes the status of the deliverables for the basic Technology Applications Team contract (NASW-4367) at RTI. The status reports for the contract add-on tasks are presented in Section 4.0.

The statement of work for the Technology Applications Team specifies the following:

- **Problem Statements** should be developed by the Team. The problem statements should seek solutions to well-defined technology requirements in bioengineering and industry.
- **24 Opportunities** for applications engineering projects with NASA Centers should result from these problem statements. An opportunity is developed by the identification of a NASA technology with the potential for meeting the technology requirements described in a problem statement.
- **15 Research and Technology Operating Plans (RTOPs)** should be developed from these opportunities at NASA Centers. An RTOP or project plan for an applications engineering project is submitted to NASA HQ for funding consideration.

The RTI Team's results in meeting these contract requirements are summarized in Table 1. Problem statements prepared by the Team during the reporting period are presented in Section 5.0. In addition to these new projects initiated this reporting period, the RTI Team continued to assist the NASA field centers in developing and monitoring projects initiated in previous contract periods. The RTI Team's activities in the coordination of these ongoing projects are described in Section 6.0.

The statement of work for the Team specifies that transfer opportunities should be developed in the following five disciplines: (1) Automation/Artificial Intelligence (Robotics); (2) Bioengineering; (3) Electronics; (4) Materials; and, (5) Rehabilitation. Table 1 includes a column indicating the classification of each project by discipline.

TABLE 1: CONTRACT STATUS OCTOBER 1988 THROUGH SEPTEMBER 1989

Problems prepared by Team	Opportunity	RTOP	Category	Center
Augmented Telerobotic Technology	YES	YES	I-A	LaRC
Carbon Dioxide Removal System for Biosphere II	YES	--	M	ARC, MSFC
Development of a Commuter Aircraft Boarding Device	YES	--	R	LaRC
Power Management in the Electroplating Industry	YES	YES	I-M	LeRC
Interactive Robotic Devices for Cognition and Manipulation Development by Young Children with Severe Physical Impairments	YES	--	R	ARC, LaRC
Long Duration Airpack for Firefighters	YES	YES	I	KSC
Medical Device Software Reliability	YES	--	B	LaRC
Monoclonal Antibodies for Cancer Diagnosis	YES	YES	B	JSC
Development Needs for Flexible Honeycomb Insulation	YES	--	I-M	ARC
Retinal Stabilization for Laser Surgery	YES	YES	B-E	JSC
Adaptive Gripping Device for Impaired Hands	YES	--	R	--
Wheelchair Pressure Relief System	YES	--	R	KSC
Enhancing MRI for Cancer Diagnosis	YES	YES	B	KSC, SSC
Measurement of Food Particle Motion and Heat Transfer During Aseptic Processing of Food	--	--	I	--
Automated EEG Analysis for Epilepsy	YES	YES	B	JSC

Table 1 Continued

Problems prepared by Team	Opportunity	RTOP	Category	Center
Safe System for Removing Foreign Bodies from the External Ear Canal	--	--	B	--
Improved Augmentative Communication Device	YES	--	R	GSFC
Sun Photometer	YES	--	I-E, M	GSFC
Large Interactive Displays for Electric Utility Dispatch Offices	YES	--	I-E	JSC
Containment of Toxic Vapors During Fuel Transport	YES	--	I-M	MSFC
Failure of Pulp Mill Smelt Spouts on Recovery Boilers	YES	--	M	LeRC
Application of Advanced Materials Technology to Increase the Life of Trim and Swage Tools	YES	--	M	LeRC
Scanning Lidar for Topographic Mapping	YES	YES	I-E	GSFC
Application of Artificial Intelligence to Adult Literacy Training	YES	YES	I	JSC
Scratch Resistant Coatings for Plastic Ophthalmic Eyeglass Lenses	YES	YES	M	LeRC
Corrosion Protection of Navy P-3 Orion Aircraft Landing Gear	YES	--	M	LeRC
Flat Panel Displays	YES	YES	I-E	LaRC
Automated Mail Processing	--	--	I-E	--

Table 1 Continued

KSC = Kennedy Space Center

JPL = Jet Propulsion Laboratory

JSC = Johnson Space Center

LeRC = Lewis Research Center

MSFC = Marshall Space Flight Center

ARC = Ames Research Center

SSC = Stennis Space Center

LaRC = Langley Research Center

HQ = NASA Headquarters

GSFC = Goddard Space Flight Center

R = Rehabilitation

B = Biomedical

I = Industry

E = Electronics

M = Materials

A = Automation

4.0 ADD-ON TASK STATUS

This section presents the status of tasks added to the basic contract NASW- 4367. The following four tasks have been assigned:

TASK 1: AdaNet Program Support

TASK 2: CAD/CAM for Custom Orthopedic Shoes

TASK 3: Optimization of the Parameters of the Rotating Reactor

TASK 4: JSC Outreach Program

TASK 1: ADANET PROGRAM SUPPORT

RTI Task Leader: Robert Wallace

Start Date: December 5, 1988

Completion: June 30, 1990

Background:

NASA, DoD and the U.S. Department of Commerce have entered into a joint program to establish AdaNet -- a multifaceted project to survey, collect, evaluate and disseminate high value-added Ada software products developed under government programs. NASA seeks to achieve early successful transfers of Ada software products through several focused applications projects. The NASA Technology Applications Team at RTI has tracked the increasing use of the Ada programming language within NASA and the DoD. The RTI TATeam will increase its ongoing Ada related technology activities by pursuing several Ada based applications projects in the coming year.

Objectives:

The objectives of this support effort are to assist AdaNet in the identification of NASA-developed Ada software product and to assist in the establishment of Ada based applications projects to serve as demonstrations of NASA Ada software technology transfer. The RTI TATeam will support the AdaNet initiative by identifying "focused" industrial application project opportunities with special emphasis on Flexible Computer Integrated Manufacturing (FCIM) projects. RTI will generate high probability problem statements, assist in developing project plans and draft NASA center RTOPs in support of NASA Ada demonstration projects. Another objective of the project is to develop collaborative efforts with other agencies to enhance and speed the transfer of NASA Ada technology into American industry. A minimum of two AdaNet problem statements and project plans for NASA Ada software technology will be prepared.

Status

Delay in operation of the AdaNet project at the University of Houston-Clearlake and West Virginia has delayed progress on this RTI task. The Application Team has maintained contact with the AdaNet Project leader and has identified one promising opportunity with commercialization potential. When an ongoing AdaNet project market assessment is completed, RTI will pursue specific application project opportunities in conjunction with the AdaNet project staff.

TASK 2: COMPUTER-AIDED DESIGN/COMPUTER-AIDED MANUFACTURING (CAD/CAM) FOR CUSTOM ORTHOPEDIC SHOES

RTI Task Leader: Robert Wallace

Start Date: December 5, 1988

Completion: September 30, 1989

Background:

The objective of this add-on task, funded by National Institute on Disability and Rehabilitation Research, is to coordinate the implementation of the recommendations from two 1984 workshops on CAD/CAM for Orthopedic Shoes and to identify NASA technology for the CAD/CAM system. The current add-on task is the third of the effort.

Objective:

In this task, a mini and/or microcomputer-based demonstration system will be developed for taking custom shoe prescriptions and foot measurements and converting the information into computerized instructions for fabricating custom shoe components. NASA-developed software planned to be utilized in this system includes NASCAD, CLIPS expert system and Relational Information Management (RIM). These software elements will be integrated to demonstrate the sequence of computer-based processing steps from foot shape data input to shoe last machining.

Status:

Manual I on fabrication of custom orthopedic footwear has been completed and has been well received by the industry. Manual II is nearing completion by RTI on this task. Progress is being made in the microcomputer-based demonstration system with an estimated date of completion of March 1990.

TASK 3: OPTIMIZATION OF THE PARAMETERS OF THE ROTATING REACTOR

RTI Task Leader: John Cleland

Start Date: December 5, 1988

Completion: July 20, 1989

Background:

The Research Triangle Institute provided support to the Marshall Space Flight Center for their project on "Optimization of the Parameters of the Rotating Reactor."

Objectives:

The primary objective of the project has been to optimize reactor rotation rates relative to microsphere particle sizes and densities and to attempt to describe both theoretically and experimentally the behavior of particles suspended in a fluid medium. Preliminary theory has already been developed.

RTI's role has been to provide engineering assistance using special experimental and analytical capabilities. This engineering assistance is aimed at providing an optimal design for the experimentation and related analysis of the data obtained. RTI's effort covered four areas:

1. Define and set priorities for the operational parameters of the rotary reactor and microsphere fluid matrix in the reactor.
2. Develop an experimental design to minimize the number of tasks required while maximizing the information derived from each experiment.
3. Describe a method for data analysis related to all parameters and variables observed.
4. Support data analysis.

Tasks 1-4 have been accomplished. RTI provided a FORTRAN code which models the reactor performance based on existing theory. Task 4 emphasized analysis and interpretations of experimental photographic data and comparison with theoretical results.

With all technical efforts complete, it is now intended that 1-2 scientific papers be submitted to technical journals. The NASA project leader has concurred that the final report will be extracted from the papers.

TASK 4: LYNDON B. JOHNSON SPACE CENTER TECHNOLOGY UTILIZATION OUTREACH SUPPORT

RTI Task Leader: Stephen A. Lehrman

Start Date: December 5, 1988

Completion: January 1990

Background:

The NASA's Lyndon B. Johnson Space Center (JSC) Technology Utilization Office has initiated an Outreach program focusing on Houston. The JSC TU Office has requested RTI assistance in this Outreach program.

Objective:

The objective of this task is to support the JSC TU Office in its Outreach program to the Houston community. The industry sectors targeted for this task are the petrochemical industry, through the Clearlake Economic Development Council (CLEDC), and the Houston medical community. In this effort, RTI will plan and conduct Outreach presentations to selected organizations and work with those groups to identify industry needs and match those needs with NASA technology.

Status:

In the petrochemical area, Stephen Lehrman met with Susan Spencer of the Clear Lake Area Economic Development Council (CLAEDC) and discussed their participation on organization of a conference addressing the needs of the petrochemical industry. CLAEDC agreed to inform its petrochemical working group of the concept for a technology transfer conference and solicit from its corporate members problem statements.

The South Freeway Corridor Association was contacted and has furnished a list of organizations that are association members. RTI has put together a letter explaining the various JSC technology thrusts and topical areas for Technology Utilization on projects. This letter will be sent to the petrochemical industry managers with a request that they suggest problems that may be amenable to a technology solution.

In the biomedical area, Dan Winfield has met with individuals representing the technology transfer functions for the Baylor College of Medicine, the University of Texas Health Science Center, and the M.D. Anderson Cancer Center. While their programs seek to transfer technology from the medical centers to industry, their goals are sufficiently common to ours that they have agreed to serve as the primary avenue for our outreach to their centers. In addition, they have given us similar contacts with the University of Texas Medical Branch at Galveston, Rice University, the University of Houston, Texas A&M University, and the Houston Area Research Centers. Each of these contacts will be soliciting project ideas from their research and clinical staff.

In addition, we have obtained a Houston area biotechnology industry directory from Biotech Initiatives. This directory includes the vast majority of biomedical and biotechnology companies in the Texas gulf coast region and gives points-of-contact as well as product line descriptions. During the next quarter, we will target our outreach to selected companies evaluating problem statements/project ideas from the university-based researchers.

5.0 NEW PROBLEM STATEMENTS

PROBLEM TITLE: ADAPTIVE GRIPPING DEVICE FOR IMPAIRED HANDS

Date of Preparation: March 6, 1989
RTI Team Personnel: Daniel L. Winfield

Problem

A large population of disabled individuals lack a very basic hand function -- grip. Individuals with stroke, head trauma, high-level spinal cord injury, severe arthritis, and certain neurological diseases may have basic elements of upper extremity movement but are unable to grasp and hold objects.

Currently, therapists must spend a considerable amount of time fabricating separate adaptive devices that can be strapped to the hand to allow the patient to do each activity independently. An endless list of devices must be strapped onto the hand to allow the patient to perform the variety of daily activities. Frequently, the opposite hand is also impaired, which severely hampers the ability to strap on many different devices.

The needed device is an adaptive gripper that can be used by the individual for a variety of basic functions. The target population will require a relatively low-cost solution, so it is recognized that a multifunctional adaptive gripper may be impractical. However, the design should include as many basic functions as possible within the cost/weight/size restrictions.

NASA Technology

Goddard Space Flight Center engineers have suggested several possibilities for consideration including a rudimentary robotics approach and a method of using shape memory alloy for actuation. These preliminary ideas must be evaluated and refined before a practical concept can be developed.

Principals

- John Vranish, GSFC
- Peg Blyskal, Reading Rehabilitation Hospital

Status

RTI organized a meeting with four Reading Rehabilitation Hospital representatives at GSFC on June 23. Requirements for various types of devices were better defined, and several opportunities for incremental improvements were identified. A Goddard engineer then visited Reading to see firsthand the requirements for various gripping devices for this

population. Goddard engineers will further develop these ideas before an RTOP is submitted.

PROBLEM TITLE: APPLICATION OF ADVANCED MATERIALS TECHNOLOGY TO INCREASE THE LIFE OF TRIM AND SWAGE TOOLS

Problem Originator: Dupont Electronics
Date of Preparation: June 8, 1989
RTI Team Personnel: Stephen A. Lehrman

Problem

Improvements in the structural integrity and wear properties of trim and swage tools used in stamping operations is needed. This may be achieved by the application of advanced materials technology.

The manufacture of electronic connector terminals is performed using trim and swage tools. The connector terminals are made of a copper- beryllium alloy at the rate of 1000 to 20000 per minute. The physical properties of the tool material have a major impact on the cost of maintaining the tools. The tool life, in turn, becomes an important factor in the cost of manufacturing.

Trim and swage tools are made from tungsten (90 wt %)-carbide (trace)- cobalt (10 wt %) materials with a Rockwell hardness of 90. Dupont Electronics previously used a material call Baxtron. When Baxtron became unavailable, Dupont switched to a similar commercial material called Ramet I. Recently, tools manufactured from Ramet I bulk material have exhibited increased porosity and larger grain size. It is believed that the changed microstructure has adversely affected the overall tool structural integrity as well as its local wear properties.

Dupont has found another supplier of tungsten-carbide tool material. Dupont is making new tools from this supplier's bulk material and will soon be testing the new tools in its manufacturing plants. The preliminary indications, based on the new material microstructure, is that these new tools will possess greater structural and wear integrity than the Ramet I tools and, therefore, solve Dupont's immediate problem of tool failure. However, Dupont realizes that the application of advanced materials technology can further increase the useful life of these tools.

Technology Required

Because of the problems with the Ramet I tools, Dupont is interested in continuing to improve swage and trim tools. During a meeting with the Lewis Research Center Materials Division, the suggestion was made to consider ceramic materials for stamping operations. The principal concern with ceramic materials is whether the material can withstand the large impact forces estimated to be 20 tons.

Three material technologies are believed to be worth considering for extending tool life:

1. bulk ceramic or ceramic matrix composites,

2. cermets,
3. ceramic or ceramic matrix coatings on a carbide substrate.

These material technologies have been proven to extend the life of tools used in machining, forging, extrusion, and other metal forming operations. However, their acceptability to stamping is generally unknown.

NASA Technology

NASA technology is required in a number of areas. For bulk ceramic, ceramic matrix composite, or cermet tools, NASA structural mechanics and failure analysis technology would be useful to assess the feasibility of the tool withstanding the high impact loading. For ceramic or ceramic matrix coatings, NASA technology can assist in the selection of the coating material and method of bonding to the substrate. Additionally, Dupont is willing to provide carbide substrates if NASA is willing to apply some trial coatings.

PROBLEM TITLE: APPLICATION OF ARTIFICIAL INTELLIGENCE TO ADULT LITERACY TRAINING

Problem Originator: Lyndon B. Johnson Space Center
Date of Preparation: September 1989
RTI Team Personnel: Stephen A. Lehrman

Problem

Integrate Intelligent Computer Aided Training (ICAT), speech recognition, and speech generation into an artificial intelligence system that mimics the expert advice of a reading teacher.

Adult literacy is a major societal problem. More than 27 million Americans are functionally illiterate and another 45 million are marginally literate. The most effective reading diagnostic tests are performed on an individual basis. This level of concentration allows diagnosticians to discover causes of reading deficiencies unique to the pupil's handicap. The evaluation of these tests results in a prescription particular to that individual's needs or deficiencies. However, there are not enough reading instructors for individual training for everyone who needs it.

Advanced technology is being used to improve adult literacy. In July 1988, Pennsylvania State University hosted the Adult Literacy and Technology National Conference. Both IBM and Apple Computers have developed computer- assisted instruction programs for adult literacy education. The IBM program, PALS, uses a touch screen monitor, interactive laser video disc, and graphical representation to instruct the pupil. Apple Computers has an Adult Education and Literacy Department.

NASA Technology

NASA has an extensive research and development base in artificial intelligence, intelligent computer-aided training, speech recognition, and speech production. Johnson Space Center (JSC) is already working on an Intelligent Physics Tutor based on the ICAT concept.

Participants

JSC will be responsible for the integration of the ICAT, voice recognition, and voice generation into a system. The University of Houston will be responsible for developing the reading consultant expert system.

PROBLEM TITLE: AUGMENTED TELEROBOTIC TECHNOLOGY

Date of Preparation: November 1988
RTI Team Personnel: John G. Cleland

Problem

Application of NASA technology for developing shared control of telerobotic devices is needed, with particular attention to telerobotics utilization in both undersea and Space Station assembly and/or operations.

The basic premise of teleoperation is that a human operator is in full control at all times. A robot, on the other hand, has a degree of autonomy. A telerobotics device can be viewed as a hybrid between these two. Selective autonomous telerobotic operation can reduce operator fatigue by occasionally eliminating the need for an operator's physical effort and mental attention to details. During a selected autonomous operation, the human operator assumes a supervisory role that is far less demanding, particularly during the execution of highly repetitive tasks. Other important areas where autonomous control can be highly beneficial include collision avoidance (especially in compact and complex work areas) and contour following where standard contours can be programmed for response through the robotic controller.

Development of autonomy augmentation of telerobotics could be applied in such fields as undersea engineering, mining, medical, and nuclear materials handling.

Kraft Telerobotics, Inc., and others in the telerobotics area are highly advanced in the teleoperated modes of operation. However, telerobots, with the autonomous operating capabilities of these systems, are less advanced. The NASA Flight Telerobotic Servicer program, and other telerobotics efforts being sponsored by the Office of Aeronautics and Space Technology, include research and development of sensors and feedback control/response to add more autonomous operation for space telerobotics. This is a part of NASA's evolutionary design to move from strict teleoperation to more and more autonomous systems. Langley Research Center, in particular, has been working in conjunction with the Oak Ridge National Laboratories, to develop such devices as acoustical sensors for proximity sensing and collision avoidance control. Research is underway to apply a laser scanning diode for contour following. A commercial user's panel on telerobotics (organized by the RTI Team) indicated that NASA technology in sensing would be the highest priority on a list of technologies to be accessed by industry and applied to telerobotics.

Technology Constraints and Specifications

Projects to enhance operation through minimized teleoperator attention would employ sensors to share control with the operator. Initially, simple binary sensors may be employed to augment the system. New sensor technology and computer software

development would expand existing technology of such companies as Kraft to provide the basis upon which selective autonomous operation will improve. A set of priorities in performing this augmentation could include:

- Survey literature on sensor needs and discuss needs with NASA technical experts
- Design telerobotic mount
- Procure and install mount and hydraulic system
- Install a dual arm telerobotic system
- Refine augmented telerobotic research tasks
- Complete definition of major technology transfer objectives with commercial concern
- Conduct automated telerobotics research program with routine consultation with NASA
- Report results of technology transfer effort and incorporate results into product line.

Status

The RTI Technology Applications Team discussed the project with the University of Kansas and with the Automation Technologies Branch at the NASA Langley Research Center (Dr. Al Meintel). The University of Kansas completed the details with the State of Kansas (cofunding) and with Kraft Telerobotics. FY89 funding has been forwarded to the University of Kansas through LaRC.

Cost to NASA

Preliminary indications are that NASA will be asked to contribute approximately $300,000 over a 28-month period. $75,000 has been budgeted for the first year. Kraft Telerobotics, Inc., has tentatively agreed to donate $280,000 of the $400,000 cost of a dual (left arm/right arm) hydraulic-master/hydraulic slave telerobotic system. The Kansas Advanced Technology Commission (KTEC) is being asked to provide $120,000.

Action

RTI evaluated and assisted with final contents of project plans from the University of Kansas and Kraft Telerobotics, including costs. RTI has re- contacted Dr. Barr to finalize plans for initiating the project. A visit to Kansas is anticipated in the first quarter of FY91.

PROBLEM TITLE: AUTOMATED EEG ANALYSIS FOR EPILEPSY

Source of Problem: Dr. James D. Frost, Jr. M.D., Baylor College of Medicine
RTI Team Personnel: Daniel L. Winfield

Problem

Advanced data analysis techniques are required to reliably identify electroencephalographic (EEG) spikes which are characteristic of epilepsy. Epilepsy, which affects 0.5 percent of the population, is one of a group of disorders of brain function characterized by recurrent seizures that have a sudden onset. Convulsive seizures result from an acute disturbance in cerebral function which is demonstrable by EEG. Intensive neuro-diagnostic monitoring is an indispensable tool for the management of epilepsy and has contributed significantly to improvements in both diagnosis and therapy.

In an effort to establish a more rapid means of assessing pharmaceutical efficacy, Dr. James Frost has determined that computer-based assessment interictal spike waveforms can be used to assess seizure hazard in a quantitative manner. However, performance of this system in successfully identifying spikes ranges between 80 percent and 90 percent. Advanced processing techniques are required to provide improved artifact recognition capability and to take into account temporal and spatial context in which the spikewave form occurred.

The data acquisition system samples the EEG at 250 Hz. Background noise ($\sim$ 15 Hz) is removed by a 40 Hz filter. The peaks of interest typically are in the 70-80 Hz frequency range. Detected events must be characterized by waveform parameters (amplitude, duration, sharpness, and second derivative at peak) and testing performed to eliminate artifacts.

Context clues must be included in the analysis. These include the experts analysis of what happened to the recording just before and just after a detected event, what happens simultaneously on the other seven channels, the overall quality of the data (i.e., noise), and what the subject was doing at the time of the detected event.

NASA Technology

Computer scientists at Johnson Space Center have proposed using neural network and expert systems techniques to improve the successful detection of characteristic epileptiform spikes in the EEG. If successful in improving accuracy to 95 percent, this could be implemented in a PC-AT compatible system for use by physicians treating epilepsy to predict seizure control.

Principals

- Robert Savely, NASA, Johnson Space Center
- James Frost, Jr., M.D., Baylor College of Medicine

Status

NASA personnel have met with Dr. Frost to discuss the requirements for this project. They are very optimistic about their capability to assist in developing a successful system. A request for FY90 TU funding has been submitted. Dr. Frost has agreed to provide data recordings to JSC so they may experiment with various data processing algorithms. Once some preliminary success is established, RTI will work with JSC and Dr. Frost to identify a company for commercialization.

PROBLEM TITLE: AUTOMATED MAIL PROCESSING

Problem Originator: Gordon Chapman, Chief, Technical Support Office, NASA Jet Propulsion Laboratory, and J.S.D. Francesco, Publishers Clearinghouse, Port Washington, NY
Date of Preparation: August 1989
RTI Team Personnel: John G. Cleland, Perry Cornelius, Jeff Antley

Problem

A method of capturing and processing direct mail-order responses without opening envelopes is needed.

Direct mail marketing companies desire a method of processing huge volumes of mail in the shortest possible time. Opening each envelope and sorting the contents (for scan input processing) is the largest contributor to the lengthy amount of time necessary for processing a response. "Outserting," as this sorting processing is called, cost Publishers Clearinghouse millions of dollars in 1988 alone. Projections indicate the problem can only worsen using current methods.

Publishers Clearinghouse presently uses the most sophisticated combination of manual and automated labor available. Present methods of automated processing include character definition and recognition, automated data storage, and high-speed paper transport. The company would like to couple these technologies with an ability to read through paper.

Insert mail is now typically handled in the following scenario:

1. The mail is first sorted electronically into similar package groupings using bar code readers. This is accomplished by reading the nine-digit zip codes that appear in the form of bar codes on the front of envelopes.
2. A scanner, in a single pass, slits the tops of the envelopes, leaving the contents intact, and separates orders from non-orders.
3. Both the orders and non-orders, with their envelope contents still intact, are grouped into control batches (trays of approximately 800 each).
4. Scannable orders and non-orders, in their batch groupings, are "read" into the system via page scanners to capture a minimum of customer identification and product codes.

Excessive handling, rehandling, batching and controlling, as described above, drive up the cost and time for processing. This is exacerbated by the fact that the business experiences extreme fluctuations in workload that demand various levels of direct labor for manual processing. Since it is not cost-effective to employ a full-time staff to meet peak demands, the industry is constantly faced with having to hiring large groups of part-time personnel.

Technology Constraints and Specifications

The ideal solution involves the capturing and processing of information from incoming mail without opening the envelope. Such a cycle would pass each piece of mail once through a scanner, which would retain and interpret data stored on both the inside and outside of the envelope. This would eliminate steps 2, 3, and 4 above. Rejects, including any piece of mail not completely readable for any reason, would be redirected for manual handling.

The key criteria that need to be considered include, but are not restricted to, the following:

- Return envelopes: must not violate postal restrictions regarding placement of stickers or bar codes on the envelope exterior; must include reference mark to orient for scan; and must be thin enough to be read through.
- Envelope contents: must also be properly oriented for scan and must also be thin enough to be read through.
- Scanner must be capable of data recognition (of specified fonts, sizes, and colors) retrieval, and storage for further processing.

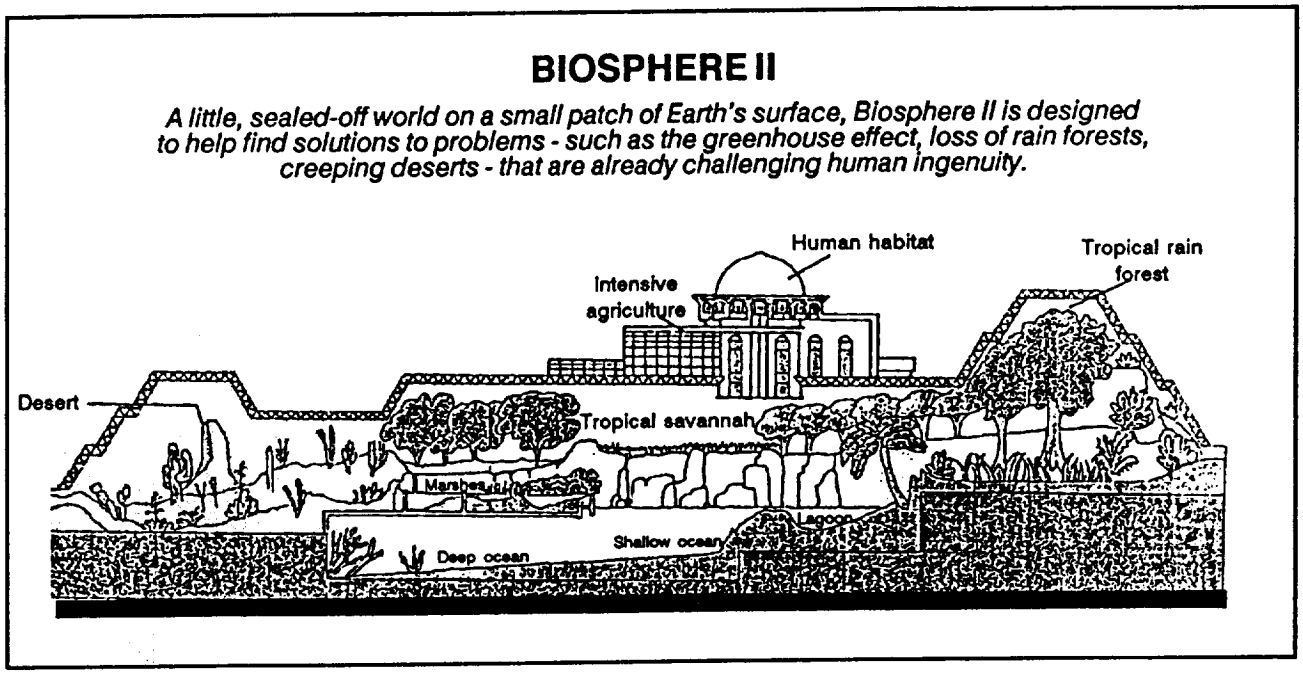
PROBLEM TITLE: CARBON DIOXIDE REMOVAL IN BIOSPHERE II

Date of Preparation: February 1989
RTI Team Personnel: John G. Cleland

Problem

A carbon dioxide removal system is needed that can partially scrub CO_2 from approximately 6M cu.ft. of air over a 24-hour period. CO_2 concentrations must be reduced from 2,000-10,000 ppm to 350-1,000 ppm.

Biosphere II is an enterprise of Space Biospheres Ventures and related support organizations. The Biosphere and support facilities are located on a 2,500-acre tract near Tucson, Arizona. The ecosystem itself will cover 2.5 acres enclosed under an impressive structure that maximizes solar insolation to the interior (see Figure 1). Biosphere II will contain approximately 5 to 7M cu.ft. volume, in 7 biomes--the habitat biome for eight resident researchers, an intensive agriculture biome for crops and domestic animals, and five wilderness biomes including a tropical rain forest, savannah, saltwater marsh, ocean (or



marine) and desert biomes. The Biosphere will contain plants, animals, and humans living in synergistic equilibrium, essentially closed to material input or output and open to energy (solar) and information exchanges. The Biosphere will enhance understanding of the Earth's biosphere, allow study of component ecological techniques such as biological systems for purification and recycling, and provide the best potential means developed to date for evaluating construction of permanent stations to be placed in space or on other planets as research and observation bases and eventually settlements. Construction is well advanced at this point with partial closure experiments beginning in mid-1989 and

a full closure phase commencing in January 1990 with full closure expected in the Fall of 1990. The Biosphere will remain closed for 2 years.

While Biosphere II will be an essentially self-sufficient system, one problem remains in maintaining an atmospheric mixture that closely approximates that at the surface of the Earth. Whereas about half the surface of the Earth is exposed to sunlight at all times, all of Biosphere II will experience nighttime during every 24-hour cycle. During hours of darkness, when photosynthesis does not take place, CO_2 concentrations may rise to 2,000 ppm (normal atmospheric concentration is approximately 300 ppm CO_2). Over several days of extensive cloud cover, CO_2 concentrations could rise as high as 10,000 ppm or 1 percent. Although these concentrations pose little threat to plants and animals at the surface, there is a problem of the absorption of excessive CO_2 into the marine environment. Buildup of carbolic acid and other effects can increase the acidity of the sea water to such an extent that the coral reef would be attacked and the ecosystem upset. Additionally, the $C0_2$ cycle becomes nonrepresentative of normal Earth biosphere conditions, possibly resulting in anomalies in scientific results. Therefore, Space Ventures, scientists are seeking a contingency solution in the form of a carbon dioxide removal system that will maintain a $C0_2$ balance with levels typically not exceeding 1,000 ppm concentration.

Existing CO_2 removal technology is quite capable of controlling levels in the biosphere. However, the best of this technology, such as that developed for NASA to recycle air in spacecraft and for such habitats as Space Station, have drawbacks. Such systems may incorporate high costs, excessive requirements for regeneration or removal of solvents or filters, design features that are unable to handle high volumes and wider ranges of concentration, and/or excessive maintenance. It is believed, however, that NASA-sponsored developments could be adaptively engineered to meet Biosphere requirements cost-effectively. NASA expert recommendations are sought.

A preliminary literature survey and discussions with NASA experts and with Space Ventures scientists, engineers, and architects reveal a number of sources for CO_2 filtration and removal. At the recommendation of NASA Ames Research Center, Space Ventures has already contacted Hamilton Standard and Garrett AirResearch, who are developing air recycling systems for Space Station. Other companies have also been contacted, but insufficient information has been received to date to allow selection of a scrubber. The most prevalent approaches to reducing carbon dioxide concentration include amine solution and membrane or molecular sieve filtration. Pellets made from powder mixtures of potassium superoxide and calcium superoxide have been studied. Concentrated algae cultures have been studied and the Bosch and Sabatier systems for CO_2 cracking and oxygen recovery have been reviewed recently for application in long- duration manned space missions. Detailed computer models have also been developed to analyze individual subsystem performance in the Space Station Environmental Control and Life Support System (ECLSS), including the air revitalization subsystem. The details and abstracts from the literature survey may be obtained from the RTI Applications Team.

Technology Constraints and Specifications

In keeping with the Biosphere concept, it is desirable to have the most benign air regeneration or CO_2 balancing system possible at reasonable cost. For example, while hydroponics might be preferred as a relatively "natural" system, support of hydroponic operation requires a chemical plant far too demanding on the existing design. The CO_2 control system must operate on a fluctuating or intermittent mode dependent on diurnal and seasonal conditions. A minimum 2-year life cycle is required with much longer life times desirable. For example, replacement of amine for a liquid solution system every 6 months is not attractive.

A maximum recovery for any removal system is estimated to be about 1300 lb. per day of CO_2. Time constraints are also an important factor. It is preferred that the system be installed for testing by July 1990. This precludes extensive research and development and emphasizes adaptive engineering of existing systems. The 6M cu. ft. air in the Biosphere is expected to be recycled twice per day. It is possible that CO_2 recovery units need not be incorporated into the air handling system but could be spaced throughout the various biomes and be optimized for the relative CO_2 concentration in each biome. Atmospheric conditions throughout the Biosphere include a temperature range of 60 to 90°F and a relative humidity range from 50 to 100 percent. Initial considerations for the exit streams from the removal system include the fact that oxygen should not be removed from the air, nor should other gas or particulate concentrations be significantly altered from those that would be expected without the existence of the CO_2 removal system. It is that liquid CO_2 could be recovered and used for such scientific operations as gas chromatography. Since freon and ammonia are undesirable for use in the Biosphere as coolants, carbon dioxide could be used as a working fluid in cooling units (e.g., in the habitat biome).

Status

The RTI Technology Applications Team has consulted with Mr. Laurance Milov of the Ames Research Center Technology Utilization Offices and R.D. Macelroy, an expert in the Life Sciences at Ames Research Center. As mentioned, several companies have been preliminarily contacted. Prompt response from sources within NASA and from its contractors will be elicited wherever possible by the Applications Team. Additional data will be received from Space Ventures on desirable operating conditions and the environment and on planning and implementation schedules for Biosphere II. These will be made available to all interested parties. The Applications Team and the Representatives from NASA Headquarters and various NASA Centers have visited the Biosphere II site and are familiar with the objectives of the Biosphere.

Cost to NASA

It is anticipated that the net cost to NASA for a project involving a carbon dioxide recovery system in Biosphere II should be minimal, especially since air regeneration systems are

an important area of research and development in several NASA programs. It is also believed that the Biosphere II experiment offers an ideal demonstration opportunity for a CO_2 recovery system, which should be attractive to NASA contractors operating in this sphere of commercialization. It is believed that NASA Technology Utilization might profitably support initial consultations, planning, and design.

PROBLEM TITLE: CONTAINMENT OF TOXIC VAPORS DURING FUEL TRANSFER

Date of Preparation: July 6, 1989
RTI Team Personnel: John G. Cleland, Perry Cornelius

Problem

Develop a system to transfer light oil (benzene, toluene, and xylene) from a 100,000 gallon tank to a rail tank car with little or no leakage of fuel vapors.

Coke is produced from coal in coke ovens that drive off the volatiles and produce a hard, polymerized fuel most extensively used in steel mills. Approximately 80 million tons of coke are produced in the United States each year. The coking process also results in a light oil byproduct composed primarily of benzene (C^6H^6), toluene ($C^6H^5CH^3$), and xylene ($C^6H^4[CH^3]^2$), or BTX. These productsare valuable especially in gasoline production, but must be handled with care, because benzene has been demonstrated to be a carcinogen, or cancer-causing agent.

The problem Drummond Co. has presented to the NASA Technology Applications Team is one of safely transferring BTX from a holding tank to a railroad tank car. The current design concept for this operation is shown in Figure 1. The Drummond Co., ABC Coke Division, produces approximately one tank car or 23,000 gallons of BTX per week. BTX

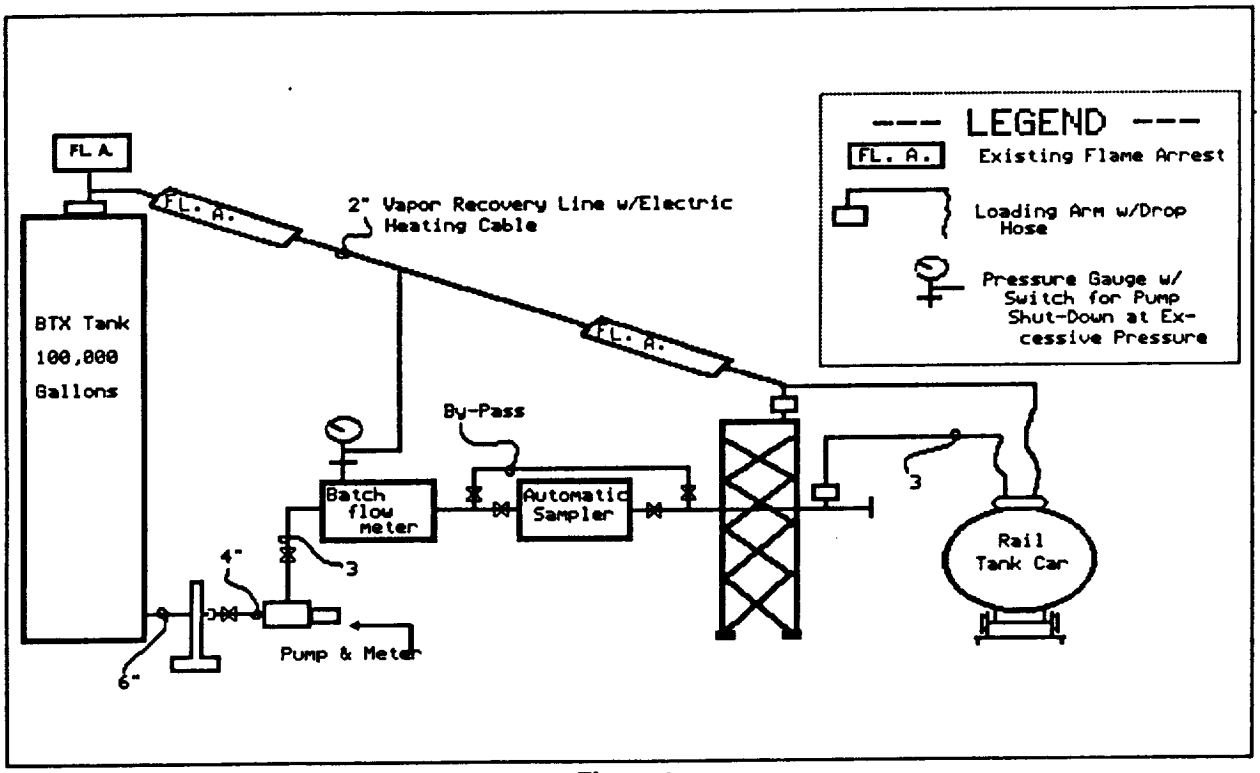


Figure 1

is typically transferred to the tank car over a six hour period, at about 65 gpm. Vapors must be kept to a minimum during transfer, and a zero leakage rate is the target.

Four problems have been identified. They are in decreasing order of importance:

- Tank car coupling and vapor recovery. Worker exposure to benzene is most likely when coupling the BTX fill line to the railroad tank car. No valves, air locks, or quick disconnects are provided with these railroad cars. A means is sought to quickly couple the fill and vapor recovery lines to the existing tank car manhole with limited or no exposure. The existing manhole is closed only with a 20-inch diameter, bolted-down, "manway" cover. Another expected problem with the vapor recovery line is the possibility of naphthalene crystallization (naphthalene is approximately 0.3 percent of the light oil by volume and has a melting point of 80.1° C).
- Flame arrestor and tank containment. Methods are sought for incorporating a tank flame arrestor and a technique for tank vapor containment that would prevent significant leaks to the atmosphere. The current BTX tank is open through an existing flame/arrestor vent. Techniques for inert gas blanketing of the BTX liquid, for a flexible seal which would allow tank vapor expansion, or for any other methods of vapor containment, would be of interest.
- BTX liquid pump. Some concern has been raised about pump design because of the desire that no leakage occur related to pump seals, even if the pump fails.
- Batch flowmeter. A flowmeter will be an addition to the transfer system and, again, a unit is sought that will not increase the likelihood of vapor leakage.

The Occupational Safety and Health Administration and the American Conference of Governmental Industrial Hygienists both have established guidelines or legal limits for BTX vapors. In addition, the Environmental Protection Agency has indicated that particularly strict new restrictions on benzene emissions will become law within the next few months. These will be applied to valves, pumps, pipelines, and other modules related to fuel transport. Drummond wants to install a new system as quickly as possible. The implications for the rest of the coking industry are obvious since over 100 million gallons of BTX are estimated to be produced from coking alone. The petroleum industry produces large volumes, with more than 8 billion gallons of BTX being consumed in the United States each year.

State-of-the-Art

Some existing tank cars have a 10-inch manifold with couplings welded in, including ball valves and a vacuum relief valve. Apparently, off-the-shelf equipment such as this will not be made available for the Drummond application and a custom design is needed. Relative to pumps, Drummond is currently using a Gould centrifugal pump and is examining both magnetic drive and can motor pump, both of which incorporate a thin shell plate between rotor and stator, or magnetic field and drive magnet, to prevent any leakage should motors and seals fail. Drummond has examined some vapor recovery heads, including one

manufactured by STS in New Jersey. The questions of vent recovery lines and vapor containment from the large tank are completely open issues at this time. It has been demonstrated that Teflon and Viton valve seals work satisfactorily for the light oil liquid.

Technology Constraints and Specifications

As stated, 23,000 gallons of BTX must be pumped over six hours on a weekly basis. A single pump is required. A nonintrusive flowmeter such as one using ultrasonics, is sought for batch flow metering. The light oil will be composed of benzene, toluene, and xylene on a weight basis of 78.2 percent, 13.1 percent, and 2.2 percent respectively, with the remainder of the oil being primarily styrene and other organic compounds. Specific gravity ranges from 0.87 to 0.89 and the boiling point of constituents ranges from 167 to 446° F. Vapor pressure for benzene is 75 mmHg. The restrictions placed on benzene releases range from 1 to 10 ppm for time-weighted averages and 5 to 25 ppm for short-term exposure. Rail tank cars must be at least 2 percent empty at all times.

Status

The Marshall Space Flight Center Technology Utilization Office and the RTI Technology Applications Team have discussed the problem with Drummond Company. The Team has completed a preliminary literature review on NASA pump research. The Kennedy Space Center Technology Utilization Office has also been contacted with respect to their expertise in fuel transport and containment. Current thinking is that NASA could provide a full transport system concept. Marshall expertise related to External Tank and on-orbit fuel transfer and Kennedy Space Center expertise in fuel handing should provide some answers to the problems described above. KSC has responded with three recommendations to the problem's solution. These have been forwarded to Drummond Co. and await further discussion.

Cost to NASA

Costs at this time are considered to be only those that would be required to support NASA in-house effort.

Action

The RTI Team is forwarding a problem statement to KSC, MSFC and to other Centers if discussions with Technology Utilization Officers warrants distribution to those Centers. Further review of a published report will be conducted related to fuel transport, coupling, and fuel handling systems. A project plan will be drafted if progress toward identifying a technical solution warrants.

PROBLEM TITLE: CORROSION PROTECTION OF NAVY P-3 ORION AIRCRAFT LANDING GEAR

Problem Originator: Naval Aviation Depot, Jacksonville, FL, Southern Technology Applications Center (STAC)
Date of Preparation: September 18, 1989
RTI Team Personnel: Stephen A. Lehrman

Problem

The Navy desires an alternative corrosion protection material or process for AISI 4340 high-strength steel landing gears subject to a saltwater spray environment.

The P-3 Orion aircraft is used by the Navy for antisubmarine activities. The plane is constantly flying surveillance over the ocean and is therefore subjected to high levels of corrosive saltwater spray. The aircraft is no longer in production and there is no supplier of critical spare parts for the aircraft's landing gear. The landing gear is made from AISI 4340 high-strength steel. During periodic repair and maintenance, the landing gear is refurbished with a new corrosion protection coating. The refurbishment process involves disassembly, chrome and nickel coating removal in plated coating strip baths, machining, nickel electroplating, chromium electroplating, final machining, and surface finishing. The nickel or chromium coatings may or may not be totally replaced. The landing gear takes longer to refurbish than the rest of the aircraft. The average time for refurbishing the landing gear is 120 days. The Navy estimates that half this time is "dead time", when no refurbishment is performed. The major reason for the "dead time" is that the many critical tasks that need to be performed during the refurbishment process are performed at widely distanced facilities.

The Navy is considering establishing a facility dedicated to the refurbishment of landing gear. This dedicated facility would solve many of the logistics problems currently encountered during the flow of the landing gear parts through the system. However, the Naval Aviation Depot at Jacksonville is on the EPA Superfund list, the Navy does not want to install any new coating strip baths or electroplating baths there and because both use hazardous materials and generate hazardous wastes.

Technology Constraints and Specifications

There are three technical requirements for a new corrosion protection material or process.

1. The processing time must be less than 120 days.
2. The material/process cannot use hazardous materials nor generate hazardous wastes.
3. The finished landing gear assembly will perform as well as, or better than, the current finished assembly.

Steel is often protected from corrosion by a nickel coating covered with a thinner coat of chromium. The combination is generally described as chromium plating. Nickel with an electrode potential of -0.250 V is cathodic with respect to iron with an electrode potential of -0.440 V. The nickel protects the steel against galvanic corrosion. The chromium coating protects the nickel from fogging. Fogging is a dulling of the nickel brightness and does not necessarily affect the corrosion protection ability of the coating. Chromium also offers a hard coating for the nickel.

As noted by Evans [1], the corrosion coating material must be selected based on the intended service environment. A cathodic coating will not prevent rusting of the steel if there are pinholes or cracks in the coating. In fact, a salt water environment may cause the corrosion of the steel to be accelerated due to the large cathode and small anode. A zinc or aluminum coating can protect steel even with pinholes or gaps provided the current carrying capacity of the steel is sufficient. These coatings, which are anodic with respect to the steel, are destroyed in providing the corrosion protection. Eventually, enough of the coating may be sacrificed to allow corrosion of the underlying steel to occur. Aluminum oxides that form on the surface have been shown to confer some degree of corrosion protection. Cadmium with an electrode potential of - 0.403 V is a good match for steel.

NASA Technology

Corrosion protection of the landing gear can be provided either by a coating or surface modification. Examples of corrosion protection coating processes include electroplating, painting, ion plating, and cladding. Examples of surface modification processes include ion nitriding and shot peening. Kennedy Space Center (KSC) has long used zinc-rich paints for corrosion protection of steel structures subject to the coastal environment. Evans [1] notes that paint containing 92 percent of metallic zinc is capable of providing cathodic protection to iron exposed at a gap in much the same way as a coating of zinc obtained by hot-dipping. Recently, KSC and Los Alamos National Laboratory have been performing research on conductive organic polymers as corrosion control coatings. The research objective is to add conductive polymers such as polypyronne and polyphenylquinoxalene in a paint formulation. Ion plating is a coating process in which a metal to be deposited is first vaporized and then deposited on the substrate material. The substrate material is first cleaned by ion bombardment to remove all surface oxide layers. After about 20 minutes, when cleaning is complete, a tungsten filament is heated by a strong current. Alternatively, a high power electron beam can provide the heating source. The heating source vaporizes and ionizes the metal to be deposited, which then flows to the substrate surface producing a strongly adherent bond.

The Materials Divisions at Marshall Space Flight Center (MSFC) and Lewis Research Center (LeRC) have performed ion plating. MSFC performed chromium ion plating of 440C stainless steel turbopump bearings. LeRC has used ion plating with various coating materials and base metals. Ion nitriding is a surface modification process in which ions diffuse into a base material surface. The diffusion rate and depth are controlled by an

electric potential applied to the base material. Since this process is not a coating process, there are no adhesion problems nor dimensional changes. Ion nitriding can provide good corrosion protection for alkaline environments such as saltwater. Neither ion plating nor ion nitriding depend on line-of-sight processing. In other words, the entire material surface is coated (ion plating) or modified (ion nitriding) without having to move or turn the surface to face the ion source. Mr. Tally Spalvins of the Materials Division at LeRC is a world leader in ion nitriding technology.

Dr. H. P. Chu of Goddard Space Flight Center has patented a method of coating a substrate with a rapidly solidified metal coating by shot peen plating. A mixture of rapidly solidified metal powder and glass beads is sprayed from a nozzle against the surface to be coated. The powder and peening particles strike the surface simultaneously, and the impact bonds the powder to the surface as a uniform coating. This technology has been licensed by Airtech Corporation.

Department of Energy Technology

An electrospark deposition (ESD) process similar to cladding has been developed by Westinghouse Hanford Company to produce superior corrosion- resistant coatings. The ESD process uses short-duration, high-current electrical pulses to deposit electrode materials on conducting surfaces. The rapid solidification produces a very fine-grained, homogeneous coating. The process forms a metallurgical bond between the coating and substrate via microwelding. Automation of the ESD process has proven to be an important part of obtaining reproducible coatings. Coating thicknesses range from 10 to 250 micron. Deposition rates for a single electrode are 1 to 20 cm2/minute. However, automation of the process and the use of multiple applicator heads enables practical production rates to be achieved.

Reference

1. Evans, Ulick R., An Introduction to Metallic Corrosion, 3rd Edition, American Society for Metals, 1982.

PROBLEM TITLE: DEVELOPMENT NEEDS FOR FLEXIBLE HONEYCOMB INSULATION

Date of Preparation: March 19, 1989
RTI Team Personnel: John G. Cleland

Problem

A need exists to apply NASA-developed or -supported technology to developing a new type of honeycomb insulation. Areas of technology requirements include (1) prototype materials testing for moisture gradient prediction, defects, geometric influences on reflectivity and total conductance, and acoustic attenuation; (2) surface-film-to-honeycomb bonding techniques; and (3) manufacture scale-up and optimization, including improvements in speed, precision, and reduced energy use.

Honeycomb materials with small, thin cellular structures are superior insulators having small heat-conducting cross sections, cells sized to restrict convection, and radiant energy capture within the cell walls. Honeycomb materials have been highly developed technically but their relatively high manufacturing costs, difficulty in processing, and typical structural rigidity have limited their use primarily to aircraft and military structural applications. No flexible honeycomb insulation has been developed with good compression recovery and moisture transmittal.

Thermalon has developed a flexible honeycomb insulating material comprised of layers of open-ended cells formed from flexible, thin, plastic sheets, which may be fastened to outside cover sheets. The materials are flexible enough to be worn as clothing. Metallized honeycomb is not required to achieve high insulating efficiency. A typical application would use a construction of 12 layers of honeycomb oriented at various angles, see Figures 1, 2, and 3.[1] The honeycomb layers are produced from a solid planar sheet of a plastic material such as polyolefin. Surface layers may be of a reflective material, fabric quilting, or other material dictated by the particular application.

The advantages of the material are described as incorporating improved thermal efficiency, light weight (density range of 0.2 to 3.0 lb/cu.ft.), high flexibility, low cost, high moisture permeability owing to the open cell structure and hydrophobic nature of the film, simplicity -- requiring only outer edge stabilization by conventional techniques to retain shape, and durability. An important initial application could be in aerospace insulation, e.g., for the aero-assist flight vehicle. Such application is supported by the fact that flexible insulation materials such as the flexible reusable surface insulation (FRSI) has replaced many of the ceramic rigid tiles used in the Thermal Protection System of the Space Shuttle. Thermalon has also identified the insulated clothing and sleeping bags market ($990 million annual sales) as a prime target for the product.

FIGURE 1

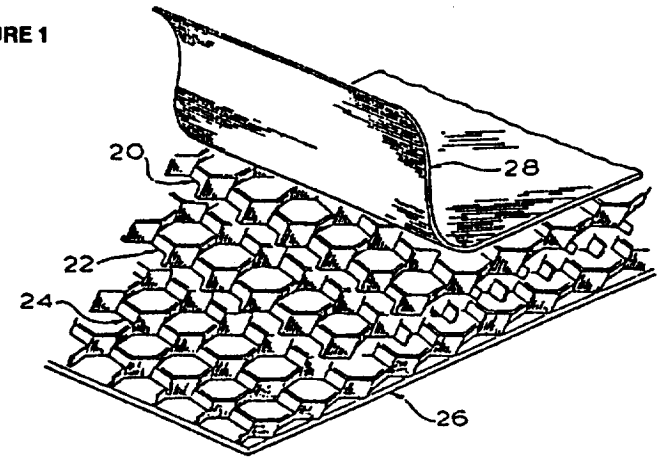


FIGURE 2

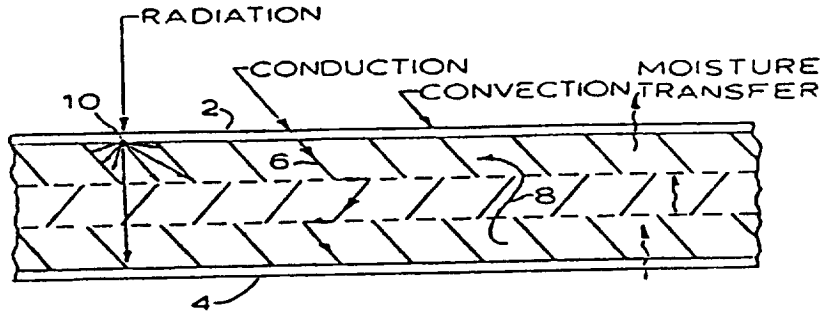
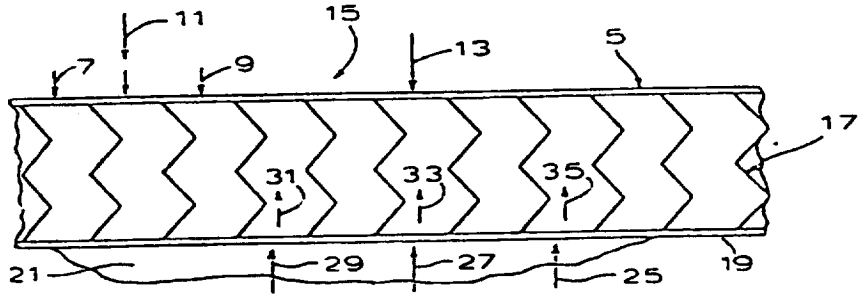


FIGURE 3



The requirements for testing that Thermalon has identified include:

- Correlation between the angles of orientation of the various layers of honeycomb with the overall reflectance of the total insulation system
- Inspection techniques, e.g., ultrasonics, for detecting debonding of surface layers or misorientation of successive honeycomb layers
- Prediction of moisture gradients and rate of moisture migration/evaporative heat transfer by theoretical and/or empirical means
- Evaluation of the acoustical attenuation of the insulation, which may provide an additional advantage of the product.

Quilting approaches and stitch bonding techniques have been satisfactorily identified for a flexible honeycomb system when used in such applications as insulated clothing. However, if more structural, or stiffer, insulation is desired (as may be required for aerospace or aircraft applications), new bonding techniques must be identified for the inner and outer surface layers. Thermoset bonding or other adhesive approaches are of interest, applied either to metal, metallized, or composite thin films.

Manufacture on a production scale remains a major hurdle to commercialization of the product. The current approach for honeycomb layer manufacture is to utilize rotary dyes that produce a pattern of slits in the planar sheets of plastic. High throughput and better geometric precision is needed for this process, which is similar to perforating sheets of postage stamps or punching out large sheets of labels. The process must be scaled from a 6" wide sheet to 48" wide. Perforated sheets are then stretched from 5 percent to 100 percent in a direction normal to the slits with heat stabilization during stretching. The layers then are cooled to room temperature rewinding. Thermalon seeks consultation with any NASA experts familiar with such processing and will provide further details on manufacturing concepts during consultation.

Initial product development for the flexible honeycomb insulation has been assisted by National Science Foundation grants under their Small Business Innovation Research Program. Phase 1 research successfully demonstrated technical feasibility and NSF has funded an expanded Phase 2 award which is underway. Final utilization of the honeycomb insulation depends upon testing for optimization, demonstration of bonding techniques and development of custom machinery since no standard equipment currently performs the same combination of processes required.

Most of the flexible sandwich materials produced previously have not appeared in the commercial market because of high costs, poor flexibility characteristics or difficulties in manufacture. Metallized honeycombs produced inhibit transfer of moisture and are susceptible to fractures in the reflective layers. Previous efforts related to honeycomb insulation are well documented in the "Description of the Prior Art" incorporated in Reference 1.

The Thermalon honeycomb insulator has been compared with polyester, polyester/olefin, goosedown, and DuPont Quallofil™. Favorable or superior results were obtained in terms of initial loft, stored bulk, thermal transmittance, evaporative heat transfer, recovery after exposure to moisture, and thermal transmission after mechanical cycling.

Technology Constraints and Specifications

Plastic sheets for the honeycomb structure are typically between 0.0003 and 0.020 in. in thickness, preferably about 0.0006 in. For terrestrial applications, the material should be absorptive to infrared radiation of 9 to 12 microns wavelength. The preferred slit pattern (see Figure 4) would have L1 of 0.1875 in., unslit spacing, L2, of 0.0625 in., and a row spacing, D1, of 0.050 in. Expanding the slit material in a direction normal to the slit, Figure

5, creates the desired honeycomb-like cellular pattern with cell dimensions of between 0.025 to 0.75 in. wide and 0.010 to 0.5 in. high, depending on the particular application. Typical layers will have a cell height of 0.09 in., a cell width of 0.12 in. and a layer height of 0.08 in. (due to the 600 angle between the cell walls and the nominal film plane). The assembly of 12 layers has an overall height to width ratio of 9.3, which is the critical parameter.

FIGURE 4

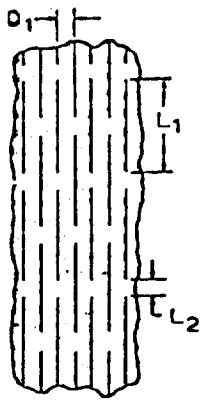
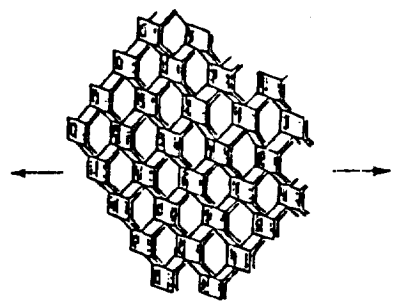


FIGURE 5



For terrestrial applications, the material should maintain flexibility over a temperature range of -60° F to 130° F and have a porosity of at least 95 percent for the free passage of water vapor.

Few technology constraints are placed upon testing, bonding or manufacturing techniques at this point. The rotary dye technique for uniformly slitting the sheet material is considered to be the best approach at any scale. Production costs should be limited to $1.75/lb of material produced. Manufacturing rates up to 8,000 to 10,000 board ft/minute would be desirable.

Status

The problem was originally brought to the attention of the RTI Technology Applications Team by Mr. Rad King, Director of NIAC/USC. The Team has discussed the concept, developments, requirements and problems with Mr. Steve Miller, President of Thermalon. Preliminary discussions have also been held with Dr. Demitri Kourtides at the NASA Ames Research Center. Documents on the product and process are available through the Team or through Mr. Miller, either for delivery to interested NASA engineers or for discussions of details by phone. The problem statement has been distributed to appropriate NASA Centers and further discussions held with engineers and material scientists at those Centers.

Cost to NASA

Not available at present.

Action

The RTI Team will obtain further details on requirements from Mr. Miller. Priority of problems and solutions will be identified with an applications project initiated if appropriate.

Reference

1. Miller, S.D., U.S. Patent No. 4,550,046, *Insulating Material*, October 29, 1985.

PROBLEM TITLE: DEVELOPMENT OF A COMMUTER AIRCRAFT BOARDING DEVICE FOR THE PHYSICALLY DISABLED

Source of Problem: Federal Aviation Administration and Paralyzed Veterans of America
Date of Preparation: October 15, 1989
RTI Team Personnel: Daniel L. Winfield

Problem

A boarding device and/or system is needed that will permit people with physical disabilities to board and deplane commuter sized aircraft. The possibility of applying computer aided design (CAD) to the problem as a way to speed up and try different concepts without incurring excessive costs due to the development of prototypes is desired.

There is an increasing gap between the necessity of airlines operating small, commercial passenger aircraft to carry passengers with physical disabilities, and the capacity of such airlines to offer acceptable service due to problems in aircraft sized and design, and deficiencies in airport services.

There are many factors contributing to the necessity to serve physically disabled passengers. In recent years, there has been a dramatic increase in the number of disabled persons traveling by air. The reasons for this include the increased accessibility of airports and fleets of large airlines, publicity concerning such improved services, more people, including the elderly, with potential mobility problems, and the promotion of air travel as a mass transportation service. There has also been an increased expectation of suitable air service on the part of passengers with physical disabilities because of these factors.

In addition, there is an increased interdependence of airlines flying small commercial passenger aircraft within the total air transport system, including the development of cost-sharing agreements with major airlines. This changes the dynamics of the load on small aircraft operators in having an increased percentage of their passengers flying the first or last leg of a flight on a major air carrier that may offer full accessible services to disabled passengers. Also, there has been a lack of attention to the equipment and service needs of small aircraft operators while industry and government activities and regulations have focused primarily on the needs of larger airlines.

Finally, small aircraft operators desire to offer good services to all passengers. However, at present, service to passengers with physical disabilities involves unnecessary stress, and even danger, to both airline personnel and passengers.

State-of-the-Art

By far the greatest need of small commercial passenger aircraft operators in serving physically disabled passengers is suitable boarding and deplaning equipment that is cost effective, easy to operate, economical to maintain, and sufficiently adaptable to serve the

multiple aircraft types and sizes currently in service. At present, there is no known equipment to meet this need.

Technology Constraints and Specifications

Tarmac boarding

Unlike the larger aircraft of the major airlines which almost exclusively use jetways or airbridges from the airport gate to the aircraft cabin door, smaller aircraft almost exclusively board and deplane from the tarmac. The standard jetway is not designed to match the low-level design of small aircraft cabin entrances.

Small aircraft steps, door openings, and cabin interiors

Small commercial passenger aircraft tend to have small and narrow steps to the cabin door. With many aircraft, these steps are only twelve inches wide. Further, boarding steps often are a physical part of the aircraft itself. In some instances, such steps do not lower sufficiently to permit a first step of up to twelve inches from the tarmac, and therefore necessitating the use of an external stepping stool. Aircraft door openings are both narrower and lower than those on larger aircraft, being as small as three feet, seven inches high, and two feet, on inch wide. Boarding and deplaning passengers often have to bend over to enter or leave the aircraft cabin.

The space inside the cabin which is important for adequately maneuvering a passenger who is physically disabled usually is small and cramped. Inside the cabins of some of the smaller aircraft, passengers cannot move about while standing upright. In others, upright passage down the aisle is made possible by lowered channels in the aisle floor, and may include a cross- brace stepover at the wing which is an additional barrier. Aisle width is narrower than in larger commercial aircraft. In some of the small, 9-seat planes the width of the aisle may be only nine inches.

The need for manual lifting

Due to the lack of any suitable boarding equipment, it is necessary for airport and airline personnel to manually lift physically disabled passengers to board and deplane them. Because of the small steps, low and narrow doors, and narrow and cramped lifting areas in the cabin, it is both difficult for personnel to lift passengers, and dangerous for both them and the passengers.

Approximately 62 percent of regional and commuter airlines operate out of 865 airports where they provide the only air service. In some airports, there are few available personnel for lifting physically disabled passengers. In fact, a number of small airlines actually have one-man stations. Further, small commercial passenger aircraft, 19-seat and below, do not have flight attendants, and the only possible available crew to assist in lifting would be the pilots and/or gate crews.

Multiple aircraft sizes

The size range of small commercial passenger aircraft is from 9-seat to 72- seat (an 8-fold differential), as compared to aircraft of the major airlines which have a sized range from 120 seats to 450 seats (a 4-fold differential).

The overall need is for specification, design, prototype development, and ultimately commercialization of equipment to assist in a safe, dignified manner the boarding and deplaning of passengers with physical disabilities into and out of small commercial passenger aircraft. New technology should be explored in the area of boarding chairs to work in conjunction with the lifting device that will negotiate the narrow aisle width in regional aircraft. The use of CAD should be explored as a mechanism to evaluate different conceptual designs within the many types of aircraft being considered so as to avoid the costly and timely development of working prototypes.

Status

The RTI Team arranged a meeting between staff from the Paralyzed Veterans of America and NASA Langley engineers at LaRC. Cost and operational constraints may preclude the utilization of solutions suggested by NASA.

PROBLEM TITLE: ENHANCING MAGNETIC RESONANCE IMAGES FOR IMPROVED CANCER DIAGNOSIS

Source of Problem: University of South Florida/American Cancer Society - Florida Division

RTI Team Personnel: Daniel L. Winfield

Problem

Proton Magnetic Resonance Imaging (MRI) has very rapidly become the most significant imaging modality since X-rays because of its ability to image soft tissues due to their differences in the magnetic relaxation behavior. However, there are many instances where the soft tissue contrast, within the individual images of the data set acquired, is not sufficient to allow the physician to make a differential diagnosis with an adequate confidence level (i.e., with sufficient sensitivity and specificity).

MRI systems produce spatial distribution estimates of several distinctive tissue parameters. These include proton densities, relation times, and flow phenomena. However, the full differential diagnostic potential of these images is currently diminished by several troublesome factors. These include:

- The breadth and overlap in the distributions of intrinsic parameter measurement values.
- The instability of intrinsic measurement values.
- The large volume of image data sets, especially for 3-D imaging techniques.
- The inherent signal-to-noise limitations.
- The instrumentation problems related to selective slice techniques, partial volume effects, RF attenuation, gradient field distortions, and antenna loading characteristics.

NASA Technology

The need to analyze and interpret remotely sensed multispectral data from orbiting satellites (i.e., images obtained at different frequencies) has given rise to a substantial technology in image processing and pattern recognition methods, such as the ELAS software developed by NASA. However, very few centers have successfully applied these methods to medical image analysis and interpretation.

The proposed method of attack therefore involves (a) improved optimization of MRI imaging methods, (b) implementation of more rigorous image standardization and registration procedures, and (c) evaluation of several methods of multispectral feature analysis, and finally (d) their implementation on high-performance computer architectures such as artificial neural net systems (ANNS).

Principals

- Laurence Clarke, Ph.D., University of South Florida
- Bob Butterfield, Kennedy Space Center
- Doug Rickman, Ph.D., Stennis Space Center

Status

A project plan has been completed and included within a formal proposal from the University of South Florida to the American Cancer Society-Florida Division. This proposal has been approved for funding by ACS. A project plan has been submitted by KSC, and FY90 funding is expected.

Commercialization

Artificial Cognition System, Inc., has committed to contribute $50K per year for the three year project. This will include provision of a state- of-the-art Neural Net System and support expertise in its use as well as actual financial contribution to USF. The resulting product should have significant commercial potential and will involve cost-effective additions to existing MRI systems and/or dedicated computer systems.

Budget

The following budget breakdown is proposed:

Year	NASA	ACS-FL	ACS, Inc.	USF
1989	$41K	$22K	$50K	$80K
1990	$44K	$22K	$50K	--
1991	$46K	$24K	$50K	--

PROBLEM TITLE: FLAT PANEL DISPLAYS

Source of Problem: Spire Corporation, Bedford, MA
Date of Preparation: September 1989
RTI Team Personnel: John G. Cleland

Problem

New techniques are sought for the production of full-color electroluminescent (EL) displays. Techniques are sought for improving EL phosphor performance and reducing production costs by reducing processing steps and increasing yield.

Flat-panel displays have recently received considerable attention from the technical as well as the popular press. Successful development of bright, full-color flat-panel displays would lead to the replacement of cathode ray tubes (CRTs) in applications ranging from aircraft cockpit displays to high-definition television (HDTV).

The aerospace community would like to replace CRTs with flat-panel displays because of their potential savings in volume, weight, power, reliability, and lifetime. Of their many potential advantages, the most important is their shape -- because they are flat and they can be placed where a CRT would not fit. In commercial markets, flat-panel displays are presently making a significant impact on microcomputer technology. However, reliable color displays represent a critical need in this area. HDTV is a longer- term goal, but there is considerable activity in Asia and elsewhere to develop flat-panel color displays for this potentially enormous market. Of several competing approaches, thin-film electroluminescence (TFEL or EL) is a strong candidate for use in flat-panel displays. Monocolor TFEL displays are presently available for portable microcomputers, and prototype full- color displays have been demonstrated.

EL color displays are far from ready to replace CRTs because the blue phosphor is not bright enough and current fabrication processes prduce low yeild. The brightness of blue EL phosphors and production yields are strongly related to the processes used to form the electroluminescent phosphors.

It is estimated that, in 1994, the consumer market for flat-panel displays will reach $1 billion and the nonconsumer market will reach $2.1 billion. However, due to the resolution, response-time, size, and viewing angle limitations present in flat-panel displays, CRTs will continue to control the display market well into the 1990s.

Full-color EL displays require phosphors emitting primary colors. In the present state-of-the-art, the preferred choices are the following:

- Red ZnS:Sm
  ZnS:Mn (with a suitable filter)
- Green ZnS:Tb
- Blue SrS:Ce
  ZnS:Tm

Of the three primary colors that can be produced, red and green phosphors are bright enough and have strong enough chromaticity for immediate application. The brightness and chromaticity of the current blue phosphors, however, are far from adequate. Serium-doped strontium sulphide is fairly bright, but its color is an unsaturated blue-green; the alternate thulium-doped zinc sulphide (ZnS:Tm) has a deep saturated blue color, but its luminance is lower by an order-of-magnitude.

The weak EL performance of ZnS:Tm is inconsistent with cathodoluminescence and photoluminance measurements of this material, which indicate very strong emission in the deep blue. Thus, the low EL luminance is probably due to extrensic causes that can be mitigated or illuminated. For example, energy losses of the EL-exciting electrons may be caused by excitations of impurities and by nonradiative transitions at defects. The presence of impurities and structural defects in the phosphor films are directly related to the thin-film EL fabrication procedure. There is strong evidence that some other techniques such as ion implantation of thulium (and the dopants for red and green phosphorous) into thin films of ZnS, can form bright EL phosphors and avoid problems of impurities and structural defects. Additionally, ion implantation, which is a direct line-of-sight process, offers the potential of forming the pixel patterns required for full-color flat-panel EL displays.

The leading competition and perhaps lead technology for flat-panel displays is liquid crystal display technology. Active-matrix LCDs combine two technologies: thin-film semiconductors and flat-panel liquid crystals. Active-matrix displays yield high contrast, good color, and a wide viewing angle. They also preserve two of the most attractive features of LCDs: low power consumption, which means portability, and low voltage, which means they can be driven from TTL logic levels. The main technological problems with these two panels include the need to develop the capability to deposit on glass defect-free arrays of thin-film transistors or diodes and the need to obtain accurate registration of such arrays with the accompanying LC structure. Further complicating production is the fact that, in a color display, the number of pixels is quadrupled, and filters must be added with critical alignment.

Technology Constraints and Specifications

Critical objectives are to move electroluminescent displays into full-color displays with high luminescence. The RGB display must be designed to obtain both chromaticity and intensity values that strike the right balance of red, green and blue. This balance is important to accommodate the varying sensitivity of the human eye to different wavelengths of color. Ten thousand hours of useful life is a goal designated for most flat-panel displays. Package thickness for flat-panel displays, which is typically 0.75 to 1.5 inches, varies from approximately 0.5 to 2.5 inches. A flat- panel display can be either AC or DC. An ultimate goal for resolution might be 640X640 pixels or an EG standard of 640X350 pixels. As stated, this will require a 1920X350 RGB display if translated from a monochrome display. EL area luminance must be increased in the first instance to match for example, such currently obtainable luminance numbers as 20-60 FL for plasma display panels.

Most of the latter constraints summarize long term goals. Near term, it is highly desirable to simply eliminate or greatly simplify some of the fabrication steps for EL such as chemical etching and separate phosphor deposition steps. Display cells must be fabricated, tested, and evaluated for each color.

NASA Technology

Exploratory tests conducted by investigators at NASA Langley Research Center indicate that ion implantation has a strong potential for introducing dopants into EL phosphor material. Under NASA sponsorship, many of these ions have been implanted into thin films of terbium-doped ZnS; optical tests on the ion-implanted EL phosphor showed a strong change of color from green to red-orange. This very preliminary result indicates that the implanted Mn ions were incorporated and optically activated in the ZnS host.

The RTI Technology Applications Team has contacted Dr. James Robertson at LaRC to discuss the advances made at that Center and to try to match interests with Spire Corporation and other possible commercial ventures. A white paper is being prepared by Spire Corporation in consultation with Dr. Robertson, which will be evaluated by the Team, the LaRC TU Office, NASA Headquarters TU and other experts.

Cost to NASA

A preliminary estimate of EL display project costs would be approximately $160,000 per year, with 50 percent of the cost being provided by the NASA Technology Utilization program. Approximately 3 years of development are anticipated to be required. Spire Corporation has indicated preliminary willingness to commit as much as $250,000 for early commercialization of the technology.

PROBLEM TITLE: FAILURE OF PULP MILL SMELT SPOUTS ON RECOVERY BOILERS

Source of Problem: International Paper Company
Date of Preparation: May 16, 1989
RTI Team Personnel: Stephen A. Lehrman

Problem

The failure of carbon steel smelt spouts on recovery boilers is a chronic pulp industry problem of important economic and safety significance. A substitute material, such as a different metal alloy, ceramic or ceramic matrix composite, or metal matrix composite, is desired to increase the useful lifetime of smelt spouts. Anticorrosion and thermal barrier coatings may also be applicable.

Pulp mills use recovery boilers to reconstitute the "black liquor" produced by the pulping process. The three critical functions of the recovery boiler are (1) recovery of pulping chemicals, (2) disposal of waste from the pulping process, and (3) production of steam for electrical power cogeneration and process use. The use of recovery boilers has a significant influence on the economics of the modern day pulp mill.

The pulping process involves cooking of wood chips with chemicals in either continuous or batch digesters. The result of this process is cooked pulp and the black liquor. The black liquor is concentrated and returned to the recovery boiler as fuel.

The fuel for the recovery boiler contains lignin, sodium sulphate (Na_2SO_4), sodium carbonate (Na_2CO_3), sodium sulphide (Na_2S), sodium hydroxide (NaOH) and such minor constituents as sodium chloride (NaCl), potassium salts, and transition metal salts. The liquor is not homogeneous. Composition and calorific value change rapidly. Drying, pyrolysis and gasification of the lignin occur as the fired liquor falls to the bottom of the boiler, leaving the inorganic salts to form a bed of molten smelt, with a surface layer of residual carbonaceous material.

The smelt in a recovery boiler is primarily composed of such inorganic salts as Na_2CO_3, Na_2SO_4 and Na_2S, and has a nominal melting point of about 750°C (1,400°F). Many other minor constituents are also present in the smelt, including potassium and chloride, both of which can produce eutectic mixtures with melting points at least as low as 580°C (1,100°F).

The bulk of the smelt in the lower section of the recovery boiler is drained via smelt spouts. There are usually three smelt spouts on each of the four sides of the boiler. The smelt spouts allow the smelt to drain into troughs, which then transport the smelt to dissolving tanks.

The smelt spouts are covered by a layer of frozen smelt. This layer of frozen smelt is believed to protect the bare metal of the smelt spouts from corrosion.

However, the smelt flow is not constant, which can result in the melting of the smelt barrier and exposing the bare metal to the smelt. Smelt spouts are made of mild carbon steel AISI 1020 or ASTM A36. In general, these smelt spouts have a lifetime of 3 to 6 months. In situ field experiments have failed to identify metals more suitable for the corrosive smelt. These experiments have included tests on alloy steels, inconels, hastalloy, and stainless steels containing chromium. Failure was due to differential expansion between the stainless steel overlay and the carbon steel nozzle. Alumina (Al_2O_3) has been shown to withstand the corrosion, however, it is very brittle. Some pulp mills have attempted to overlay the carbon steel with stainless steel or hastalloy.

However, the differences in the coefficients of thermal expansion have resulted in separation of the cladding. A number of years ago, a Finnish company was offering a ceramic smelt spout. This spout did not catch on very well because of failure due to mechanical shock. Periodically, the smelt spout opening becomes clogged by frozen smelt. When this occurs, the frozen smelt is "rammed" out. For this reason, ceramic smelt spouts, which are brittle, have not been a suitable material substitution.

A one-pass water jacket is used to maintain the surface temperature of the smelt spouts. The water jacket inlet temperature is approximately 70°F and the outlet temperature is approximately 100°F. If the water jacket or weld penetration to the recovery boiler fails, a smelt-water explosion may occur. This accident is of significant risk to personnel and can cause severe damage to the recovery boiler.

Thermal and mechanical fatigue contribute to the failure of the smelt spouts. As stated above, the smelt flow is not constant, which leads to thermal transients and fatigue. The vibration of the smelt entering the dissolving tanks is transmitted through the troughs back to the smelt spout.

Technology Required

The technology required is to design, fabricate, test, and install a non-water-cooled smelt spout that will operate for one year without forcing a recovery boiler shutdown because of failure or required maintenance. This technology will result in higher recovery boiler availability and improved safety from potential smelt-water explosions. The availability and safety benefits apply to every pulp mill operating a recovery boiler.

NASA Technology

NASA has a strong technology base in metal alloys, ceramics and ceramic matrix composites, metal matrix composites, coatings, and material processing. As noted above, metal smelt spouts have been susceptible to corrosion assisted failure and ceramic smelt spouts have failed due to brittle fracture. NASA technology could be used to design:

1. A non-water cooled metal alloy or metal matrix composite smelt spout that is more resistant to the corrosion caused by the inorganic salts in the smelt, or

2. A non-water cooled ceramic or ceramic matrix composite smelt spout that is less brittle and also capable of withstanding the molten salt corrosion.

Another acceptable approach is to develop an anticorrosion or thermal barrier coating that can be applied to the carbon steel smelt spouts. Although this approach does not eliminate the water jacket, it may prolong the useful life of the smelt spout to the desired one year.

Status

Dr. Nathan Jacobson of Lewis Research Center responded to the problem statement. Dr. Jacobson suggested coating the smelt spouts with a MCrAlY type coating where the M is FE, Co, Ni or some combination of these metals. His suggestions were forwarded to International Paper for their review. International Paper has responded that they are interested in further discussions in reference to Dr. Jacobson's solution as well as other solutions that would eliminate the water cooling jacket around the smelt spout. A meeting at Lewis is being planned for November to discuss these opportunities.

Goddard Space Flight Center also responded to the problem statement. GSFC recommended that International Paper contact Lanxide Corporation of Newark, DE regarding the use of Lanxide Armor for this application. GSFC's response was forwarded to International Paper.

PROBLEM TITLE: IMPROVED AUGMENTATIVE COMMUNICATION DEVICE

Date of Preparation: June 23, 1989
RTI Team Personnel: Daniel L. Winfield

Problem

Consolidation and miniaturization of electronics are required to reduce a speech output device for the vocally impaired to a portable, hand-held size for use by ambulatory persons. There are more than one-million nonvocal, intellectually capable people in the United States who can benefit educationally, socially, emotionally, and economically from a hand-held, lightweight, portable, human sounding augmentative communication device. Augmentative communication devices are electronic devices used by these individuals to send a message to another person.

Speech devices are being used everyday for socializing, working, travelling, and education. Unfortunately, because of their size and weight, these products often hinder the ambulatory/nonvocal user from fully benefitting from the capabilities of the device. This system needs to be modified to a hand-held unit with keyboard for input, one-line text screen for verification of input, microprocessors, memory, output speaker, and battery. This smaller unit will provide increased independence for at least 250,000 nonvocal/ambulatory persons.

NASA Technology

NASA expertise on surface mount technology and large scale integration can aid in the design and development of custom ASICs (application-specific integrated circuits) to reduce the number of circuit boards from 3 to 1.

Principals

- Mr. David A. Gordon, President, Adaptive Communication Systems, Inc.
- Mr. John Williams, Consultant to Adaptive Communication Systems, Inc.
- Mr. Murzy Jhabvala, Goddard Space Flight Center

Status

Adaptive Communications Systems, Inc., has submitted an SBIR grant application to NIDRR. NASA is listed as a technical consultant but with no commitment of NASA funds. NIDRR has informed Mr. Gordon that the proposal has been recommended for funding and he will be notified of the funding decision prior to the end of December.

PROBLEM TITLE: INTERACTIVE ROBOTIC DEVICES FOR COGNITION AND MANIPULATION SKILL DEVELOPMENT BY YOUNG CHILDREN WITH SEVERE PHYSICAL IMPAIRMENTS

Date of Preparation: October 1988
RTI Team Personnel: John G. Cleland

Problems

A safety sensing system is needed that is capable of providing input to a robot controller. Intelligent control software must be developed to sense and control robot proximity to the individual interacting with the robotic device. Artificial intelligence development is also needed to facilitate use of an Interactive Robot Device (IRD) and to ensure that IRD capabilities "grow" with the child.

Unlike typical industrial applications in which human and robot do not share work spaces, applications of robotics to rehabilitation require, by their very nature, an overlapping workspace. Activity must occur in spaces that both the robot and the human share. Assurance of the safety of the disabled individual assumes an even greater importance under these circumstances. The characteristics of safety sensing systems also change with an overlapping workspace. Rather than establishing a safety "fence" through which the intrusion of a human results in a halt in activity, sensing and the intelligent control system's response to sensory input must accommodate two dynamic features of the specified task and task activities. Decisions to be made include: at what location in the workspace is human presence permitted? What proximity to the human is permissible for the robot arm? In what orientation and at what distance is proximity between the segments of the robot arm and the human permissible?

These considerations are particularly important in relation to the use of robotic devices for developing cognition and manipulative skills in young children with severe physical impairments. Such children grow and develop in an environment over which they have little or no control. Much of a child's basic cognitive development has its basis in the child's interaction with and manipulation of the physical environment. Many children with severe physical impairments miss important developmental activity progressing from simple exploratory actions to actions permitting vigorous exploration of the properties of objects to complex, coordinated chains of actions performed upon a set of objects. An extension of their limited physical abilities through using a robotic device could offer an important advantage to these children's development.

To date, the major technological solution to the cognitive and adaptive needs of young children with physical handicaps who may also exhibit significant intellectual delays has been the use of microswitches to permit response-contingent activation of battery-powered toys, tape recorders, and vibrators.[1,2] Response-contingent stimulation, in turn, has been used for the improvement of motor functioning, e.g., head control.[3] The use of

response-contingent stimulation provides, however, only the most primitive of cognitive challenges.

Recently completed research[4,5] has developed a prototype IRD and demonstrated the feasibility of using it to facilitate the development of cognitive and manipulative skills by handicapped children. The IRD is defined as an intelligently controlled robot manipulator arm system that can perform complex activities under the user's control, cooperatively and interactively. Artificial intelligence can be used to control task activity by the robot based on input from the child, to monitor individual child performance while interacting with the IRD, and to evaluate the child's progress in learning and applying cognitive and manipulative skills.

Technology Constraints and Specifications

Priorities for developing a safety sensing system for an IRD to be applied in the development of handicapped children include:

- Proximity of the various articulated segments of the robot arm component of the IRD to the human must be available to the intelligent control software
- "Failsafe" proximity data must be directly available to the robot controller
- Proximity must be continuously updated
- Cost must represent only a small proportion of the total cost of the IRD system (robot arm, computer, interface devices).

AI requirements address the child/machine interface and simultaneous performance evaluation. One challenge to developing a robot control "expert system" is that it must evolve with the child's increasing abilities.

Status

The problem statement was forwarded to ARC and LaRC. Purdue further consulted in the second quarter and indicated continued interest. Goddard Space Flight Center has responded with a description of a proximity sensor approach that could allow collision avoidance.

Action

The Applications Team will recontact Purdue and initiate contacts with JPL.

References:

1. Wethered, C., Teacher-Maid. "Response-contingent Materials," In Greer et al. eds., *Strategies for Helping Severely and Multiply Handicapped Citizens*,Baltimore, 1982.

2. York, J., Neitupski, J., and Hamre-Neitupski, S., "A Decision-Making Process for Using Microswitches", *Journal of the Association for Persons with Severe Handicaps*, 10, 214-224, 1982.

3. Maloney, F.P., and Kurtz, P.A., "The Use of Mercury Head Switch Control Devices in Profoundly Retarded, Multiply Handicapped Children." *Physical and Occupational Therapy in Pediatrics*, 2 (4), 11-17, 1982.

4. Knof, S.Y., Karlan, G.R., and Widmer, N.S., "Development of a Prototype Interactive Robotic Device for Use by Multiply Handicapped Children." Presented at RESNA Conference (*ICAART 88*), Montreal, June 1988.

5. Karlan, G.R., et al., "Preliminary Clinical Evaluations of a Prototype Interactive Robotic Device (IRD-1), "Presented at RESNA Conference (*ICAART 88*), Montreal, June 1988.

PROBLEM TITLE: LARGE, INTERACTIVE DISPLAY FOR UNION ELECTRIC DISPATCH OFFICE

Source of Problem: Union Electric - St. Louis
Date of Preparation: July 6, 1989
RTI Team Personnel: John G. Cleland, Jeff Antley

Problem

An adaptable, interactive, and inexpensive method of lighting and maintaining a set of power distribution mapboards of a large city area is required.

Dispatchers and other companies processing data over an expansive network desire a method of displaying information instantaneously and efficiently. The most efficient method of assimilating such data in an easily retrievable fashion is to generate a large, detailed display on a wall, screen, mapboard, or similar surface. Display methods presently in use only partially fulfill the needs of being adaptable to changes and being user-interactive.

A system of displaying computer-generated, workstation-driven information on a large screen or mapboard is needed to accommodate instantaneous changes in either an information network or a map itself, for actual or hypothetical situations. Such a system would offer flexibility and expandability, and would be interfaced easily with existing computer networks.

Implementation of a video projection system can have far-reaching applications in utility companies; dispatchers for fire, police, and rescue; airline, train, and other mass-transit systems; military and tactical needs; and any other organization desiring large, real-time projected images.

State of the Art

Present methods of group display include LED mapboards behind computer or hand-drawn paper maps, etched slides, or overhead projection plates. These practices have very limited flexibility, requiring preparatory time to allow for changes in the map or in the company's information network.

The use of LED displays leads to wiring problems, especially as the number of LED lamps becomes very large. This system, therefore, can also be resistant to frequent updates.

Laser-generated displays are a new alternative. However, government health restrictions have forced some companies to reject this method, including Union Electric.

NASA's Johnson Space Center, until recently, has been using the same system developed in the 1960's for monitoring all space missions and launches, whereby maps are projected onto a large screen from etched plate glass slides.

Union Electric of Saint Louis currently uses an unlit mapboard. Computer- drawn paper maps of the area are mounted on plywood. This system offers no interactive capabilities, and updating requires redrawing and replacing the entire map.

Technology Constraints and Specifications

Required is a method of lighting and maintaining mapboards that would be lit with points of four-state capability (red, green, amber, and off). These colored points are needed to monitor the status and location of various switches in a power system. Five thousand point display capability is needed for the mapboards, which would vary in size from 8' x 8' to 15' x 26'. Also required is software for updating and driving all indications located on the mapboard.

Union Electric has specifically asked for six mapboards, with between 5,000 and 15,000 indication points on each mapboard. Also to be provided is the software for the RS232/Ethernet interface between the computer and the mapboard controller. Total cost for the upgrading of facilities is not to exceed $500,000.

Ideally, the display should be easily adaptable and interactive. As changes are made to the information base, the display would be similarly updated. Engineers should also be able to analyze the status of the network through the remote testing of switches by monitoring the response of other switches throughout the network.

It has been suggested that a video projection system would offer a simple solution to the subtle requirements of such a flexible system. Software for the remote-testing capability could be easily introduced into a computer-based system. Such a system would eliminate the wiring difficulties of an LED display, the health hazards of a laser-generated display, and the delay time involved in plate-glass etching.

Companies that are developing such video projection systems include Hughes Research Laboratories, General Electric, and Barco Electronics. NASA's Johnson Space Center currently contracts with Hughes of Fullerton, California for an upgraded display system to be used in their Mission Control Room. Barco Electronics already produces the equipment that would fulfill these needs.

PROBLEM TITLE: LONG DURATION AIRPACK FOR FIRE FIGHTERS

Date of Preparation: December 12, 1988
RTI Team Personnel: Stephen A. Lehrman

Problem

In certain applications, fire fighters need a longer duration breathing apparatus than can be provided by commercially available compressed air bottles. These applications include fires in high rise buildings, subways, warehouses, basements, ships, airports and hazardous material handling.

Fire fighters use compressed air to breathe when combating a fire in a closed environment. The compressed air bottles are rated from 30 minutes to 60 minutes. However, when fighting a fire, a fire fighter's respiratory rate increases resulting in depletion of compressed air bottles in half the rated time.

American Heat video service documented the Los Angeles First Interstate Bank Building Fire. This fire occurred on the twelfth through sixteenth floors of a high rise office building. It has been described as the worst high rise fire in Los Angeles history. One of the major problems cited by the Los Angeles fire department was that the fire fighters would run out of air and have to leave the fire to replenish their air supply.

Kennedy Space Center (KSC) has developed a liquid airpack for use at KSC. The liquid airpack was shown on part 2 of the American Heat video and resulted in approximately a dozen calls to KSC requesting more information. Fire Department Chiefs in Boston, Washington, DC, and elsewhere, as well as some manufacturers of self-contained breathing apparatus (SCBA), have expressed interest in participating in a demonstration of the liquid airpack.

NASA Technology

The liquid airpack is an open-circuit, positive-pressure, on-demand system that is initially charged with 6 pounds of liquid air. The system carries the equivalent of 60 minutes (conservative estimate) of breathing air and weighs only 24 pounds. A comparable compressed air pack weighs 35 pounds.

The liquid air is cryogenically cooled to -317°F at 150 psi and stored in a tank called a dewar. As the liquid air leaves the dewar, it passes through expansion tubes and changes to a gaseous phase. The air is then accumulated in an accumulator tank.

Tests have demonstrated that the air provided is cool and of sufficient quantity to ensure positive pressure within the mask, even during high rate work. Recently, KSC learned that by lowering the temperature of the breathed air to 38°F, they can reduce the core temperature of the fire fighter. This is of benefit in reducing fire fighter fatigue.

KSC has developed the technology to mix large quantities (500 liters) of liquid air from liquid nitrogen and liquid oxygen. Liquid nitrogen and liquid oxygen are commercially available in most metropolitan areas, although liquid air is not. Therefore, the cryogenic mixing technology is as important as the liquid airpack technology.

Principals

- George Nolan, Kennedy Space Center
- Don Doerr, Kennedy Space Center

Status

Chief Richard Cross gave a presentation on the NASA Liquid Airpack to the Florida Fire Chiefs at Palm Beach, Florida on July 27. He also gave a presentation to the International Association of Fire Chiefs (IAFC) annual meeting in Indianapolis, Indiana on August 28-30. George Nolan (KSC), Tom Hammond (KSC), and Stephen Lehrman (RTI) attended the IAFC meeting where RTI had a booth for displaying the liquid airpack. Over 200 fire fighting professionals visited the booth to discuss the merits of the liquid airpack. Four manufacturers of self-contained air breathing apparatus visited. The consensus from the user community was that the liquid airpack would be desirable. Sixty-six questionnaires were completed.

A presentation of the liquid airpack is scheduled for December 12 at KSC. Manufacturers, fire departments, Navy and Air Force representatives, and federal officials are being invited.

PROBLEM TITLE: MEASUREMENT OF FOOD PARTICLE MOTION AND HEAT TRANSFER DURING ASEPTIC PROCESSING OF FOOD

Date of Preparation: March 30, 1989
Source of Problem: National Food Processors Association
RTI Team Personnel: Stephen A. Lehrman

Problem

New and improved techniques for measuring the motion and heat transfer of food particles in a carrier fluid is needed.

In the past year, almost a dozen manufacturers have introduced lines of microwaveable foods that need no refrigeration. Good for 18 to 24 months, shelf stable products are being investigated by most major food processors. Already cooked, these foods can be prepared in 25 percent of the time of a comparable frozen package.

A major problem in aseptic processing of particulate food is knowing how long the food resides in the product heater and holding tube. If the residence time is too short, not enough of the bacteria is killed. If the residence time is too long, the food is overcooked. Therefore, accurate methods for measuring the motion of the food particles through the process system and better techniques for transferring the heat to and from the food are necessary.

The ultimate goal of aseptic processed foods is a natural tasting product, in a microwaveable container, that is shelf stable and does not require refrigeration or freezing. Currently, to make food shelf stable, uncooked food is vacuum packaged in specially designed plastic containers. Then, the package and contents are cooked in a process using steam and hot water. However, it has been demonstrated that if the container sterilization process and the food cooking process can be separated, the overall results are significantly more natural tasting food as compared to the traditional canning process.

Aseptic food processing and packaging can be described as the sterile handling of food material and containers, after both have been individually processed (i.e. cooked) or sterilized in separate environments. Aseptic processing differs from current, conventional bulk food handling in which the food and container, principally metal cans, are cooked and sterilized after sealing as a single unit.

In an aseptic processing system, heat is transferred first from a scraped surface or tubular heat exchanger to a carrier fluid. The carrier fluid is heated to between 130°C and 150°C. The mixture enters a holding tube where heat is transferred from the carrier fluid to the food particle by convective transfer.

Finally, the mixture enters another heat exchanger where it is cooled to a temperature necessary for packaging.

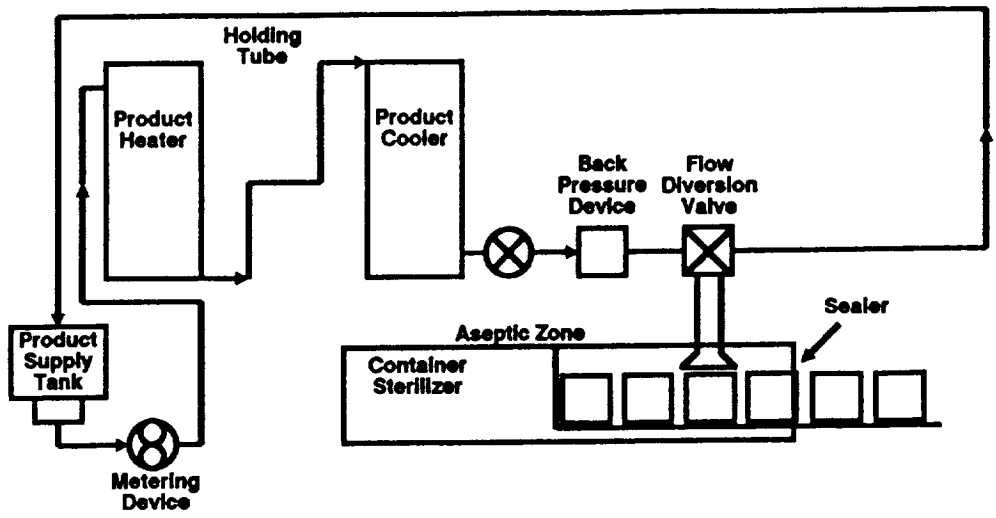


FIGURE 1: ASEPTIC PROCESS SCHEMATIC

New heat transfer methods are also being developed. Ohmic heating is being tried in Great Britain as a method for directly heating food particles. The heating effect is similar to that obtained with microwaves in that electrical energy is transformed into thermal energy. The application of ohmic heating requires that the food particle be electrically conductive. Most food particles contain dissolved ionic salts and water and are sufficiently conductive.

In aseptic processing complete sterilization of the food does not need to occur, provided that the food particle center has been heated to a sufficiently lethal temperature and the additional processing (i.e. filling and sealing) maintains the desired environment. It is critical that the sealed, internal environment of the resultant package does not allow for the further growth of bacteria. Incomplete seals can result in dangerous bacteria formation, product oxidation, and spoilage.

Aseptic processing of food is rapidly advancing due to three factors: energy savings in processing, better food quality, and lower packaging material costs. The food industry is packaging more of its products in plastic cups, trays, and pouches. The technology in these areas is becoming more complicated due to the needs required for aseptic handling, modified atmosphere and hot-filled packaging, and the packaging of low acid foods. Better techniques for measuring food particle motion and heat transfer would have a significant effect on energy consumption.

State-of-the-Art

Direct measurement of the temperature of continuously moving food particles is not possible using current technology. In order to overcome this technology barrier, the

aseptic food processing industry relies on a combination of mathematical models for particle temperature, process simulations, and biological measurement techniques.

Mathematical models of aseptic processing of low acid foods containing particles have been developed by Dail [1985], Sastry [1986], Chandarana and Gavin [1987], and Larkin [1989]. In general, these models involve the solution of the heat transfer equation for conduction into a solid subject to the appropriate boundary conditions. The mot important parameter necessary to validate the models is the fluid to particle convective heat transfer coefficient. This coefficient is difficult to measure or estimate. Hence, there does not exist a large quantity of experimental data. Other parameters that must be considered in the mathematical models include particle size, particle shape, and the thermal properties of the particle material.

Mathematical and experimental simulations have been developed of the heat hold-cool process. The mathematical process simulations attempt to determine the minimum time a food particle must reside in the heat exchangers and holding tube in order to receive a lethal sterilization dose. Calculations of residence time must consider the particle size, particle shape, carrier liquid velocity, heat exchanger type, and holding tube configuration. The National Food Processors Association has constructed an experimental aseptic particulate process simulator. Cubes of silicon, which has thermal properties similar to meat, were used as model particles for heat transfer studies. The silicon cubes were instrumented with a thermocouple in order to measure the particle center temperature.

Lacking sufficient experimental data, the Food and Drug Administration (FDA) requires that aseptic food processors take a conservative approach to determine food particle residence time. In their view, biological lethality should be calculated on the basis of the coldest temperature in the fastest moving food particle in the holding tube.

Technology Constraints and Specifications

One of the principal barriers to FDA approval of aseptic thermal processes for particulate foods is the lack of basic knowledge on flow behavior and heat transfer between the food particle and the carrier fluid. Techniques and equipment are required to measure:

1) the relative motion between the food particles and the carrier fluid at various stages of the aseptic system;

2) the residence time of the food particles in the heat exchangers and holding tubes;

3) the fluid-to-particle convective heat transfer coefficient; and

4) the particle temperature in a continuous flow system.

The types of heat exchangers presently being used to cook and cool the food represent a second technology barrier. The more rapidly the food particle center can be heated to the desired temperature for the desired holding time, followed by rapid cooling, the more efficient the process becomes. Rapid heating and cooling of the particle center is a direct function of the heat exchanger type and configuration. As noted above, ohmic heating is

being attempted. It appears nobody is investigating other heating methods such as microwave. Innovative methods for heating and cooling the food particles are of interest.

NASA Technology

The primary needs of the aseptic food processing industry are better techniques for measuring the food particle motion and convective heat transfer. NASA Technology in flow measurement or flow visualization of two phase solid-liquid flows would be helpful in determining the relative motion of the food particle in the carrier fluid. Also, NASA Technology is required for determining the convective heat transfer coefficient and the food particle temperature while the food particle is in motion.

A second important area where NASA Technology can contribute to optimizing aseptic processing is the development of new techniques to rapidly heat and cool the food particles. These new techniques may include new heat exchanger designs, application of heat pipes, radio waves or microwaves.

PROBLEM TITLE: MEDICAL DEVICE SOFTWARE RELIABILITY

Source of Problem: The Health Industry Manufacturers Association
Date of Preparation: October 3, 1988
RTI Team Personnel: Daniel L. Winfield

Problem

As more medical devices are developed to work in an autonomous mode in life critical applications, validation and verification of the operational software becomes a critical concern. Advanced techniques for fault tolerant software development and software validation and verification are sought for application to medical device software systems.

Recent years have seen an increase in the application of software-based systems to life-critical applications. The results of a software fault in such an application could be loss of property, injury or death. It becomes imperative that the system present an acceptable level of risk while preserving the benefits it was designed to provide.

In the medical device industry, representative devices in this category include: (1) implantable defibrillators that continuously monitor the heart electrical activity in order to detect arrhythmias and then deliver a defibrillating electrical pulse to the heart, and (2) closed loop infusion pumps that include sensor feedback to control the rate of drug and/or fluid infusion to the body (an example is using a measurement of blood pressure to control delivery of an antihypertensive agent).

Between 1983 and 1985, 37 of 41 computerized medical device problems reported to FDA involved software failures. In a widely publicized case, a radiation therapy system was responsible for the death of at least two patients. The highly sophisticated machine operates at a power of 25 million electron volts and administers two types of radiation therapy, X- ray and electron, for different cancers. The two patients apparently received radiation overdoses of more than 100 times the average treatment. In the manufacturer's report to the Food and Drug Administration, the company stated that the software failed to access the appropriate calibration data under the special editing sequence documented at the medical center. Subsequently, a third patient was reported to receive a similar overdose from a similar but not identical software glitch. These cases highlight the extreme importance that software plays in product performance and the critical nature of software quality assurance programs.

State-of-the-Art

Identifying software safety as a discrete design goal is a relatively new idea in the medical device industry where hardware designs were generally favored over software designs until recently. Frequently, safety mechanisms were slapped on after the fact in order to eliminate problems, however, these were easily overridden or defeated by the operator. It is apparent that organizations must balance the cost of finding every last software bug

against the liability of a catastrophic loss. However, for both regulatory and liability reasons, the company must be prepared to show they've done everything practical to eliminate software errors.

There are few publications on software reliability programs in the medical device industry. Since there are a number of large companies and a very large number of small, even cottage, industries, one can expect a broad range of software quality assurance programs. Advanced software reliability procedures need to be developed which are cost effective for these smaller companies as well as the large companies.

The integration of safety into the software development process, in general, begins with a hazard analysis following the product description. Potential hazards are identified and classified according to their criticality and probability of occurrence. This hazard analysis dictates the software safety requirements which are incorporated into a functional specifications document.

For validation and verification of the software system, most companies attempt to exercise all portions of the computer code to the extent practical. However, for many companies, there is little basis for determining the extent of this software testing. Hewlett Packard has reported on a software quality assurance testing procedure for a computer- based ECG monitoring system. This system has approximately 135,000 lines of computer code, and the total software test effort required approximately 16 person months. Functional testing was performed in multiple test environments including four separate inhouse laboratories and a hospital field test system. The functional testing was categorized as either specifications testing, random values testing or special values testing. A total of 261 errors were reported at a rate of 1.93 detected errors per 1,000 lines of computer code.

Technology Constraints and Specifications

NASA has extensive experience in software engineering for reliable complex systems, such as flight control systems. The agency has supported work in software management and environments, fault tolerant software, software reliability modeling, and software performance measurement. The results of this work may be transferrable for application to medical device software systems in order to increase software reliability.

Among the items of interest are:

1) techniques to support development of formal specifications for software requirements to fulfill functional design requirements.

2) software languages which improve the ability for incremental software specification and development,

3) automated software engineering tools that verify the code and validate that it satisfies the functional and performance requirements,

4) fault tolerant techniques in which software errors do not result in overall loss of system safety,

5) models that can predict software reliability based on the nature of undetected software errors and their effects.

In evaluating possible transferrable technologies, keep in mind that there must be a balance between the amount of software testing and the calculated risk of failure. Proposed software development techniques should not have such a negative effect on productivity as to preclude their use. Also, the techniques should lend themselves to training programs for a wide array of potential users.

References

1) Bassen, H. et al, "Computerized Medical Devices: Trends, Problems, and Safety", *IEEE AES Magazine*, September 1986, pp. 20-24.

2) Joyce, Ed, "Software Bugs: A Matter of Life and Liability", *Datamation*, May 15, 1987, pp. 88-92.

3) Ward, W.T., "Using Quality Metrics for Critical Application Software", *Hewlett Packard Journal*, Vol. 37, March 1986, pp. 28-31.

4) Fries, R.C., "Establishing a Software Quality Assurance Program for Microprocessor-based Medical Equipment," *Medical Instrumentation*, Vol. 20(3), May 1986, pp. 156-161.

5) Conference on Regulation of Medical Software, sponsored by the Health Industry Manufacturers Association, October 20-21, 1988, Rockville, MD.

PROBLEM TITLE: MONOCLONAL ANTIBODIES FOR CANCER DIAGNOSIS

RTI Team Personnel: Daniel L. Winfield

Problem

It has long been known that certain patients with neoplasms exhibit abnormal levels of proteins and enzymes associated with the normal clot- dissolving mechanisms in the human body. Since 1981 several papers have been published that clearly show that certain cancer cells, particularly melanoma, secrete urokinase or tissue plasminogen activator. It has long been suspected that individual metastasizing cells must secrete urokinase or some other fibrin-dissolving enzymes in order to invade new (non- malignant) tissues. Until now there have not been any assays sensitive enough to distinguish urokinase from other types of enzymes, such as pro- urokinase, therefore, it has not been practical to screen patients' plasma, cells, or biopsied tissue to quantitatively measure secretion of enzymes by metastatic tumors. The use of specific antibodies to urokinase could be used by pathologists to identify those cells that are metastatic and actively invading tissue.

NASA Technology

Previous NASA flight experiments that separated human kidney cells into 33 different groups required the development of new monoclonal antibodies to different molecular forms of urokinase that are produced by these cells. Research sponsored by NASA at the Baylor College of Medicine has led to the development of a family of polyclonal antibodies that are reactive with only certain regions on the urokinase molecules. Selected monoclonal antibodies can now be developed and used to establish diagnostic tests for small numbers of human cells, tissue samples, and plasma from patients.

Principals

- Dennis Morrison, Ph.D., NASA-Johnson Space Center
- Dr. M. Z. Atassi, Baylor College of Medicine
- Dr. Tod Johnson, Cytology Technology, Inc.

Cost to NASA

Projected cost estimates are as follows:

	FY89	FY90	FY91
NASA TU	$60K	$100K	$98K
Industry	$20K	$30K	$45K
Academia	$12K	$10K	$10K
ACS	--	--	$50K

Status

A complete, three-phase project plan has been prepared, and Phase I is underway (See plan below). Existing polyclonal antibodies will be screened against very pure samples of the different molecular forms of urokinase. Specific clones that produce the best antibodies will be identified and cultured to large quantities to produce the best monoclonal antibodies (Phase I). These will be used to develop standard radioimmunoassay, enzyme-linked immunoassays, and fluorescent staining assays for accurately measuring plasma levels of specific forms of urokinase and to stain pathology tissue specimens of metastatic cells (Phase II). Once developed, these tests will be used to determine their value in diagnosis of metastatic potential of various types of cancer (Phase III).

This plan has been submitted to the American Cancer Society - Florida Division for possible cofunding. ACS response was very favorable, and they have requested that a formal proposal be submitted to ACS for funding.

PROBLEM TITLE: POWER MANAGEMENT IN THE ELECTROPLATING INDUSTRY

Source of Problem: Basic Industries Research Laboratory at Northwestern University
Date of Preparation: October 6, 1988
RTI Team Personnel: Stephen A. Lehrman

Problem

Recent changes in environmental regulations enacted by the U.S. Environmental Protection Agency (EPA) are forcing electroplaters to change their waste control procedures. New and improved methods are needed to minimize and recycle the chemical and metal waste produced by electroplating.

In current practice, toxic metals are removed from aqueous waste streams by precipitation with strong alkalies. This is adequate to meet water standards, but results in a mixed metal hydroxide sludge which must be sent to a hazardous waste landfill for disposal. The latest EPA regulations, which encourage waste minimization and recycling rather than disposal, require that metal containing wastes pass a leachability test before disposal. Most sludges will require stabilization with fly ash or Portland Cement in order to pass the leachability test. Some stabilized sludges will not pass a leachability test putting the hazardous waste generator (the plater) in jeopardy of violating provisions in the law limiting "storage" to 90 days. Even if stabilized sludges pass the leach test, the landfill might leak in the future leaving the waste generator liable for cleanup and damages. Furthermore, stabilization doubles the landfill cost.

Commercial technology is available that leads to solid waste minimization and recycling but it is more expensive than precipitation, and can only treat single metal waste streams rather than the mixed metal streams treated with precipitation technology. Small job shops, which comprise one-third of the industry, do not have the financial and technical resources to fully evaluate all alternatives or develop their own waste control technology. They have an especially poor track record at implementing new waste control technology due to their inadequacies cited above, and due to premature commercialization of equipment by the suppliers.

Most of the waste generated in an electroplating shop results from rinsing the parts after each unit operation. A part to be plated is cleaned in alkaline and acid solutions then electroplated as required. A final step on some objects is a chemical dip coating of chromate, phosphate or zincate which improves corrosion resistance and paintability. Rinsing is required after each step to remove all traces of process chemicals which could ruin the finish. In addition, rinsing decreases contamination of process baths which could limit their useful life. Other sources of waste are spills, leaks and process solution dumps. Spills and leaks can be minimized by proper attention to housekeeping. Most process

solutions are dumped very infrequently, and as such, contribute relatively little to the overall waste load.

The capital cost of waste control equipment is directly proportional to the volume of water that must be treated. Therefore, the recommended waste control strategy is to minimize the amount of water required for rinsing. This is accomplished through counter-flow rinsing. After each process step, parts are dipped in a drag-out tank followed by two or three counter- flow rinse tanks. Clean water is introduced into the final rinse tank and allowed to overflow to all the preceding tanks except the drag-out tank. Effluent from the first counter-flow rinse tank is sent to waste treatment. Each counter-flow rinse tank reduces the water required by a factor of 10- 20 versus a single running rinse tank. The drag-out tank has no influent or effluent except that which adheres to the parts on their way in and out of the tank. The drag-out tank is usually the ideal location for installing waste recovery equipment.

The overall strategy for a vast majority of electroplaters is to collect all alkaline and acid streams together so two streams flow into the waste treatment plant. Any cyanide in the alkaline stream is destroyed via chlorine oxidation. Hexavalent chromium in the acid stream is reduced to trivalent chromium with sodium bisulfite. This reduces chromium's toxicity and allows it to be precipitated with strong alkalies. The acid and alkaline streams are mixed following the cyanide destruction and chromium reduction steps. The pH is adjusted to 8.5-10 to precipitate the heavy metals. The solids are allowed to settle in a clarifier and are dewatered in a pressure leaf filter forming a filter cake that is approximately 30-40 percent solids. The filter cake, a mixture of metal hydroxides, is sent to a landfill for disposal. The filtrate and the clarifier over-flow are discharged through an end of pipe polishing filter. The latest regulations require that the sludge be stabilized with Portland Cement or fly ash to minimize the potential for metal leaching to the surrounding earth and water supplies.

A "typical" job shop really doesn't exist. Each has a specialty that differentiates it from competitors. Although non-cyanide alternatives exist, copper, cadmium, and zinc cyanides remain popular. Nickel and chromium are typically plated from acidic baths. Acid and alkaline tin plating baths are used routinely. There is a good deal of precious metal plating but the metal value is high enough to pay for extraordinary recovery techniques.

The average electroplating job shop has 40-50 employees and has sales amounting to $1 Million per year. The water treatment requirement is approximately 40,000 to 80,000 liters per day. Metal concentrations vary from 50 to 100 milligrams per liter per metal plated. Sodium cyanide concentration is typically in the range of 100 to 1000 milligrams per liter. The average shop disposes 40 to 80 cubic yards of sludge per year. The EPA regulations permit no more than 7 milligram per liter total heavy metal concentration and 1 milligram per liter total cyanide concentration in aqueous discharges.

The advantages of precipitation technology are that it has become familiar to the platers over the years and it can be used to treat all the metal wastes in the shop simultaneously. This simplifies maintenance and lowers costs due to economies of scale. The disadvantages of precipitation technology are that it produces a hazardous waste which has little or no economic value and that chlorine oxidation only destroys the "free" cyanide. Cyanide complexed with iron, nickel and cobalt is much more stable and not as susceptible to destruction. However, there is long term decomposition of this complex in the sludge, allowing the formation of leachable cyanide. The EPA is currently reviewing cyanide disposal rules. Equipment suppliers have noted the deficiencies of precipitation and developed alternatives.

Technology Specification

There are a number of commercial recycling and recovery technologies available which job shops can install to minimize the volume of waste. These include evaporation, reverse osmosis, electrodialysis, ion exchange and electrowinning. They are typically capable of treating only one plating rinse stream at a time and are normally installed on the drag-out tank to achieve maximum effectiveness.

Evaporators boil water from the rinse solution and reuse it for rinsing. The concentrated bottoms are returned to the process tank. Atmospheric evaporators allow the vaporized water to be carried away by exhausted air. No condensate is available for return to rinsing in this case. Evaporators of both types are especially effective for treating heated process baths. A good deal of water evaporates from the surface of the heated process bath and must be replenished. Evaporators are especially popular for hexavalent chromium plating.

Reverse osmosis uses high pressure to drive purified water through a semipermeable membrane. This separates the incoming rinse stream into a purified "permeate" stream and a concentrate stream. The "permeate" is returned to the rinse while the concentrate is added to the process bath. Feed solutions must be in a pH range of 2 to 11 or membrane life suffers. Heated process baths are most amenable to this system as discussed above for evaporator technology. Reverse osmosis has been used with most success on mildly acidic nickel plating baths.

An electrodialysis unit consists of a series of alternately-placed cation- permeable and anion-permeable membranes. Rinse solution is allowed to flow in the channels between the membranes. An electric field applied across the membrane stack promotes the migration of ions through the membranes. This forms two streams on alternate sides of each membrane -- one ion-rich, one ion-poor. The ion-rich stream is recycled to the process tank and the ion-poor stream is reused in the rinse.

Ion exchange resins selectively remove an ion from solution and replace it with an ion from the surface of the resin bead. If the metal cations are exchanged for hydrogen ions in a cation exchange column and the rinse solution anions are exchanged for hydroxyl ions, the resulting water is of high purity and can be recycled in the rinse, A major disadvantage

of ion exchange units is that the resin must be regenerated periodically resulting in considerable waste water. The complex operation has not been assimilated very well by job shops.

Metals in the rinse solution can be recovered by electrochemical deposition on a high surface area cathode -- a process known as electrowinning. The recovered metal is of high purity and can be recycled in the shop or sold to a reclaiming service. Most electroplating rinses are amenable to electrowinning with the exception of hexavalent chromium. Electrowinning is also not used on acid and alkaline cleaning rinses because the mixed metals generally do not deposit efficiently.

All these technologies have found applications in shops which plate a limited number of metals. However, they have not proven to be economical for multiple metal shops which must purchase at least one unit for each metal plated. The additional manpower necessary to run a variety of unit operations is also a barrier to the widespread introduction of these recovery technologies into job shops.

Recycling companies are being formed to accept waste and process it to a useful form. In general, their services greatly exceed the cost of disposal and stabilization.

Technology Needs

It is evident from the foregoing discussion that waste minimization and recycling technologies are needed for the electroplating industry to remain viable. Specific needs include:

1) A safe and convenient means of iron, nickel and cobalt cyanide destruction.

2) A method of recovering acid and alkali cleaning baths.

3) New techniques for capturing dilute metals in rinse streams. Possible techniques may be based on ion chromatography or on the charge to mass ratio of the ions.

4) Non-alkaline and non-acidic cleaners.

5) Economic uses for mixed metal hydroxide sludges.

6) Replacement for cyanide in electroplating and cleaning baths.

7) Better methods to interconvert hexavalent and trivalent chromium species in solution.

Participants

Dr. Richard Varjian, Basic Industries Research Laboratory at Northwestern University, supported by a consortium of electroplating companies, is developing an electroplating system test bed. One of the purposes of the test bed is to independently evaluate new and improved waste minimization and recycling technologies.

PROBLEM TITLE: RETINAL STABILIZATION FOR LASER SURGERY

Date of Preparation: October 1988
RTI Team Personnel: Daniel L. Winfield

Problem

In certain types of laser surgery on the retina of the eye, accurate positioning of the laser focus is very important. This may include cases where the surgeon must perform laser treatment in close proximity to the macula, the region of central vision. In such cases, it would be most desirable to fix the laser position to the retina position, thus eliminating errors that may result from eye movements. Thus far attempts to do this have been unsuccessful, and currently laser positioning is done via manual control.

Innovision, Inc. is developing an electro-optical system that acquires a video image of the retina and correlates it to a stored reference image. Thus only if an adequate correlation between the real-time image and reference image exists can the laser be fired. The current, developmental system uses digital correlation that, while less expensive, must use a binarized image which limits the accuracy of the system.

NASA Technology

The optical correlator, developed by NASA-Johnson Space Center and Texas Instruments, can be employed to perform an optical joint transform on a gray-scale image. The optical module will receive input from the Innovision-developed CCD imaging system, perform frame-to-base-frame correlation, and output to drive a servo tracking mirror, also developed by Innovision. Increased accuracy will be provided by operating on the full gray-scale image from the CCD.

Principals

- Richard Juday, Ph.D., NASA-Johnson Space Center
- Steven Charles, M.D., Innovision, Inc. and Center for Engineering Applications
- Jeff Sampsell. Ph.D., Texas Instruments, Inc.

Cost to NASA

Cost estimate for this 18 month project is $180,000. Dr. Charles has indicated the willingness of Innovision to co-fund the effort.

Status

RTI met with the project participants on September 12, 1988 to discuss the advantages of using the joint transform correlator. Existing hardware components were discussed. A TU project plan has been submitted, and project start is pending funding availability. The majority of the work will be contracted to TI to design and build the custom data-formatting front end, the frame-addressed DMD drive electronics, control electronics

and frame- addressed DMDs. These will be designed to work as integral part of existing Innovision image acquisition and servo control systems to take maximum advantage of the prior development.

PROBLEM TITLE: SAFE SYSTEM FOR REMOVING FOREIGN BODIES FROM THE EXTERNAL EAR CANAL

Date of Preparation: June 5, 1989
Source of Problem: Dr. Dorothy Shannon, Sinai Rehabilitation Center, Baltimore, Maryland
RTI Team Personnel: Daniel L. Winfield

Problem

Advances in medical instrumentation are needed to safely and quickly remove foreign bodies from the external ear canal.

The removal of foreign objects from the external ear canal is a dangerous and frustrating task for a physician. Foreign objects like vegetables (beans, peas, corn, rice), insects, plastic beads, earring parts, cotton, paper, and small 1.5 volt button sized batteries are accidentally inserted into the ear canal and are extremely difficult to remove. Eighty-eight percent of these cases are children under the age of six who insert the foreign object out of curiosity, during play, or to help relieve the irritation associated with a chronic ear infection. Unsuccessful traumatic attempts to extract the object can lead to significant damage to the ear canal, including possible perforation of the tympanic membrane and loss of hearing. Unsuccessful attempts to remove the object force it into a more inaccessible place and induce pain, edema and bleeding. Finally, the patient is referred to a Ear, Nose and Throat specialist (ENT), where general anesthesia and surgical techniques are sometimes used to extract the object. Approximately 1 percent of ENT referrals are due to problems with impacted foreign objects in the external ear canal and nose that require surgical removal.

State of the Art

Anatomy

The external ear canal runs from the external concha to the tympanic membrane (ear drum). This canal is very short in infants, but lengthens to 2.5 cm in adults. The external 1/3 of the canal is cartilaginous, where glands under the skin constantly make cerumen (ear wax), and the internal 2/3 of the canal is imbedded in the temporal bone. The ear canal is not straight, but is convoluted and varies in diameter. The most external opening is about the width of a pencil, and can accommodate objects up to 12.0 mm in diameter. The two most common places in the ear canal for a foreign object to become lodged are: 1) The cartilage/bone union. The cartilage is slightly compressible, so that an object is halted by the incompressible bony surroundings. 2) A bony constriction called the isthmus, about 5.0 mm from the tympanic membrane. If an object is forced beyond this point, it will fall very close to the tympanic membrane.

The entire canal is lined by skin similar to the rest of the body. The walls of the internal 2/3 of the ear canal are extremely sensitive to touch, where even slight stimulation is perceived as painful. The tympanic membrane is delicate and richly innervated by nerves sensitive to changes in pressure.

This membrane forms a tight seal separating the external ear canal from the middle ear cavity. This membrane must remain intact as the first step for the transduction of sound waves into the something that we "hear."

Although most foreign objects in the external ear canal are not a medical emergency, some objects can cause serious complications and should be removed as soon as possible. Innocuous vegetables caught in the ear invoke a severe inflammatory reaction, eventually plugging the meatus and causing temporary deafness in the affected ear. Button-sized batteries, such as those used in a hearing-aid or a calculator are very dangerous when lodged in the ear, because the ear is a conductive environment for an electrical burn. Studies have shown that permanent damage to the ear occurs within ten minutes of inserting the battery. In addition to a current burn, a deteriorating or punctured battery can leak electrolytes that permanently damage the ear canal, tympanic membrane, middle and internal ear cavities. Insects which inadvertently fly into the external ear canal are extremely painful and distressing to a patient, and considered a medical emergency. The physical trauma to the ear canal and tympanic membrane due to unsuccessful attempts to remove a foreign object causes the majority of damage in most cases.

Instrumentation

The most common instrument to use for the removal of irregularly shaped foreign objects is alligator forceps. This device functions similarly to a set of household scissors with a corrugated edge arranged like tweezers to grasp objects, but with blunt ends to prevent trauma to the ear canal. Due to the curves of the external ear canal, this device is hard to use for objects deeper than 1/3 the length of the canal. As with most instruments to follow, these forceps are unable to grasp smooth, round objects, such as a plastic bead or a small battery. Finally, this instrument is difficult to maneuver within the confines of the ear canal, and any stimulation of the walls of the ear canal with the instrument is extremely uncomfortable for the patient. Children are especially prone to move and inflict permanent damage when a metal instrument is in their ear.

To move an object to within the reach of the alligator forceps, the physician often irrigates the ear with warm water, hoping to create enough pressure behind the object to to push it externally within the range of the forceps. An object made of vegetable matter will swell with the addition of water or ear drops creating a tight seal between the foreign body and the ear canal, increasing the difficulty of removing the object. The physician must be very careful not to inject water directly upon the tympanic membrane because it will easily rupture. The tympanic membrane must be intact in order to use the irrigation technique, because unsterile water with the risks of infection will be introduced into the middle ear

cavity through a small perforation in the tympanic membrane. In addition, this pressure created against the tympanic membrane is very uncomfortable for the patient. Irrigation is a technique used very conservatively by physicians, due to the dangers involved.

Instruments such as a loop curette shaped as a scoop and a 90 degree wire curette are used to insert between the object and the ear canal, to pull the object externally. These curettes are very uncomfortable for the patient because there is pressure put on the ear canal walls. In addition, there is a significant risk of further damage when these devices slip and rupture the tympanic membrane.

For spherical objects, various suction devices have been used to pull the object out of the ear canal. There is a significant danger involved because a tight seal formed on the ear canal will cause a direct pressure change on the tympanic membrane, and force it to rupture. Many suction devices are inadequate because the tip of the device does not form a tight seal against the foreign object, therefore not enough suction force is maintained to grasp and extract impacted objects. Current suction devices used in ENT offices have a maximum pressure differential of 26 inches of mercury. Flexible magnets have been used with success to grasp and extract metal objects with virtually no risks to the patient. Physicians even use straightened paper clips with a small drop of a cyanoacrylate polymer ("super glue") to stick to the foreign body and pull it out of the ear canal. This method is extremely risky for the patient because risk of accidentally sticking this dangerous probe elsewhere in the ear canal is extremely high, necessitating emergency surgical removal.

Finally, when the risk for further damage to the patient has been judged to be too high to risk current methods of extraction, a general anesthetic is used. The ear canal is surgically exposed through the temporal bone behind the external ear, and the object is extracted.

Technology Constraints and Specifications

The delicate removal of foreign objects from the external ear canal requires technology that can limit any additional trauma that may be inflicted upon the patient. Ear, nose and throat specialists, general practitioners, and pediatricians all have a need for this technology, so that the cost should be kept to a minimum to insure widespread use. Possible solutions include but are not limited to the areas of mechanical devices, improvements in suction design, or novel applications of polymers. The possible solutions to this problem are widespread, but with any solution the following guidelines should be kept in mind. Since patients tend to move frequently when the external ear is being examined, the device should be quick to insert and remove. To minimize any risks while a device is in the ear, it should be flexible, have a smooth surface, not adhere to the walls of the ear canal, and made of non-irritative material. The device should be "agile" enough to remove small objects, but have strong enough grip to forcefully pull an impacted object out of the ear canal.

PROBLEM TITLE: SCANNING LIDAR FOR TOPOGRAPHIC MAPPING

Problem Originator: Goddard Space Flight Center
Date of Preparation: September, 1989
RTI Team Personnel: Stephen A. Lehrman

Problem

There is a need to demonstrate and develop a commercial scanning lidar system for precise topographic mapping.

Topographic mapping of large areas is currently performed using airborne photogrammetric systems. The principal manufacturers are Carl Zeiss and Wild Leitz. A minimum of three vertical and two horizontal ground control points are required. The information from the aerial photographs is input to a stereo plotter to produce three-dimensional topographic maps.

Photogrammetric systems work best during the spring and fall when tree foliage coverage is minimal. They may also be affected by cloud cover. Accuracy of the topographic map is determined by the altitude of the airplane. For example, an accuracy of 3 inches can be attained at an aircraft altitude of 1,800 ft.

Many companies are using Global Positioning System (GPS) for kinematic positioning. The principal companies selling GPS for this use are Trimble Navigation, Ashtech Inc., and Magnavox Corporation. Also, digital mapping using GIS (Global Information System) or LIS (Land Information System) is becoming more prevalent.

NASA Technology

Goddard Space Flight Center (GSFC) has developed a research lidar instrument, the Airborne Oceanographic Lidar (AOL), which is capable of making precise range measurements from an aircraft. Using differential GPS, the aircraft position can be determined very accurately (e.g., to 10 cm) thus allowing the development of precise topographic mapping. Since the laser does not measure altitude directly, but rather a range to the surface in whichever direction the instrument is pointing, aircraft pitch and roll data from the aircraft inertial navigation system must be used to correct each measurement.

As noted above, a major problem in performing topographic mapping is tree foliage that obscures the ground. The AOL sends a pulse that is transmitted to the forest canopy. Part of the energy is reflected, producing a "surface" return. Another part of the energy penetrates to the forest floor, frequently reflecting a "bottom" return. The sum of the "surface" (i.e., canopy) and the "depth" (i.e., tree height) yields a slant range measurement from the aircraft to the ground. In this way, the AOL can produce topographic maps of forested areas.

Participants

The Federal Emergency Management Agency, the National Park Service, and the North Carolina State Division of Coastal Management have agreed to cofund a demonstration of the AOL for topographic mapping on the Outer Banks of North Carolina from approximately the U.S. Army Corps of Engineers' Field Research Facility to Cape Hatteras.

References

1. Krabill, W.B. et al., Airborne Laser Topographic Mapping Results, Photogrammetric Engineering and Remote Sensing, Vol. 50, No. 6, June 1984, pp. 685-694.

2. Krabill, W.B., and C.F. Martin, Aircraft Positioning Using Global Positioning System Carrier Phase Data, Navigation: Journal of the Institute of Navigation, Vol. 34, No. 1, Spring 1987.

PROBLEM TITLE: SCRATCH RESISTANT COATINGS FOR PLASTIC OPHTHALMIC EYEGLASS LENSES

Problem Originator: Air Products Inc.
Date of Preparation: September 15, 1989
RTI Team Personnel: Stephen A. Lehrman

Problem

Scratch-resistant coatings for plastic ophthalmic eyeglass lenses are degraded by ultraviolet (UV) light and, generally, after 12 months, no longer provide scratch resistance. A new, long-lasting, coating material or process is required.

Each year, 60 million pairs of prescription eyeglasses are sold for a retail value of $450 million. Seventy percent of these lenses are plastic with allyl diglycol carbonate (CR-39) accounting for 65 percent of the total lens market. The use of polycarbonate for lens material is increasing but is still only 3 to 5 percent of the total market.

Originally, CR-39 was developed for plastic lenses because of its good scratch resistance, chemical resistance, and optical clarity. The scratch resistance of CR-39 is improved with the application of a suitable coating. Polycarbonate's scratch and solvent resistance is very low, thus it is essentially useless without proper coatings.

There are generally three types of commercially available scratch-resistant coatings:

- Organic coatings
- Organo-silane or organo-siloxane coatings
- Inorganic coatings of quartz or glass.

Polysiloxane is the leading scratch-resistant coating. Polysiloxane is usually applied by a spray or dip process. However, polysiloxane is degraded by UV light and, generally, after 12 months no longer provides scratch resistance.

The major U.S. eyeglass lens manufacturers are:

	Lens Sales ($M/yr)
Coburn (SOLA), CA	>80
Silor, NY	>100
American Optical, MA	>75
Signet Armorlite, CA	40
Younger Optics, CA	10

Coburn is British-owned and Silor is French-owned. The lens supplier is the principal focus for scratch-resistant coatings. More that 50 percent of all lenses are coated at the factory.

Air Products is a $2.4 billion company with 13,000 employees in 180 plants worldwide. Their R&D budget was $75 million in 1988. Air Products already has a program in diamond-like carbon (DLC) and diamond coatings. Their focus is to develop coated products for electronic and optical applications from DLC and polycrystalline diamond. Air Products' plan is to form a joint venture or strategic alliance with a lens manufacturer. They estimate the market for DLC scratch resistant plastic lens at $200 to $250 million per year (45 to 50 million lens pairs, each coated at $2.50 per lens).

Technical Constraints and Specifications

Masso [1] specifies eight requirements for scratch-resistant coatings for plastic ophthalmic eyeglass lenses:

1. The coated lens must meet applicable government regulations.
2. The coating must not reduce or impair the primary optical function of the lens. The coating must be optical clear.
3. A scratch-resistant coating must significantly improve the scratch resistance over that of an uncoated lens in actual use.
4. The coating must be durable and free from catastrophic failure in use. Therefore, the coating must have good adhesion and impact resistance.
5. The coating must be resistant to household chemicals and solvents.
6. The scratch resistance of the coating must not be transient.
7. The coated lens should meet acceptable cosmetic standards.
8. The coated lens should be compatible with existing prescription processing systems for edging, dyeing, etc.

NASA Technology

NASA Lewis Research Center Electro-Physics Office is a world leader in depositing DLC coatings on silicon and plastic substrates. Air Products already has an exclusive license from NASA LeRC for Dual Ion Beam Technology for DLC coatings. They are already in the process of using this technology to develop scratch-resistant sunglass lenses which they expect to bring to market in 12 months. Air Products would like to continue working with LeRC because the expertise of the Electro-Physics Office can significantly reduce Air Products' development time for scratch-resistant DLC coatings for ophthalmic eyeglass lenses. The critical technical problem is how thick a DLC coating can be made (0.5 micron) and still remain optically clear. Air Products is looking for technical assistance from LeRC for this problem. For sunglasses, optical clarity is not necessary. However, for eyeglasses, it is essential.

Cost to NASA

The cost to NASA is estimated to be $70 to 80 K for fiscal year 1990. This money will be used by LeRC for equipment and for contractor support. Air Products has agreed to cofund the project equally under the terms of a Space Act Agreement.

Participants

- Jack Galdieri, Air Products
- Phil Winkler, Air Products
- Bruce Banks, LeRC Electro-Physics Office
- Mike Mirtich, LeRC Electro-Physics Office

References

1. Masso, Jon D., Evaluation of Coating for Plastic Ophthalmic Lenses, Ophthalmic Optics, Proceedings of SPIE, Volume 601, Karl Guenther, Ed., SPIE, Bellingham, WA, 1986.

2. Guenther, K. H., Thin Film Coating Technology for Ophthalmic Lenses, Ophthalmic Optics, Proceedings of SPIE, Volume 601, Karl Guenther, Ed., SPIE, Bellingham, WA, 1986.

PROBLEM TITLE: SUN PHOTOMETER

Date of Preparation: June 1989
RTI Team Personnel: John G. Cleland

Problem

A solar photometer that is commercially available in the United States is required. Important criteria are low cost, ruggedness and reliability, and ease of maintenance. Sun photometers have been used for many years to measure the optical properties of the atmosphere. Photometry is the calculation and measurement of the quantities describing light, such as luminous intensity, luminous flux, luminous flux density, light distribution, color, absorption factor, spectral distribution, and the reflectance and transmittance of light. The basic design of a sun photometer is simple, with a small aperture (typically 2° or less), a sighting capability, a set of spectral filters, a photo diode, and some peak holding circuitry to compensate for slight misalignments. Outputs are typically analyzed through a microcomputer; for example, using Beer's laws, calculations of the optical thickness of the atmosphere can be done in a straightforward manner. Other approaches with different lenses, application of such principles as thermoelectrics, and use of bandpass filters, may be incorporated in photometer designs.

As the Earth-orbiting satellite (EOS) system era begins, with the capability to atmospherically correct visible and near infrared satellite data, sun photometers will provide ground-truth to verify the results. Sun photometer monitoring has also been important in assessing biomass production models developed for semi-arid areas. A NASA-supported satellite, aircraft, and surface field campaign is planned for the summer of 1990 in the Amazon basin to monitor aerosol production and transport and associated greenhouse gas production from deforestation by burning. The EPA and NOAA have a number of programs for atmospheric assessment that require reliable sun photometers. Particulate (dust), water vapor, and ozone measurement are particularly important, and, in some cases, trace gases in the atmosphere may be assessed using phometers. Little data currently exist on the variability of the optical thickness of the atmosphere over time and space. It has been estimated that anywhere from dozens to hundreds of optimized sun photometers could be marketed each year.

State-of-the-Art

There are no American companies making sun photometers. At least three foreign companies market them, including EKO in Japan, Noll in Germany, and Sonnotek in Canada. Sun photometers have a history of requiring repair and adjustment despite their simple construction. Commercial instruments requiring repair and adjustment must be returned to the factory, significant expense and paper work, and usually unacceptable downtime. In many cases, customized units are developed by users. NOAA has built some its own units and the University of Miami has provided units for its studies and some

NASA experiments. Costs of sun photometers typically exceed $5,000 per instrument and may be much higher, e.g., the French have built a sun photometer that meets most of the criteria for current use but costs $60,000.

Reliability is often a problem because filter wheels often break, temperature sensitivity of the instrument is often hard to calibrate, and filters may drift due to water vapor and sunlight effects on the optical thickness of the filters. One option under consideration for sun photometers is to use defraction gratings instead of filters. A literature survey showed that Langley Research Center and Goddard Space Flight Center are working with sun photometers.[1] A new sun photometer (FISBAT) was described in 1984 by the Italians.[2] Matsumoto et. al. recently described a new sun photometer system and patent application.[3]

Technology Constraints and Specifications

The World Meteorological Organization (WMO) has set some general specifications for photometers that may be obtained from them or from NASA. Primary constraints for an improved sun photometer are lowered cost and higher reliability (greater than one year between failures). Target cost is $3,000 per instrument. An improved sun photometer should incorporate:

- Portability,
- Long battery life, preferably up to one year,
- Ruggedness,
- A self-contained case,
- At least six channels,
- Peak holding,
- Sample holding,
- Compatibility with Langley and Sphere Calibration Method and measurement capability for: aerosol optical thickness, sky radiance, ground radiance, solar aureole, and almucantar (parallel of attitude) observation.

Instruments should have at least 10-bit accuracy, read out directly in radiometric units, be operable by untrained personnel, be shippable by commercial carriers to anywhere in the world, and be operable from 0°C to 50°C. It would be desirable to make at least 20 instruments based on an initial prototype. It is anticipated that instruments would sell typically in groups of 50-60. The primary users for these instruments will be federal agencies and possibly universities.

Status

The RTI Applications Team has completed a preliminary literature survey of both Engineering Index and NTIS. Very little has been published in the last 3 years on new designs of sun photometers. This problem was brought to our attention originally by Don Vargo, who

had spoken with Brent Holben at GSFC in June of 1989. The RTI Team has discussed current requirements with Mr. Holvin at GSFC and with Mr. Don Freidman, Technology Utilization Officer at GSFC. The Team spoke to John Delowesee at NOAA at Boulder, CO and with Pat Reddy at the same facility. On their recommendation, we also talked with John Hickey at Eppley Labs to get a preliminary assessment of potential commercial interest in a sun photometer. Response has been encouraging to date. With Mr. Reddy's help, the Team has compiled a list of other companies potentially interested in manufacturing and marketing an improved sun photometer. These include Photo Research/Optronic Laboratories, Inc., Orlando, FL; Southwestern Engineering and Equipment Company, Albuquerque, NM; Li-Cor, Lincoln, NE; Photo Research Spectra-Metrics, Burbank, CA; and International Light, Inc., Newburyport, MA. Materials provided by Mr. Holben, especially those related to a proposal to NASA Headquarters for support of the trans-Amazon Optical Properties Experiment, have been reviewed by the RTI Team. Don Vargo has indicated that he will be in touch with the Department of Agriculture to assess their interest.

Cost to NASA

An estimate to produce 20 units, including an optimized prototype for a project duration of 2 to 3 years is between $60,000 and $100,000. It is believed that cost sharing, at least in kind, will be available for interested vendors. Included in this level of support would be participation by NASA engineers and scientists with vested interest in an improved sun photometer.

Action

The RTI Team will have this problem statement reviewed by NASA participants, especially GSFC Technology Utilization Office, and technical experts. The Team will obtain specification on design, fabrication, and techniques for lowering costs and assuring reliability from NASA engineers. Information will be sent from NASA Center(s) to interested companies for review. The Team will check with GSFC and other NASA Centers to assess supporting expertise. The Team will next talk with the GSFC TU Office and with W.H. Jones or other project engineers at GSFC associated with design of sun photometers.

PROBLEM TITLE: WHEELCHAIR PRESSURE RELIEF SYSTEM

Source of Problem: Reading Rehabilitation Hospital
Date of Preparation: March 9, 1989
RTI Team Personnel: Daniel L. Winfield

Problem

A dynamic mechanical system is needed to periodically relieve pressure between the wheelchair seat and the soft tissues of a quadriplegic or other severely physically disabled person. Approximately 6 million people in the United States are severely physically disabled and require specialized seating systems. Pressure relief is crucial for the prevention of decubitus ulcers, commonly known as pressure sores. The incidence of pressure sores is 80 percent among spinal cord injured persons, and many have repeated incidence of pressure sores. The entire population of spinal cord injured patients, estimated at 280,000, can benefit from specialized seating intervention. In addition, an estimated 1 million elderly experience at least one pressure sore. Costs for the resolution of a single severe pressure sore have been estimated to range from $8,000 to $30,000.

Passive seating systems, such as foam and foam-in-plore cushions, have been only partly successful in reducing pressure sore occurrence. For those individuals at increased risk, there is a need for some type of dynamic system that can vary the pressure at the tissue-seat interface so that any given location can experience a reduced pressure for a period of time sufficient to promote blood circulation and prevent soft tissue breakdown.

NASA Technology

Two responses to this problem statement have been received. Each proposes a different approach to powering a cellular seat cushion with variable pressure cells. Engineers at NASA-Lewis propose to use a small battery- powered air pump to inflate individual cells. Electromechanical valves have been identified to inflate/deflate either a single cell or a series of cells. Engineers at NASA-Johnson proposed a similar system but using the mechanical power available during wheelchair movement. Both of these approaches are under review by staff at the Reading Rehabilitation Hospital.

In addition, the concept of a "cold engine," developed by Otto Fedor at KSC, to power the variable pressure cushion is under consideration. Kinetic Concepts, Inc., has expressed interest and is evaluating this approach.

6.0 COORDINATION OF ONGOING PROJECTS

AUTOMATED INFRARED SPECTROSCOPY

RTI Team Personnel: Daniel L. Winfield

Problem

Infrared analysis in the clinical environment is fast becoming a means of more quickly and accurately determining the concentrations of parameters in solutions, body tissues, and whole cells. The analysis of these spectra is completely automated so that one parameter varying in concentration can be quantified quickly and accurately. Unfortunately, when analyzing solutions with more than one parameter in question, their characteristic wavelength "signatures" can interfere in an unpredictable manner, and the automated analysis system breaks down. A method to improve the multiple linear regression technique of infrared analysis is needed to compensate for these unpredictable interferences.

Robert Berger has shown Near Infrared Analysis (NIRA) multiple linear regression techniques that give a 99 percent correlation to analytical techniques in the ADP, ATP, and phosphate concentration range of 5 to 100 micromole. Unfortunately, when more than one compound in question is present in solution, various unpredictable interferences appear, and the automated analysis system breaks down. Suggested solutions include a neural net analysis system that will serve as the mathematical technique for performing the spectral analysis.

NASA Technology

NASA JSC has proposed the use of neural network techniques for pattern recognition of the NIRA spectral data. While neural networks require specialized computers to develop the algorithms, they can be implemented on PC-AT equivalent computers.

Principals

- Robert Savely, NASA Johnson Space Center
- Robert Berger, Ph.D., National Heart, Lung and Blood Institute
- Isaac Landau, LT Industries

Status

Sample data have been supplied to JSC to explore the possibility that the neural net analysis system that they have set up may be an ideal mathematical technique for performing the spectral analysis. Preliminary success has been attained at higher concentrations of the subject materials. However, funding has not been available to support a sufficient effort to fully develop this capability.

Action

Many other applications of this technology have been pinpointed, so that this artificial intelligence technology can also be applied to the areas of blood, urine, and fecal analysis. Robert Berger will explore the possibility of obtaining National Institutes of Health funds, and RTI will explore commercial interest and possible funding. Also, NASA-Ames is investigating NIRA for space life sciences research purposes, and RTI has made them aware of the JSC capabilities.

AUTOMOBILE EMERGENCY VEHICLE ALERT SYSTEM

RTI Team Personnel: Daniel L. Winfield, John G. Cleland

Problem

The Gallaudet Research Institute found through recent focus group discussions that hearing-impaired people want to be alerted to approaching emergency vehicles (e.g., fire, police, and emergency medical services) while driving. The problem of not being able to hear the siren of an oncoming vehicle is not unique to the hearing impaired. Most drivers become functionally hearing impaired when driving with their windows rolled up, air conditioner on, and/or radio playing. In addition, the emergency vehicle drivers themselves sometimes find that their own sirens mask the sirens of other responding vehicles.

The true scope of the hazard has not been measured, but emergency service officials do recognize the problem. The National Highway Safety Administration estimates that in 1986 between 16,000 and 31,400 emergency vehicles were involved in accidents, resulting in 135 recorded deaths. Also, drivers who do not pull aside can delay an ambulance or fire engine, possibly resulting in tragedy for those in need of emergency services.

Only one sound-detection device is known to be commercially available, and informal tests indicated that it could not adequately discriminate between road bumps and more powerful sirens. Another system based on acoustic recognition is currently being developed in Japan, where deaf persons are denied drivers' licenses. The developers report that the device gave 20 false alarms in 46 minutes of road testing, an error rate that would be unacceptable to American drivers.

It has been proposed, therefore, that a satisfactory alerting system must have the following attributes: high reliability, that is false negative and false positive responses would not be tolerated; low cost, for both automobile drivers and emergency service providers; automatic, or passive, operation for the drivers of both vehicles; and optimal information, that is, the alerting signal provides enough information to be useful, but not so much as to confuse the driver.

NASA Technology

There are at least two technical approaches to consider for transmitting and receiving the signal: detection of an acoustical signature, and radiofrequency transmission. A system based on recognizing the acoustical signature of the siren is appealing because only the passenger vehicle would have to be equipped with a device. However, the technical challenges include the diversity of sirens in use, the difficulty of detecting a siren in competing noise from traffic and wind, and the design of a low-cost microphone or other receiving device that could withstand the elements and still perform reliably.

An alternative to acoustical detection of sirens is the direct transmission of a radiofrequency signal from the emergency vehicle to the citizen's vehicle and to other emergency vehicles. A coded signal, which might contain such information as range, direction, and speed of the emergency vehicle, could be used to activate a display in the receiving vehicle. The major disadvantage of radio transmission is that it requires both vehicles to be equipped with new or modified devices, an approach that has significant policy and cost implications.

NASA technology has been identified at two field centers for the possible solutions described above: acoustical recognition at LaRC and radio- frequency transmission at MSFC. At this time, there is not enough evidence to support one technical approach over the other. The plan proposed involves a parallel engineering effort until each technology is sufficiently developed so that prototype alerting systems can be evaluated.

Because the radiofrequency system proposed by MSFC involves more off-the- shelf hardware and less development effort, it will most likely be available for testing sooner than the system based on acoustical recognition. The testing of the radio transmis sion system at an early time will be invaluable for providing information on (1) the best way to alert the vehicle driver, (2) how much information is needed, and (3) the location and type of display that should be used. In addition, an early demonstration of an emergency vehicle alerting system will help increase public awareness of the problem and gain support from public agencies and providers of emergency services. The system using detection of an acoustical signature (LaRC) will take longer and possibly be more expensive to develop, but may ultimately be the more practical, cost-effective solution.

Principals

- Dr. Judith E. Harkins, Gallaudet Research Institute
- Dr. Carl J. Jensema, Gallaudet Research Institute
- Mr. Harlan K. Holmes, LaRC
- Mr. James R. Currie, MSFC

Status

The Technology Applications Team at RTI arranged meetings at three NASA field centers (LaRC, MSFC, and GSFC) for the Gallaudet project staff to meet with NASA engineers, discuss the problem, and propose technical approaches for a solution. Two project plans have been submitted to NASA- HQ incorporating the technologies suggested by LaRC and MSFC. MSFC has begun to purchase some of the hardware needed for prototype development. GSFC will consult on technical aspects of the project as needed. Three teleconferences have been held by the principals in the MSFC project.

Action

RTI and Gallaudet have been involved in identifying cofunding sources and contacting potential manufacturers of the alerting system. Gallaudet will continue addressing the policy side of the problem by contacting organizations such as the Department of Transportation, the Department of Commerce, the Federal Communications Commission, and various automobile manufacturers and related associations. RTI will re-contact LARC to finalize a project plan intended for possible funding in FY91.

BLADDER VOLUME SENSING

RTI Team Personnel: Daniel L. Winfield

Problem

Loss of the sensation of bladder fullness is a common clinical problem and is often seen in patients suffering from spinal cord injury, stroke, and diabetes mellitus. This problem is often associated with urinary incontinence and can be a very limiting and sometimes embarrassing malady. Clinically, retention can result in urine reflux into the kidneys causing infection, a leading cause of death in patients with spinal cord injury. In addition, toilet training of many of the severely retarded is never realized because there is no useful means of helping them to associate bladder fullness with the appropriate behaviors.

The development of a compact, easy-to-use, bladder fullness sensing device would greatly benefit both populations. Such a device would work throughout the day and would operate by warning the user when the bladder reaches some preset volume threshold. The device would give the patient the security needed to carry on normal daily activities and, in the case of the retarded client, would provide the paired stimulus necessary to implement a toilet training procedure.

NASA Technology

A device proposed by the LaRC would incorporate state-of-the-art technologies in ultrasonic transducers and signal processing.

Principals

- Dr. Albert Cavalier, Association for Retarded Citizens, Arlington, TX
- Dr. Joseph Heyman, LaRC, Hampton, VA
- Dr. Frederich Klein, University of Tennessee, Knoxville, TN
- John Companion, LaRC, Hampton, VA

Cost to NASA

	FY85	FY86	FY87	FY88
NASA	$ 22,300	$105,000	$ 55,000	--
NIDRR	$102,000	$118,700	$101,700	$50,000

Commercialization Strategy

An agreement has been completed between the Association for Retarded Citizens (ARC) and NASA, giving the Association licensing rights for medical applications. At a January 13, 1989, meeting at RTI, ARC, NASA, RTI, and Johnson & Johnson discussed commercialization of the device. A subsequent meeting was held at Johnson & Johnson Patient Care in New Brunswick, NJ at which the device was demonstrated and the necessary

technical steps for a preproduction prototype were discussed. Unfortunately, J&J has decided not to pursue this project because it does not fit well with their current product lines which are primarily soft goods rather than electronic instruments. Subsequently, ARC has solicited interest from four additional companies and is currently evaluating options to pursue commercialization. A patent was issued on August 1, 1989 covering this invention.

Status

Equipment was completed and Phase 0 studies begun at the Medical College of Virginia in June 1986. Initial results indicate greater variability, particularly among women, than expected. A revised design was completed and further Phase 0 tests conducted from September to December 1986.

The design was fixed and field tests conducted on NASA-LaRC employee volunteers as well as Association for Retarded Citizens volunteers. Results have proven the validity of the measurement technique and correlation to bladder fullness, but they have also revealed transducer fragility and unacceptable power consumption. Battery life has been extended and further work completed to make the transducer more durable. A second unit was delivered to the University of Tennessee in October 1987, and tests there have reiterated the difficulty of obtaining reliable signals from women due to the position of the bladder. Further work on transducer positioning and depth of field have eliminated many of these problems in locating the bladder reliably. A report has been prepared by ARC staff documenting the test results with the device.

CLOSED-CIRCUIT TELEVISION IN CORRECTIONAL FACILITIES

RTI Team Personnel: John G. Cleland

Problem

The use of closed-circuit television (CCTV) has become widespread in jails and prisons during the past two decades and represents perhaps the greatest infusion of technology into correctional institutions.

In general, CCTV systems have proven to be a cost-effective tool for monitoring fence lines, rooftops, perimeter blindspots, and pedestrian and vehicle sally ports. Most correctional administrators are quick to point out, however, that CCTV supplements staff; it does not replace staff.

CCTV systems provide one of the primary means of visually assessing the cause of an alarm raised by an intrusion detection system. Accurate and rapid assessment of a remote system alarm by CCTV (or by observation tower staff) is essential so that relevant information (attempted escape in progress or false alarm) can be communicated to appropriate facility staff (e.g., mobile perimeter patrols or maintenance staff).

The increased use of CCTV has resulted in the addition of many monitoring screens in institution control rooms, sometimes as many as 15 to 20 screens. Frequently, the staff person responsible for monitoring the screens has additional responsibilities because the control room or center also serves as the communications center of the facility.

Major questions include:

- How many screens can one person monitor effectively and for how long?
- What is the best display technique for rapidly assessing and communicating information over the CCTV network?
- What NASA modifications of current technology or new technology can provide more cost-effective tools for such monitoring?
- Is there NASA technology that might address this problem, such as NASA experience in remote sensing, multiplexing communications, and heads- up displays? NASA technology might be applied to devise a hand-held or otherwise portable monitor or to provide special displays to select, highlight, track, or focus on particular activities displayed. Results of NASA physiological testing of both flight and scientific personnel who must monitor a number of displays for launch or on-orbit activities could be useful.

Principals

- James E. Murphy, College Park, MD
- Charlotte A. Nesbitt, American Correctional Association
- Tony Travisono, Executive Director, American Correctional Association

- Susan M. Hunter, National Institute of Corrections
- Ray L. Gilbert, Office of Commercial Programs, NASA Headquarters

Cost to NASA

Undetermined.

Status

The RTI Applications Team has surveyed NASA technology that might be applicable to the problem. A problem statement has been distributed. The NASA Standard 3000 Database related to ergonomics is being recommended to the Department of Corrections. This database, created by the Manned Systems Integration Working Group of the Manned Systems Division at NASA JSC, will be obtained by the Team. The database is written on RBase 5000 and updated on diskettes [contact Cletis Booher (713) 483-3696]. The team has also located NASA LaRC research on "Assessment of Computer Interface Device for Voice Control of Remote TV Cameras," Anthony M. Basquets, which is being evaluated.

COMMERCIAL APPLICATIONS FOR DIAMOND-LIKE CARBON AND DIAMOND FILM

RTI Team Personnel: Stephen A. Lehrman

Problem

Diamond-like carbon (DLC) and diamond film technology promises to have dramatic terrestrial commercial applications. Japan and the Soviet Union have pioneered the technology. Within the past four years, there has been national emphasis on the United States catching up in this area.

NASA Technology

The LeRC Electro-Physics Office is the only group within NASA performing DLC and diamond film deposition. They have written more than 25 papers on this subject since 1984. Because of the wide dissemination of these papers, 24 companies contacted the Electro-Physics Office in CY87 regarding commercial applications of the technology.

A feasibility study is necessary for the Electro-Physics Office to properly evaluate, rank, recommend and plan the commercial applications of this technology. The focus of the study will be to identify the best commercial applications for DLC and diamond films in electronics, optics, wear resistant films, thermal packaging, and audio equipment. A final report describing a plan for developing these commercial applications will be prepared.

Principals

- Dr. Donald A. Jaworske and Mrs. Marla Perez-Davis, LeRC

Status

A questionnaire survey has been completed with more than 30 responses. A unique application for NASA DLC film technology has been identified. This application involves using DLC film as a scratch-resistant coating on prescription eyeglasses. The optical properties of DLC look very good for this application.

On August 22, Air Products met with NASA and RTI at Lewis Research Center. The purpose of the meeting was to discuss whether NASA could assist Air Products in characterizing DLC films on ophthalmic eyeglass lenses. It was agreed to proceed with an Applications Engineering Project on scratch- resistant, diamondlike carbon coatings for ophthalmic lenses.

DEVELOPMENT OF AN EMISSION SCRUBBER AND A STATE-OF-THE-ART INCINERATOR

RTI Team Personnel: John G. Cleland

Problem

Incinerators have been used for solid waste disposal for many years. When state and local air control requirements were changed to meet more stringent guidelines, incinerator manufacturers replaced the conventional single-chamber incinerators with a more efficient two-stage combustion system. A primary concern at present is the burning of pathological infectious red bag waste from hospitals and other medical facilities. The emission controls on this type of waste disposal are especially stringent due to the possibility of emitting infectious gases during burning. A two or three second gas residence time in the secondary chamber and a redesign of the incinerator are required to meet the strict emission controls imposed upon industrial disposal of red bag waste.

Incinerators have long been used for solid waste disposal. These disposal systems are used by hospitals, schools, community centers, and other city, state and local organizations.

There are five types of waste that are burned in these incinerators:

		HEAT CONTENT BTU/LB
Type 0	- Pathological Infectious Red Bag Waste	8500
Type I	- Rubbish	6500
Type II	- Refuse	4300
Type III	- Garbage	2500
Type IV	- Animal Solids	1000

The old design incinerators consisted of a single chamber where the waste was loaded and burned. A fossil fuel burner and regulated combustion air were provided to burn the waste. This system did not always result in complete combustion of the waste. In many cases, due to overloading of the incinerator or when the type of waste was different from the primary design requirements, incomplete combustion occurred and black smoke was observed from the stack.

With the number of more stringent and local air control requirements, the incinerator manufacturers redesigned their equipment using a two-stage combustion system. The design is shown in Figure 1, resulted in a more reliable and adjustable combustion control. The controlled air supply to both the primary and secondary chambers ensured complete waste combustion over a wide range of waste types and burning rate requirements.

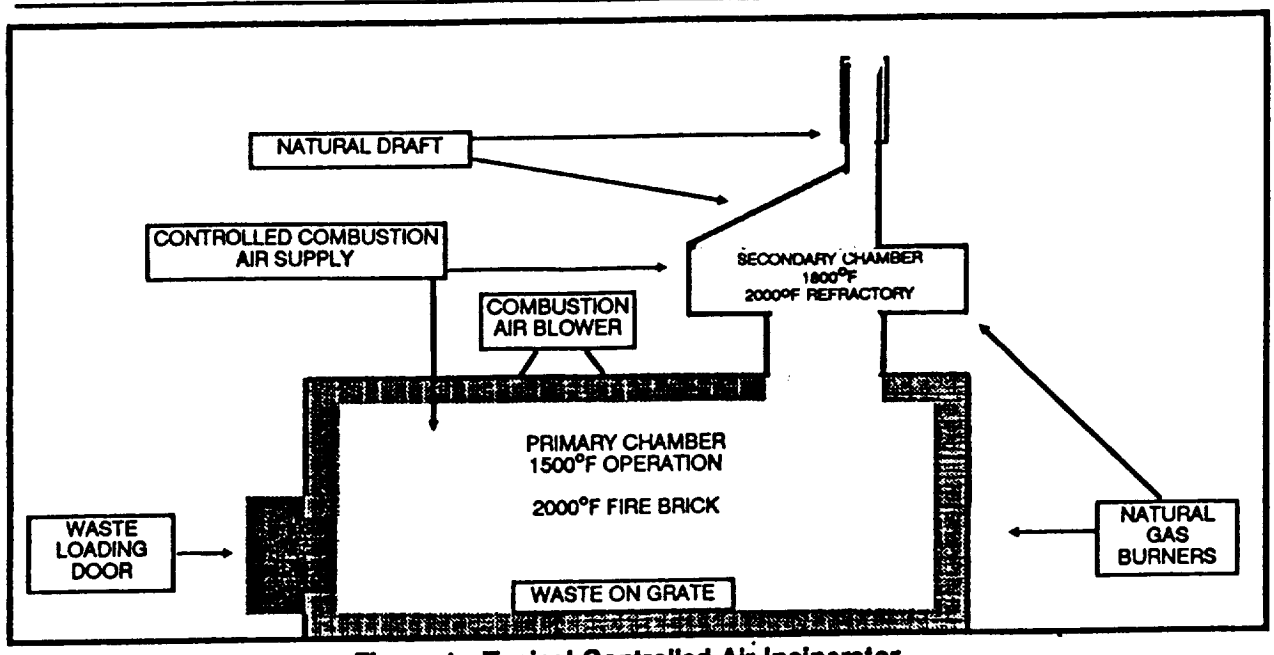


Figure 1: Typical Controlled Air Incinerator

Although the development of the new incinerators has helped to meet the air control requirements in most applications, the current technology is inadequate for disposing of pathological infectious red bag waste.

Technology Specification

The current air control regulations in most states require a gas residence time of a minimum of one second in the secondary chamber and ash and particulate limits from the stack emissions. These requirements caused resizing of the secondary chamber and stack internal diameter. Additionally, a material and energy balance for each application is required to meet specific waste requirements. The primary concern at present is the burning of the pathological infectious red bag waste from hospitals and other medical facilities. Not only is the waste to be completely burned, but there is concern of emitting infectious gases. This would require two or three seconds gas residence time in the secondary chamber and a redesign of the incinerator.

Currently, New York, Texas, Florida, and some cities in other states, require limiting the hydrochloric acid (HCl) emission to a maximum of four pounds per hour and sulfur dioxide (SO_2) to other limits. In order to meet these requirements, the incinerator manufacturer must install an air scrubber downstream from the secondary chamber.

The air scrubbers that are used by refineries, power plants, and large waste disposal plants are a wet type system. The gases are washed with chemical solutions and the HCl and SO_2 are removed from the emission gases. This system requires a water supply, an underground holding tank, and a dilution processing system before the waste fluid can be released into the local sewage system. The present scrubber suppliers manufacture scrubbers that are designed for gas flow of 100,000 to 1.5 million cfm. The wet system requires an additional permit that the user must obtain prior to operation.

The typical incinerators used by hospitals and other users are sized to burn waste from 50 lb/hr to 750 lb/hr. These controlled air incinerators have exhaust emission in the range of 1000 cfm to 10,000 cfm. The smallest commercial scrubber system is designed for ten times the flow of the largest incinerator and costs about $100,000. The $100,000 cost of the scrubber would double the sales price of the 750 lb/hr incinerator.

A reliable dry type scrubber to be installed and easily preplaced between the primary and secondary chamber needs to be designed and developed. The scrubbing equipment should be manufactured in four sizes ranging from 3 cubic feet in volume for 1000 cfm gas flow to 30 cubic feet in volume for the 10,000 cfm incinerator. Ideally, the scrubber should have a minimum life span of three years with a minimum of adjustments or settings. A device similar to an automotive catalytic converter exhaust emission control system would be ideal for this application.

The target cost for this equipment should be between $6,000 for the 1000 cfm system and $15,000 for the 10,000 cfm exhaust flow incinerator. The scrubber should be designed for installation in existing incinerators and for redesigned equipment. A city the size of Houston, TX, will need a hundred units to meet the new air control requirements. On a national basis, the retrofit could be as high as 10,000 units.

In addition to the scrubber, there is a need for a high technology incinerator, especially for pathological waste applications. As illustrated in the figure, the incinerator manufacturers are still using old design technology. The new incinerator could utilize some advanced heat insulation materials and also use another, more efficient energy source to decompose and burn the waste with the accompanying removal of undesirable emission products. The primary objectives are: (1) lower manufacturing cost, (2) lighter weight, (3) lower energy consumption. The use of fossil fuel burners on existing incinerators is a source of air pollution. A new method of burning the waste with emission products cleaning would meet current and future requirements.

NASA Technology

The technology to handle exhaust emissions has been advanced in conjunction with Space Station development. The waste management and toxic gas control scrubber for the habitat modules might be directly applicable to this problem. NASA JPL is developing a reducing reaction chamber for toxic waste destruction.

Participants

- Douglas J. Skinner, International Management and Technical Services (IMATS)

Status

A teleconference among IMATS, JPL, and RTI was held. NASA Headquarters TU is supporting the JPL incineration concept, which will be tracked by IMATS. EPA contacts and literature survey results have been provided to IMATS by the Team.

DEVELOPMENT OF AN INTELLIGENT TUTORING SYSTEM FOR HIGH SCHOOL PHYSICS

RTI Team Personnel: Stephen A. Lehrman

Problem

The federal government has cited the poor performance of American students in mathematics and science as a national crisis that must be addressed. In 1986-1987, the American Institute of Physics conducted a nationwide survey of secondary school teachers of physics. One of the highlights of this survey was that, in comparison to other countries, American students fare poorly in terms of both the proportion of students exposed to physics and the performance of those enrolled in the most advanced courses offered.

The integration of the computer into the K-12 instructional program began in the 1960's and has accelerated with the availability of inexpensive microcomputers and a growing amount of useful instructional software. The bulk of the computer-aided instruction today is limited to rather simple programs that are useful for drill- and-practice, automated "page-turning" and the administration of objective examinations. Only a small percentage of the educational software available today for K-12 used simulation, extensive branching to diagnose, and remediate and/or AI technology.

NASA Technology

The Artificial Intelligence Section at NASA JSC, in cooperation with the faculty at the University of Houston, has developed expertise in the application of AI technology to the training and/or tutoring task. They have developed a prototype intelligent tutoring system (ITS) for tutoring students in the production language CLIPS. This system has a general purpose user interface that should be adaptable to a variety of tutoring tasks.

NASA plans to use this expertise to develop an intelligent tutoring system for use in the first year of high school physics. The goal of this ITS would not be limited to the conveyance of facts and concepts but would concentrate on transferring problem-solving skills to the student. Ultimately, this project would also provide a development structure suitable for building additional intelligent tutors for other academic subjects that require the application of problem-solving skills.

Principals

- Dr. R. Bowen Loftin, University of Houston-Downtown
- Dr. Stephen Brown, Texas Learning Center

Status

Development of the Intelligent Physics Tutor software continues on schedule. JSC has informed the Texas Association of School Boards (TASB) that TASB needs to make a significant commitment to support the project if TASB wants to become the licensee and distributor of the software.

Bob Savely and Bowen Loftin presented the Intelligent Physics Tutor to the U.S. House of Representatives Subcommittee on Space Science and Applications.

Bowen Loftin has received a $214,000, two year grant from the State of Texas to support the development of the Intelligent Physics Tutor. The Physics Tutor is presently being used in a Houston-area high school. Eight MacIntosh SE computers are being used. The project team is adding new curriculum topics as the class progresses. Representatives from Apple Computers Classroom for Tomorrow are scheduled to conduct a site visit on November 29, 1989.

DEVELOPMENT OF A PLASMA AND NEUTRAL BEAM SOURCE FOR SEMICONDUCTOR PROCESSING

RTI Team Personnel: Stephen A. Lehrman

Problem

The semiconductor industry uses radiofrequency-generated plasmas to etch, that is remove or pattern, films on silicon, silicon compounds, photoresist, and aluminum in the fabrication of integrated circuits. As dimensions of the features approach the micron in size, as seen in VLSI chips, highly anisotropic etching is required. At the same time, the reduction in size of circuit components increases the likelihood of damage by energetic ions. Two important manufacturing requirements for a plasma etcher are a fast etch rate and high selectivity (i.e., preferentially etching some materials much faster than others). These requirements are a function of the plasma energy, flux, and gas composition.

NASA Technology

Since 1985 the Princeton Plasma Physics Laboratory (PPPL) has been involved in research with low energy (2 to 10 eV) neutral atoms to study beam- surface interactions. Sponsored by NASA's Marshall Space Flight Center the goal of this work is to understand the physical and chemical mechanisms involved in the erosion of materials in low earth orbit. The successful development at PPPL of novel plasma and neutral sources for this research has suggested a number of technological applications in surface modification and semiconductor processing. As noted above, plasma devices are the basis of much semiconductor processing and the development of new and better sources is important to the industry. The development of the lower hybrid (LH) plasma source and the application of the atomic oxygen source to study erosion for space applications suggested to use their potential for industrial microfabrication of materials modification. The most promising application is the use of an enhanced version of NASA's LH microwave plasma source for semiconductor processing. Another potential application is the use of reactive neutral beams (such as atomic oxygen) for charge-free stripping of photoresist and etching of semiconductors.

Principals

- Dr. William Langer, Princeton Plasma Physics Laboratory
- Dr. David Richman, Sematech Center for Excellence in Plasma Etching at the David Sarnoff Research Center

Status

On October 18, 1989, MSFC procurement sent the Department of Energy representative for Princeton Plasma Physics Laboratory the paperwork necessary for an Interagency transfer of funds. DoE is reviewing the paperwork. Dr. Langer has proceeded with the

design of the new radiofrequency source with a water coded central cathode. Fabrication of the RF source will commence once the Interagency transfer is signed.

DIE CASTING APPLICATIONS

RTI Team Personnel: Stephen A. Lehrman

Problem

Die casting is the process by which pressurized molten metal is introduced to a cavity or mold until solidification of the metal is completed. Because solidification occurs in a few seconds, this process has been widely adopted to manufacture large quantities of near net shape parts of nonferrous alloys such as aluminum (Al) and zinc (Zn). The final part geometry is often of fairly intricate design.

Die casting dies are relatively expensive to fabricate and sometimes cost as much or more than the equipment used to operate them. This is particularly true for dies used in aluminum die casting. Therefore, an improvement in die life is important to this industry.

The common type of failure for die casting dies is heat checking or mudlike cracking due to the thermal-corrosion-fatigue environment of the process. As this heat checking appears on the die surfaces, it begins to leave a corresponding network of fins on the casting that must be removed in subsequent finishing operations. As the number of parts manufactured or cycles per die increases, the extent and depth of the cracking also increases, and a more pronounced network of fins is left on the finished part. When these fins either can no longer be removed economically or interfere with the operation, the die is removed for repair or replacement.

NASA Technology

LeRC and Case Western Reserve University (CWRU) in cooperation with the Die Casting Research Foundation, undertook a project to investigate the effect of ion-sputtered coatings on the lifetime of H-13 die steel specimens exposed to a simulated aluminum die casting environment. Coatings investigated were molybdenum (Mo), tungsten (W), platinum (Pt), silver, gold, cobalt, chromium, silver and copper, Mo + Pt, W + Pt, silicon nitride (Si_3N_4), aluminum nitride (AlN), chromium carbide (Cr_3C_2), tantalum silicate (Ta_5Si_3), and zirconium oxide (ZrO_2). Average coating thickness was 1 micron meter. The effect of typical die lubricants on some of these coated specimens was also invest igated.

The results of this study indicated that a significant improvement in the thermal-corrosion-fatigue resistance was obtained in specimens coated with platinum, molybdenum, and tungsten. The other coatings did not improve and, in some instances, lowered the resistance of the die material to heat checking. Additionally, it was observed that the coated specimens tested with excess lubricants exhibited the lowest resistance to heat checking. So far, an experiment has not been made to test the performance of the best coatings found in the LeRC study on a die in an actual aluminum die casting environment. Because of the small thickness of the coatings applied by the ion sputtering method, it is

expected that the coatings could be removed easily from the die because of mechanical wear and die polishing. Additionally, this coating process would be difficult to perform on dies of very large surface areas and of intricate designs.

Because of this, it is suggested that the coating be applied using a simpler method that can deposit thicknesses between 0.005 and 0.025 in. so that the coating can remain on the surface after the die is machined to final dimensions. Also, the coating method should provide a coating with the required bonding strength and should be capable of applying the coating to intricate surfaces in a relatively short period of time. A coating method such as plasma spray satisfies these requirements.

Ideally, the coating should protect the die material from the thermal shock condition and corrosion fatigue environment, resist dissolution by molten aluminum, and exhibit a lubrication property. Initial candidates for the coatings of the die material could be those shown to be beneficial by LeRC (Pt, W, and Mo) or those coatings known to resist attack by molten aluminum such as aluminum oxide, silicon carbide, titanium dioxide, magnesium zirconate, and others. LeRC has also suggested the use of TAZ-8A, a nickel-based NASA-developed alloy, because it exhibits high resistance to thermal shock, with high strength and oxidation resistance at temperature. However, because nickel, like iron, is also dissolved by molten aluminum, a further suggestion is to coat TAZ-8A with a high-temperature solid lubricant that is not reactive to molten aluminum. For example, boron nitride has been used as a protective and release coating in certain aluminum casting operations. This type of coating system would have the following advantages:

1. Thermal shock would be minimized because the hot surface of the die would not be exposed to the effect of the room temperature lubricant during each cycle. Also, any corrosive effect caused by the lubricant chemistry and the hot steam generated during lubricant application would be eliminated.
2. The solid lubricant coating would minimize any possible dissolution of the nickel-base TAZ-8A coating by molten aluminum.
3. The solid lubricant coating would reduce the manufacturing time by eliminating the lubrication step during operation.
4. Casting porosity could be reduced because the porosity of the part due to evaporation of the lubricant would be eliminated.

Principals

- Dan Soltis, LeRC
- Dr. Walter Smith, Die Cast Dies, Inc.
- Curt Pohly, Superior Die Cast
- Dennis Sobol, Rex-Buckeye
- Case Western Reserve University (CWRU)
- Ohio State University (OSU)

Status

In FY89, LeRC funded the Engineering Research Center for Net Shape Manufacturing (ERC/NSM) at Ohio State University to evaluate various NASA-developed coatings and lubricants for increased service life of aluminum die casting dies. The main objective of the first year's research plan was to evaluate coatings for the erosive wear of a single die pin. The research plan consisted of the following tasks:

- Establish procedures for die wear testing
- Conduct preliminary accelerated tests on one-pin, single-cavity die
- Conduct preliminary tests on multi-pin die to evaluate the new test procedure
- Provide performance comparisons for various coatings.

In the first year (Oct. 1, 1988 - Sept. 30, 1989) a single-pin single- cavity H-13 die was tested. Accelerated tests on this uncoated die showed significant erosion of the die pin, even after 500 shots (die castings). Therefore, a six-pin die was designed to enable a number of coatings to be tested simultaneously. This die set is being fabricated and will be run with different coatings in the last quarter of the first year and the first quarter of the second year.

This investigation has been interfaced with the ongoing research program at ERC/NSM on Wear in Die Casting. As part of this joint effort, the following reports have been prepared:

- A state-of-technology report in die casting (ERC/NSM-87-12)
- A state-of-technology report in die wear (ERC/NSM-88-05)
- A report on the design and manufacturing of dies and evaluation of die life in die casting (ERC/NSM-C-89-07)
- A progress report: Development of an Accelerated Testing Procedure for Die Casting (ERC/NSM-C-89-14)

LeRC has approved a proposal by ERC/NSM to continue funding this effort for two more years.

ENCAPSULATED CELLS FOR HORMONE DEFICIENCIES

RTI Team Personnel: John G. Cleland, Doris Rouse

Problem

Diabetes is a serious, chronic condition that affects about one in every twenty people in the United States It is the leading cause of new blindness, the third leading cause of death, and accounts for 40,000 limb amputations per year in the United States. The American Diabetes Association estimates that the United States economic drain due to diabetes is about $18 billion annually. Insulin injection therapy and strict diet are the primary approaches to treatment of diabetes. However, this does not prevent the secondary complications of diabetes since insulin injection cannot duplicate the precise feedback of functioning cell islets. The blood glucose levels of those on insulin therapy fluctuate significantly and often are excessively high (hyperglycemia). Prolonged periods of hyperglycemia are thought to lead to the long-term complications of the disease.

Other methods being investigated to replace the diabetic's insulin deficiency include implantation of insulin pumps or mechanical artificial pancreases. Transplantation of the pancreas is another possible solution. All these techniques have encountered major problems including difficulties in developing a biosensor to monitor the amount of insulin required, blood clotting, fibroblast overgrowth, overdosage, and rejection of transplanted tissues.

NASA Technology

NASA has supported microencapsulation technology and droplet formation research for potential applications ranging from calibration standards to phase change encapsulated materials to fusion energy conversion targets. Studies have involved basic droplet dynamics, fluid mechanics, potential approaches to materials development in microgravity, acoustic levitation, and particle coating. The potential of microencapsulation technology applied to disease treatment by transplantation of living cells in humans is extremely attractive. Cells of interest are enclosed within a semipermeable membrane and thus are protected from the "hostile" surrounding medium, including antibodies and cytotoxic factors, while allowing nutrients to pass freely through the membrane to maintain the viability and normal function of the enclosed cells. For diabetes, transplantation of encapsulated islets of Langerhans would be investigated. Langerhans are clusters of cells within the substance of the pancreas gland, that are responsible for secreting insulin necessary to control the blood sugar levels in humans. This technology has been investigated by scientists at the Jet Propulsion Laboratory working primarily in cooperation with the University of California Los Angeles (UCLA).

Principals

- Dr. Taylor G. Wang, Director, Center for Materials Research and Applications, Vanderbilt University
- Dr. Patrick Soon-Shiong, M.D., Director of the Pancreas Transplant Program, UCLA
- Dr. Robert Snyder, NASA Marshall Space Flight Center

Cost to NASA

Estimated to be $150,000 for the first-phase effort.

Status

Dr. Wang submitted a proposal and project plan to the Office of Commercial Programs, NASA. The RTI Technology Applications Team further discussed the problem and solution with Dr. Wang and with Dr. Snyder at MSFC. The Team recently reviewed the proposal and provided comments to the NASA Headquarters TU division. Funding in the second quarter of FY89 was approved as a grant award.

FLY ASH CONVERSION TO PREMIUM OXIDES

RTI Team Personnel: John G. Cleland

Problem

Large-scale coal consumption by utilities has made coal ash the fourth most abundant mineral resource in the United States. Only stone, coal, and sand are more plentiful. About 70 million tons of coal ash were generated in United States coal-fired utilities in 1987. Fifty million tons of that was fly ash. Eighty percent of the fly ash was disposed of, and the balance was absorbed in construction markets at substantially less than $40/ton, the price of cement.

However, the inherent value of fly ash in terms of its constituent oxides is much greater. Average ash composition from coal-fired plants is approximately 27 percent silica (SiO2), 26 percent gypsum ($CaSO_4$), 18 percent alumina (Al_2O_3), 4 percent hematite (Fe_2O_3), 8 percent lime (CaO), 4 percent magnesium (MgO), and 1 percent titanium (TiO_2). Current average prices of pure varieties of the high-grade component range from $500/ton for silica to $1,500/ton for hematite and titanium. Accordingly, the value of such ash in the above components is about $280/ton. The Electric Power Research Institute (EPRI) has published a study to upgrade fly ash value to about $85/ton by beneficiation and hydrochloric acid leaching. At that price, the study projected a 30 percent return on investment after 20 years for a plant processing 1 million tons of ash per year. These performance values are not yet adequate to attract commercial interest.

Over the last few years, a hydrofluoric (HF) leaching process has been developed for extracting oxides, metals, and oxygen from lunar soil for lunar base and cislunar orbiter applications. It is desired to have NASA and such organizations as the United States Bureau of Mines and the American Coal Ash Association review this process and determine its possible applicability to fly ash. Lunar Industries, Inc., is interested in performing initial experiments that would demonstrate the technical validity and make economic estimates of the process. NASA expertise related to mineral recovery, especially from the lunar materials, is needed. Indications are that most coal fly ash is very similar in composition to lunar soil. Specific NASA expertise related to carbonation, gypsum management, integration of the operations for extraction, and determination of the purity of output would be extremely helpful.

NASA Technology

NASA's efforts to extract oxides, metals, and oxygen from lunar soil have been directed by JSC. Two lunar scientists at JSC, Dr. Michael Duke and Mr. David McKay, are interested in this problem. Any NASA expertise on carbonation, gypsum separation, and aspects of hydrofluoric acid/water recovery would be important.

Principals

- Mr. William N. Agosto, Lunar Industries, Inc.
- Dr. Michael Duke, JSC
- Dr. Robert Waldren, Rockwell International
- Mr. David McKay, JSC
- Mr. Dean Glenn, Technology Utilization Office, JSC

Cost to NASA

Cofunding estimates for an initial project are as follows: NASA, $40,000; Lunar Industries, Inc., $40,000.

Status

Mr. Agosto has supplied technology requirements and potential advantages of the HF process (including comparison with the EPRI process). The Technology Applications Team has reviewed the technology and possible solutions. Conversations have been held with JSC experts, with the US Bureau of Mines, with all the principals, and with the American Coal Ash Association. The latter association is reviewing the technical scope of work and is assessing the process in relation to previous attempts to extract metal oxides from coal ash. Additional extraction opportunities presented by the process (e.g., extraction of titanium oxides) are now being reviewed. Dr. Agosto has received $25K of JSC support for initial research. Commercial support is still being sought by Lunar Industries.

IMAGE ENHANCEMENT FOR LOW-VISION REHABILITATION

RTI Team Personnel: Dan L. Winfield

Problem

In 1977, there were in excess of 1.4 million persons in this country with severe visual impairment, of which the vast majority have some remaining functional vision. These persons are said to be "partially sighted" or to have "low vision." A NASA/Wilmer Eye Institute workshop highlighted the fact that currently available vision aids for this population are, on the whole, woefully inadequate. Most of these are purely optical devices with inherent limitations in both capability and acceptability. Although some closed-circuit television systems are used to provide magnification and, in some cases, contrast enhancement, the full range of possibilities for image enhancement have not yet been explored. The Wilmer Eye Institute has asked NASA to explore the capabilities of image processing as it relates to the provision of enhanced images to low-vision individuals.

NASA Technology

Research on how low-vision persons, or even normally sighted persons, use their vision in the performance of various daily tasks is limited by the research equipment used to assess visual performance during performance of real tasks. Stennis Space Center, in collaboration with Wilmer Eye Institute, will provide a first generation image processing machine to permit this visual research to progress at a vastly enhanced rate. It is expected that this system will evolve, and, based on research knowledge generated, improved hardware capabilities, and continued funding, a portable, affordable low-vision aid can be developed.

SSC completed a Phase O study and has developed a project plan including resource requirements and scheduling. An MOU was signed and a more detailed agreement was drafted by RTI at the request of NASA-HQ. This Agreement has now been signed by all parties. A draft requirements document has been completed. An initial reimbursables payment of $150K has been received from Wilmer.

Funding schedule for Phase 1 is:

	FY88	FY89	FY90
NASA TU	$50K	$200K	$200K
Wilmer Eye Institute	--	$150K	$800K

RTI has assisted SSC and WEI in evaluating the role in their system for a video-rate programmable remapper developed by JSC. JSC, in conjunction with the University of Houston, is employing the remapper to test the applicability of spatial remapping to low-vision rehabilitation. Various remapping algorithms are being tested on both normal

and low-vision subjects in various daily living tasks: reading, navigation, and face recognition. However, the first version remapper is cumbersome to operate and has certain bugs in the image flow. Incorporation into a low vision system will require development of Remapper II, which will require $250K for the first copy and $135K for each copy thereafter. SSC/WEI have elected to delay incorporation of spatial remapping until the technology is more mature. JSC will continue to test the remapper with human subjects and seek funding sources to develop Remapper II.

Funding

	FY87	FY88	FY89
NASA TU	$40K	$60K	$75K
U.S. Army	$90K	$100K	$125K
University of Houston	$0	$40K	$50K

RTI has assisted the Jet Propulsion Laboratory (JPL) by putting them in touch with V-Tek, a company which produces closed circuit TV systems for the visually impaired. An agreement between JPL and V-Tek has been reached.

The objective of this project is to develop a portable, inexpensive ($2,000) low-vision aid with the following features:

- Process images in real-time
- Custom VLSI chips for image enhancement
- Initially in the form of a portable CCTV system
- Ultimately in a head-mounted camera/display version.

This device will consist of:

- Closed-circuit display (CCD) camera
- PIFEX convolvers and digital/analog (D/A) interface
- Display (cathode-ray tube (CRT) or liquid-crystal display (LCD))
- Battery-powered CMOS circuitry
- Programmability through master computer (e.g., microVAX).

The specific technical approach to image enhancement involves measurement of the individual's transfer function via contrast sensitivity testing and computing the reciprocal. This will be used to develop an optimum compensation filter that will be convolved with the images in real-time. Preliminary research has yielded a 20-percent reduction in magnification required for word recognition accompanied by two to three times the reading speed.

V-Tek has loaned one of their instruments to JPL for engineering interface to the real-time image processing boards. The system will then be tested with additional subjects and the technology commercialized by V-Tek.

INTRACRANIAL PRESSURE MONITOR

RTI Team Personnel: Daniel L. Winfield

Problem

All current methods for monitoring intracranial pressure (ICP), i.e., pressure within the skull, require invasive procedures. These consist of either insertion of an intraventricular catheter or a transcranial bolt instrumented with pressure transducers. Risks associated with these invasive procedures (primarily infection) limit their usefulness in many marginal cases of head trauma and limit the length of time they can be used. A noninvasive method to measure ICP would be an extremely valuable clinical and research tool.

NASA Technology

NASA-developed ultrasonic pulsed phase-locked loop (P^2L^2) technology can be used to make sensitive measurements of variations in sound propagation properties of materials due to environmental influences. Since sound propagation within the skull will vary with ICP, P^2L^2 technology should be capable of detecting changes in ICP.

Principals

- Dr. Tom Yost, LaRC, Hampton, VA
- Dr. Anthony Marmarou, Department of Neurosurgery, Medical College of Virginia (MCV), Richmond, VA
- Richard Moberg, Interspec, Inc., Conshohocker, PA

Cost to NASA

NASA funding has been committed as follows:

FY84	FY85	FY87	FY88	FY89
$25,000	$59,700	$100,000	$85,000	$68,000

Status

Concept feasibility has been proven in tests involving a skull filled with a pressurized bladder. Instrumentation for animal studies was completed at LaRC and delivered to MCV in May 1986. LaRC hypothesized that, in addition to developing a correlation to ICP, the instrument may also directly measure the pressure-volume index (PVI), which would provide a direct, noninvasive measure of brain compliance. Tests at MCV confirmed this, and Dr. Marmarou was pleasantly surprised at the accuracy with which PVI was measured noninvasively. Although the PVI is a clinically useful parameter, the hoped-for objective remains actual ICP measurement, which will require further signal processing development.

LaRC has continued theoretical and experimental studies to validate a naive, two-component, acoustic model of the brain. LaRC has developed additional signal processing to attempt to extract actual ICP from the return signal. In addition, a second instrument has been built in preparation for clinical studies, which are to begin in the next quarter.

Commercialization Status

The RTI Team prepared an announcement placed in the *Commerce Business Daily* and a prospectus on this project was distributed to 12 companies. Responses were received from nine companies, and these were evaluated by a committee at LaRC (including an RTI Team representative). The three companies found to have the required resources for the project were invited to visit LaRC during October 1988 for detailed discussions. One company, Interspec, Inc., of Conshohocken, PA, has submitted a phased plan for commercialization of the technology. LaRC and MCV have decided some preliminary clinical tests should be conducted prior to finalizing an agreement with a manufacturer.

RTI identified interest at NASA-Ames (Dr. Alan Hargens) in a noninvasive intercranial pressure monitor for both ground and flight experiments. This interest was discussed with Interspec, and Interspec has submitted an SBIR proposal to NASA for further testing and development of this technology. NASA-Ames has contacted Tom Yost at LaRC regarding this technology. They would like to obtain a system to use in animal studies at Ames and Stanford University. Funding is uncertain at this time.

LINEAR POWER GENERATION FOR THE ARNOLD OSCILLATING CASCADE POWER SYSTEM

RTI Team Personnel: John G. Cleland

Problem

The patented Arnold Oscillating Power System (AOPS) is a revolutionary new approach to low-cost energy absorption and power generation. The technology involves a cascade of airfoils or hydrofoils that oscillate in moving fluid streams (either air or water) harnessing kinetic energy to produce useful work. A dynamically scaled model of the device has undergone testing in the wind mode. Although all conventional rotating wind and water turbines invariably involve bearings, the oscillatory nature of the AOPS makes it possible to use reciprocating pumps and electric generators that may be more reliable and efficient than rotating devices. Rotating machinery loads generated near the blade tips must be carried by the beam-like structure of the turbine blades to the point where the loads are removed at the rotor hub. Structural weight, and therefore cost, of rotors increases rapidly as the radius increases.

The concept requires demonstration and testing in a wind tunnel. NASA assistance is also sought for model design and construction. For the AOPS, it is reasonable to remove power from many points along the span. Another possible requirement for this device is a linear generator or alternator for power takeoff. A prototype generator producing a maximum of 500 W might be sufficient for initial testing. Linear velocity (based on frequency of oscillation in pure plunge) is estimated to be from 20 to 200 ft/s in a stroke not exceeding 1 ft.

NASA Technology

LaRC has available low-speed, large test chamber wind tunnels. LaRC can also provide expertise in model design, bearings selection, and test instrumentation.

Engineers at LeRC are working on linear generators and related technology (magnetic heat pumps). It has been indicated that LeRC efforts are related to electromagnetic launchers, other pulsion requirements, and possibly the Stirling engine program.

Principals

- Dr. Lee Arnold, Arnold Systems, Inc.
- Dr. Peter Halpern, Arnold Systems, Inc.
- Mr. Lee Douglas, former General Manager, Boeing-Vertol

Cost to NASA

Cofunding estimates for an initial project are as follows: NASA $80,000; Arnold Systems $50,000.

Status

Arnold Systems first talked with the RTI Team, the LaRC TU Office, and Langley managers in the fields of aerodynamics concerning possible testing of the AOPS in Langley wind tunnels. This option has been undertaken; LaRC is assisting with model fabrication and preliminary testing. The RTI Team has discussed design and fabrication requirements of models with LeRC, Mechanical Technology, Inc. (MTI), Microcraft Inc., Accutool Corp., Sunpower Corp., and Split Cycle Cooler Co. The first demonstration of a working model was conducted at LaRC in February. The first wind tunnel tests were conducted at LaRC in August. Status reports are being submitted by Arnold Systems on a monthly basis to LaRC, with copies to the RTI Team.

MULTICHANNEL FLOW CYTOMETRY

RTI Team Personnel: Daniel L. Winfield

Problem

The technical difficulties in performing multichannel flow cytometry limit its usefulness in both clinical and laboratory settings. Technical improvements needed include improved signal processing for multichannel analysis of optical emission spectra, reductions in complexity, size, and numbers of optical sensors, simplification of sample preparation, and expert system software. The American Cancer Society-Florida Division expressed this need to KSC and RTI. RTI conducted further background research and located ongoing research and development work on these problems within JSC.

A new technology is needed to allow multispectral analysis of an emission spectra that may include overlapping spectra from several (up to five or six) fluorescent dyes. In addition, it would be desirable to use a single excitation light source rather than multiple lasers. Underlying all aspects is the need for the system to be user friendly in all aspects so that it may be used routinely in clinical and laboratory settings by staff with limited training in optical physics. This includes minimizing the complexity of setup and operation and simplifying sample preparation and may include the use of expert systems technology to assist operation as well as interpretation of data.

NASA Technology

Dr. Gerald Taylor of JSC contracted with the Los Alamos National Laboratory to investigate the feasibility of designing and developing a Flow Cytometer for Space Station with the following requirements:

- User (i.e., astronaut) friendly
- Minimum of five, preferably eight, channels
- Rugged but lightweight
- Modularity to facilitate performance upgrades.
- Reduce size to 1 m^3
- Safe, low-power light source
- Efficient handling of wastes and expendables.

Because these requirements are comparable to those for an earth-based clinical system, subsequent development will be directly applicable to a terrestrial spinoff.

Principals

- Dr. Gerald Taylor, JSC Life Sciences
- Dr. Tudor Buican, Los Alamos National Laboratory
- Dr. David Robinson, ACS/University of Miami
- Dr. Mack Fulwyler, University of California - San Francisco

Funding: (10^3)

	FY87	FY88	FY89	FY90	FY91
NASA TU	15	90	50	100	--
NASA Life Sciences	05	100	170	300	600
ACS	10	51	43	101	70
Industry	--	--	--	100	100

Status

The Advanced Flow Cytometry Workshop was conducted by RTI in Los Alamos, NM, June 1-3, 1987. The meeting (1) confirmed the technical feasibility of building an instrument to meet NASA's requirements, (2) recommended this technology be combined in some form with imaging capability, and (3) confirmed that the technological developments will be of great benefit to Earth-based applications. The Team was instrumental in preparing a proposal for ACS cofunding in the amount of $301,000 over 4 years. In April 1988, the ACS executive committee approved funding for Tasks 1 and 2.

The project plan consists of four tasks: (1) applications study groups, (2) design verification, (3) prototype development, and (4) laboratory testing. Results of the feasibility study and Tasks 1 and 2 were reported at a project meeting at the Society for Analytical Cytology. The reports from the Applications Study Groups have been summarized and distributed by Dr. Taylor. Two companies loaned state-of-the-art instruments to NASA-JSC to evaluate performance of various experiments recommended by the project study groups. This preliminary testing will help finalize the design requirements for release of an RFP by late CY89.

JSC conducted a workshop in Houston on May 31-June 2 to obtain final input from the scientific community on functional requirements and design specifications. ACS will conduct a conference in November 1989 to focus on the application of flow cytometry to clinical oncology.

PASSIVE SENSORS FOR AMBULATORY MONITORING OF FETAL HEART RATE AND FETAL MOVEMENT

RTI Team Personnel: Daniel L. Winfield

Problem

Improved passive sensors, such as microphones and accelerometers, are needed to incorporate into an ambulatory fetal monitoring unit for use in high-risk pregnancies. A passive sensor, such as a microphone array, is needed to listen for the fetal heart rate. However, the mother's heartbeat as well as other bodily sounds and environmental sounds are superimposed on the sound of the fetal heartbeat. Recent advances in signal processing technology allow the use of autocorrelation techniques to identify the fetal heart rate from this complex signal. Experiments to date indicate two frequencies that correlate highly with the fetal heart rate -- 30 Hz and 120 Hz.

NASA Technology

Acoustics experts at NASA-LaRC propose using polyvinylidene fluoride film as a piezoelectric sensor for fetal heart sounds and fetal movement. The sensor would be developed in-house at LaRC with signal processing being developed at Old Dominion University.

Principals

- Dr. Allan Zuckerwar, NASA-LaRC
- Dr. Donald Baker, Spokane, WA
- Dr. James Stoughton, Old Dominion University
- Dr. Tibor Foldvari, Corometrics Medical Systems

Status

RTI has held telephone discussions with Dr. Baker and several potential manufacturers. Corometrics Medical Systems has been identified as a desired commercial participant.

Several prototype belts incorporating PVDF microphones have been fabricated. The spectral analysis algorithms have been developed by Old Dominion University; in addition, RTI has identified a set of algorithms developed at the Medical College of Georgia. An optoelectronic isolation connector to preclude any possible shock to the wearer has been built. Clinical testing indicates the need for better transducer design to easily locate the fetal heart sounds and to eliminate 60-Hz pickup in the signal.

These improvements have been completed and additional clinical tests will begin in the next quarter. Digital adaptive filtering will be used to eliminate movement artifacts and to focus on the frequencies of interest (30 and 50 Hz).

PRESSURE SENSING SYSTEM FOR THE HUMAN-SEAT INTERFACE

RTI Team Personnel: Daniel L. Winfield

Problem

Decubitus ulcers, or pressure sores, have long been recognized as a serious health threat to those persons using wheelchairs for personal mobility, particularly the spinal cord injured person with sensory loss. Every year, 14,000 people with spinal cord injuries are hospitalized for treatment of pressure sores at costs of $20,000 per sore.

Pressure sores are caused by prolonged pressure to the skin that inhibits circulation resulting in tissue breakdown. Current practice is to identify areas of high pressure and to select cushion materials and design to reduce peak pressures. Current systems to measure this pressure are inadequate.

An improved pressure-sensing method is required that will not obscure the measurement as a result of the presence of the measuring device. It must be flexible to conform to the involved surfaces and provide a matrix of measuring points with at least 1-inch resolution. Pressures may range up to 300 mmHg. The system should either be unaffected by shear loading or be able to measure it.

NASA Technology

Engineers at MSFC have proposed a technique using resistive coatings on polymer substrates. Coatings, in the form of ink printing, can be applied to polymer film and change resistance in response to compression. Thus, the sensing component will consist of a polymer sheet (flexible) with a conductive matrix and electrical connection at the edges. A computer can automatically sequence and record the matrix of measuring sites for later display and analysis.

Principals

- Gerald Scott, Martin Marietta
- Craig Richlen, Tekscan, Inc.
- Greg Shaw, University of Tennessee Rehabilitation Engineering Center

Status

A contractor (Tekscan) has been identified to supply the printed sensor film and data acquisition hardware. A ROM cost estimate of $72K manpower and $60K equipment has been submitted to NASA TU.

Action

Tekscan has indicated they are currently unable to cost share this project. They are interested in this application, however, and have submitted a proposal to the Veterans Administration.

PROTECTIVE COATINGS FOR ADVANCED CUTTING MATERIALS

RTI Team Personnel: Stephen A. Lehrman

Problem

The machining of difficult-to-machine metal alloys and composite materials requires the use of tools made with advanced cutting materials. Although tool materials have been developed continuously, they have not always kept pace with the increasing difficulty of machining that has resulted from developments in new work materials. Polished synthetic polycrystalline diamond and polycrystalline cubic boron nitride cutting edges bonded to a carbide substrate have demonstrated excellent wear characteristics. A vapor deposition process is desired for applying these polycrystalline materials or diamond-like carbon films to the substrate so that cutting and tool life are improved.

Coated machine tools are widely used by the metal cutting industry. Layers of titanium carbide, titanium carbo-nitrite, and titanium nitride coatings are applied to a carbide substrate and provide excellent wear resistance for machining of ferrous and nonferrous metals. The coatings are applied by chemical vapor deposition and physical vapor deposition at economical growth rates.

Another class of cutting tools consists of synthetic polycrystalline diamond and polycrystalline cubic boron nitride cutting edges bonded to a strong carbide substrate. The polished synthetic polycrystalline diamond material has a randomly oriented crystalline structure that makes the cutting edge superior in strength to a natural diamond. It provides a sharp cutting edge that remains sharp even when machining nonferrous and abrasive materials such as A390 aluminum, copper alloys, bronze, composites, and glass-fiber-reinforced plastics.

The polycrystalline cubic boron nitride has a high hot hardness and chemical inertness that permits it to machine-harden ferrous and difficult- to-machine high-temperature alloys. Examples of material that may be machined by the polycrystalline cubic boron nitride include tool steels, bearing steels, Inconel 718, Stellite, Incoloy 901, and Waspaloy.

It is desired to replace the bonding of a chip of the polycrystalline diamond or polycrystalline cubic boron nitride by a vapor deposition process. Vapor deposition has the advantage of coating the entire substrate and thus permitting the tool to be indexed.

NASA Technology

The LeRC Electro-Physics Office has developed various methods for depositing diamond-like carbon films on substrates. Three of these methods are ion beam deposition, dual ion beam sputtering, and DC magnetron sputtering. They are developing the capability to deposit diamond films on substrates. A thermal chemical vapor deposition (CVD) chamber and vacuum arc/hydrogen hollow cathode facility have been completed for

diamond film deposition. A hydrogen/methane hollow cathode facility is under construction.

Principals

- Bruce Banks, Chief, Electrophysics Office, LeRC
- Dr. Dennis Quinto, Manager, New Materials Technology, Kennametal, Inc.

Status

A meeting between NASA LeRC, Kennametal, and RTI was held at LeRC on May 24, 1988. The Applications Engineering Project objectives and schedule were discussed. Kennametal submitted a letter, agreeing to cofund the project, to Dan Soltis (LeRC-TUO).

Diane Swec (LeRC) attended a meeting at Kennametal, Inc., in Greensburg, PA. to discuss the approach for developing a diamond-like carbon (DLC) and/or diamond coating for cutting tools. An outline and schedule of activities was prepared and agreed to by Kennametal and LeRC.

Kennametal supplied LeRC with 50 each cemented tungsten carbine (WC-Co) and silon cutting tools to be used as substrates. The first set of samples will be used to determine the maximum thickness of DLC film that can be deposited on the cutting tools. Ion beam sputtering, ion beam deposition, and DC magnetron sputtering will be evaluated.

LeRC has sputter-deposited DLC films as thick as 5000 Å on WC-Co and silon cutting tools. These samples will be evaluated by Kennametal for adhesion and hardness. Deposition from the thermal CVD system at LeRC has resulted in diamond films as determined by scanning electron microscopy (SEM) and X-ray diffraction (XRD) with a grazing angle of incidence. Films deposited by the carbon arc alone have been determined to be graphite by X- ray diffraction.

LeRC sent Kennametal five WC-Co tools coated with 500-Å DLC by sputter deposition and five tools similarly coated by direct deposition. Examination has shown the sputter coatings to be very uniform and the ion beam coatings to be less uniform. The coatings were too thin to be visualized in the SEM. The tools will be examined by Auger at Kennemetal. The tools arrived too late (9/7/88) to be taken to Penn State to be coated with a diamond film. The purpose of taking the DLC-coated tools to Penn State is to evaluate if the DLC film affects the growth of the diamond film. Kennametal will contact Penn State to determine when the tools can be coated.

The cemented carbide cutting tools half coated with 500 Å of sputter- deposited or direct-deposited DLC were sent to Penn State for coating with diamond. The DLC is being tested as a "seed" material for diamond film growth.

SEM examination by Kennametal of sputter-deposited DLC (1,400, 2,000, 2,500, and 5,000 Å thick) on cemented carbide and sialon showed the films to be very smooth and almost transparent to the electron beam. The thickest samples are awaiting XRD.

Cemented carbide and sialon coated with direct-deposited DLC (1,550, 1,900, and 4,500 Å thick) were also examined by SEM at Kennametal. The thinner samples were much like the sputter-deposited films, though spalling was noted on the 1900 Å sample. However, the thickest sample on sialon showed a fine (0.1 μm) crystal structure. As above, the thickest samples have been submitted for XRD.

Kennametal examined by SEM a sample of 2000 Å of diamond film deposited by hot-filament CVD on silicon, and found the film to have an extremely fine grained morphology (0.1 μm). This is atypical of CVD diamond, but may be due to the thinness of the film. The sample is awaiting XRD, and will then be examined in the transmision electron microscope.

Lewis has successfully deposited DLC films by DC magnetron sputtering. LeRC is currently optimizing deposition parameters. On average, the deposition rate is ~ 130 Å/min, which more than doubles the rate of current deposition methods.

Action

In August 1989, it was agreed that Kennametal and LeRC would both perform metal cutting experiments on the DLC coated cutting tools. The purpose of these experiments was to gather data on how the DLC coating adheres to the substrate and on how the DLC coating wears. Results of the testing are anticipated in FY90.

ROBOTIC SYSTEM FOR GREENHOUSE AUTOMATION

RTI Team Personnel: John G. Cleland

Problem

The University of Georgia Agricultural Engineering Experimental Station has initiated a program of robotized agriculture. One agricultural industry that contains many manipulation tasks requiring constant decisionmaking is the nursery and greenhouse industry, which is extremely labor-intensive. Europeans have been responsible for most of the greenhouse automation efforts and creative new concepts in greenhouse design and management.

The University of Georgia, however, is examining several promising tasks, including grafting and budding, custom and selective harvesting, quality sorting, and transplanting. The first application for the University of Georgia Laboratory is the processing of geranium cuttings. This is being done with the cooperation of Oglevee Products, Inc., one of the largest United States greenhouse facilities for such processing.

Propagation of geranium stock proceeds in the following steps:

1. Bring in tissue culture.
2. Grow in pots, in a controlled, near-clean-room environment.
3. Take cuttings and place cuttings in bags.
4. Strip lower leaves, cut main stem, and put in rooting hormone in assembly line operation.
5. Transfer back to greenhouse.
6. Ship to growers.

A robot is anticipated to assist in the performance of steps 3 to 5, including such operations as trimming, stripping, and stem placement in trays.

The first requirement for this operation is to set up a machine vision system to locate the growing tip on the plants. This information is required to perform the functions mentioned and requires selection of the proper system development of controlled software and interface with the robot. Currently planned robot equipment for these functions is an ASEA IRB 1000 unit operating with a Heurikon HK68/V2f series computer for supervisory control. This is a VME bus, 20-MHz, MC68020/68881 system running Microware's OS9/68K operating system and using 1 Mb of local 60-nsec RAM.

The University of Georgia is also very interested in developing an expert system to assist with the grading process in processing cuttings. This would be a knowledge-based system closely linked to the artificial vision feedback information and interfaced with direct operator control to compensate for any limitations in the capability of the expert system

or supervisory computer. The University of Georgia would welcome NASA assistance in computer control programming, vision systems, expert system interfacing and control, and any other aspects of robotized processing related to the greenhouse processing problem.

Principals

- Dr. Ward Simonton and Dr. Brahm Versua, University of Georgia, Athens, GA
- Oglevee Products, Inc., Georgia
- Mr. Max Sharpe, Mr. William Hill, Mr. Thomas Bryan, Mr. Ismail Akbay and Mr. John Richardson, Marshall Space Flight Center, Huntsville, AL.
- Mr. Russel O'Neal, Mr. James Montogomery, and Mr. Henry Phillips; Martin Marietta Corporation

Cost to NASA

Estimated at $110K in the first year with equal cost share by other participants.

Status

Some of the laboratory organization at the University of Georgia for supervisory controlled robotics research has been developed from a plan developed by Bejczy[1] at JPL. The RTI Applications Team discussed the problems with Dr. Simonton[2] and followed up with an initial contact at KSC where robotics are being applied for a seed planter related to an ecological life support system for the Space Station. The Team met with the MSFC TUO, NASA engineers and managers, and Martin Marietta Corporation on February 8 - 10 and March 30. Martin Marietta support to the project is being initiated through a Technical Directive. The MSFC TU office arranged a tour of NASA facilities. A project plan was drafted, reviewed, and submitted. First year funding has been received. An initial status report was forwarded by the University of Georgia to the RTI Team in late June.

References

1. Bejczy, A. K., "Control of Robotic Manipulators," *Handbook of Industrial Robotics*, Shimon Noff, Ed., John Wylie and Sons, NY, 1985.

2. Simonton, W., "A Supervisory Controlled Robotic System for Agricultural Automation Research," Paper No. 88-3027, Presented at the International Summer Meeting of the American Society of Agricultural Engineers, Rapid City, SD, June 26-29, 1988.

TEXTILE MANUFACTURING PROCESS CONTROL: EXPERT SYSTEM

RTI Team Personnel: John G. Cleland

Problem

The Institute of Textile Technology (ITT) is a nonprofit and academic organization supported entirely by American textile companies. At present, approximately 45 percent of the textile manufacturing capacity in the United States is associated with this institute. ITT is seeking and developing for its members technology such as AI (e.g., expert systems and robotics) to improve the competitiveness of the United States textile industry. The RTI Team visited ITT at its headquarters and research center in Charlottesville, VA to explain the NASA TU Program and discuss problems and needs in the textile industry that might be met by NASA technology. One problem defined was the need for an expert system for manufacturing process monitoring, fault diagnosis, response, and control. The Team arranged for a meeting between ITT and Mr. Tom Davis, Manager of AI Development at KSC. Another meeting was arranged at the AI Conference at Charleston, SC, and a subsequent meeting was held between ITT and two of its industry affiliates at KSC. KSC will be transferring expert system technology developed primarily for Space Shuttle operations and other space system activities. The expert system, the Knowledge-based Automated Test Engineer (KATE), emphasizes sensor monitoring, fault diagnosis, and decision tree response. Other problems identified by ITT include requirements for improved sensors for recognizing patterns in textile weaves and fiber, for measuring fiber uniformity, and for color sensing. Increased automation across the board is desirable in textile fiber manufacturing.

Principals

- Neil Cahill, Vice President, Manufacturing Technology, ITT
- Richard C. Corson, Project Manager, Automated Systems
- Peter Kleeman, Project Manager, Artificial Intelligence, Institute of Textile Technology
- Mr. Tom Davis, KSC
- Mr. Tom Hammond, TU Office, KSC.

Cost to NASA

ITT requests no NASA funding.

Status

The RTI Team assisted in the preparation of an MOU between ITT and KSC. This MOU has been approved by the participating organizations. Applications efforts are underway at ITT and regular communications with KSC are scheduled.

ULTRASONIC IMAGING FOR SPEECH AND SWALLOWING DISORDERS

RTI Personnel: Daniel L. Winfield

Problem

It is estimated that 10 million people in the United States are affected by speech disabilities ranging from an inability to speak at all to varying levels of normal effective speech. The primary articulator in speech production is the tongue. Speech scientists have placed great emphasis on developing a method of imaging the tongue during speech. Ultrasound is the only technique that allows a direct, noninvasive, dynamic or real-time picture of the soft tissues of the tongue and the other muscles of the floor of the mouth during speech production. These tissues can be clearly imaged with ultrasound because the air interface at the tongue's surface has been found to be a nearly perfect reflector of sound energy.

However, investigations by researchers at NIH have shown that ultrasonic diagnostic imaging for speech and swallowing is limited by the size of the ultrasound sector and by the timing rate of the ultrasound pulses. With the current 90 degree sector, the laryngeal and pharyngeal areas cannot be imaged simultaneously, as can be done on x-ray. In addition, an increase in the ultrasound pulse rate would aid the analysis and collection of acoustically based data (vowels and consonants) and more closely approximate the sound source.

NASA Technology

Researchers at SCC have proposed image processing methods to extract maximum information from the existing data sets and using mathematical models to interpret the data. This will improve capability with existing ultrasound hardware until improved sector scanning and pulse rates can be developed by the ultrasound industry.

Principals

- Dr. Maureen Stone, National Institutes of Health
- Dr. Gary Ransford, Stennis Space Center

Status

RTI arranged a teleconference between NIH and SSC to further explore the requirements and the approach suggested by SSC. Subsequently, SSC and NIH held a video conference to further explore the problems of information extraction from the ultrasound image. Further research is required, thus this does not appear to be a good candidate for a TU project. However, SSC may propose certain work that could be funded directly by NIH if they are interested.

ULTRASOUND DIAGNOSIS OF BURN DEPTH

RTI Team Personnel: Daniel L. Winfield

Problem

Approximately 2 million Americans suffer serious burns each year, and 200 to 300 thousand of these people require hospital treatment. Among those hospitalized, 70,000 receive intensive care and 10,000 to 12,000 patients die from their injuries. The cost of intensive care exceeds $300 million per year. The traditional treatment of burn victims is to allow natural debridement, sloughing of necrotic tissue, to occur and then to close the resulting open wounds with skin grafts. Unfortunately, the weeks required for spontaneous sloughing often result in infection and sepsis; indeed, the major cause of death in burn victims is bacterial infection. Modern treat ment, therefore, is based on early recognition and removal of necrotic tissue to reduce infection and hasten healing. This surgical or chemical debridement depends upon accurate burn depth information for optimal results. Current methods for burn depth determination are inaccurate, cumbersome, or both.

Solution

Ultrasound may be used to map precisely and conveniently the depths of the interface between viable and necrotic tissue in burn injuries. Preliminary studies in pigs demonstrate a good correlation between depths of burns measured by pulse-echo ultrasound and by histological techniques. NASA advanced ultrasonic technology developed at LaRC for the characterization of materials is directly applicable to this project.

Principals

- Dr. John H. Cantrell, Jr. and Dr. Tom Yost, LaRC, Hampton, VA
- Dr. Boyd Haynes, Jr., Director, Burn Unit, MCV, Richmond, VA
- Mr. Jack Cantwell, Fulmer Dyson, Inc., Englewood, NJ.

Commercialization Status

Following Advanced Technology Laboratories' decision to terminate their involvement in the project due to marketing strategies, RTI coordinated meetings with two additional interested companies in February 1988. One of these companies, Fulmer Dyson, Inc., has visited LaRC and MCV on several occasions and has submitted a request to LaRC for exclusive license of this technology. The NASA developments will be used as a front end to an ultrasound instrument developed by Fulmer Dyson.

Status

In the preliminary series of tests, the breadboard instrument results demonstrated a 93 percent correlation with histological measurements. A second prototype was built for a

small clinical trial at MCV. These results were summarized in a final report prepared by LaRC.

The NASA instrument has been integrated with the Fulmer Dyson B-Scan System, and tests at MCV have corroborated results with earlier tests. Fulmer Dyson will complete development and support clinical studies of burn assessment and other dermatological applications such as melanoma detection.

URODYNAMIC PRESSURE-SENSING CATHETER

RTI Team Personnel: Daniel L. Winfield

Problem

Miniature pressure transducer technology is required to provide more accurate, controlled measurements of the pressure profile within the urethra relative to the pressure within the bladder. The objective of urodynamic diagnostic procedures is to measure the pressure profile within the urethra relative to the bladder pressure under a variety of conditions, particularly during exertion (coughs, body movements, etc.). A method is needed to measure the urethral pressure or closing force throughout its length simultaneously. The pressure transducers must measure pressures in the range of 0 to 200 cm/H_2O (0 to 7.0 psi) with an accuracy of 2 cm/H_2O (0.07 psi). The optimal design would be able to measure closing force within the urethra from all directions, 360 degrees, and throughout its length, 3.0 cm. If a continuous pressure sensor down the length is not possible, incremental measurements with a resolution of 3 to 5 mm would be acceptable.

NASA Technology

NASA-Langley engineers have proposed a technique to include at least four, possibly up to six, sphincter-closing force measurements simultaneously.

Principals

- Dr. Andrew Fantl, MCV
- Dr. Harlon Holmes, NASA-Langley
- Dr. Terry Radebaugh, NIA

Cost to NASA

Dr. Fantl is currently funded by NIA to study urodynamic pressure measurements in stress incontinence. NASA provided funding of $35,000 in FY86 and $25,000 in FY87 to support prototype development in-house. An additional $10K has been allocated for final work on the data acquisition system.

Commercialization Strategy

At the request of LaRC, the RTI Team has developed a prospectus on the project for distribution to companies. Meetings with two companies were held on January 24, 1989 at which the technical details and clinical advantages of the catheter were discussed. One company, Surgitec/Medical Engineering, remains interested and is continuing discussions with Dr. Fantl at MCV.

Status

The sensor assembly has been incorporated into a 0.125-in. diameter catheter with medically approved coating. Initial clinical tests of a working prototype were conducted successfully with Dr. Fantl in December 1987. Dr. Fantl has indicated to his NIH grant administrator that he is very pleased with the work done by NASA. Expanded clinical evaluations began in November 1988 with excellent performance of the catheter. Data from these studies have been analyzed, and a scientific article will be prepared for submission. A third-generation catheter has been developed along with improved data acquisition electronics, and a final series of clinical tests will begin later this year.

WATER JET NOZZLE DESIGN

RTI Team Personnel: John G. Cleland

Problem

A growing number of industries are using high-pressure water jet cutting. Materials as diverse as brake linings, printed circuit boards, and advanced aerospace composites as well as cardboard, diapers, and cakes are being cut quickly by needle-thin jets of water forced out of sapphire nozzles at velocities approaching three times the speed of sound (3,000 ft/s). Although water alone will cut most porous materials, high-pressure abrasives in the water jet are used to cut most metals and concrete. Abrasive additives are typically garnet or silicon particles educed into the jet stream upstream of the nozzle. Another application being offered by Kennametal is that of machine tool chip breaking, where a high-pressure water jet is directed against the chip spiraling off a part being machined. This allows close chip size control and, ultimately, machine integration into a completely automated factory. In both cutting and chip breaking, water jet manufacturers have found that considerable losses are indicated in the nozzle region. These nozzles are typically sharp-edged, ranging from 0.003 and 0.018 in. in diameter.

Current life expectancy is about 200 hr. Discharge coefficients have not been analyzed adequately, but energy recovery estimates for overall water jet systems are typically less than 10 percent. An optimized nozzle design is needed. One complicating factor is that nozzle orifices, especially for abrasive cutting, wear away to larger diameters, often change shape from circular to oval, and develop grooves. Small increases in efficiency could lead to considerable decreases in operating costs. The market has been growing so rapidly that only minimal research has been conducted.

Principals

- Mr. Michael Dixon, Ingersoll-Rand, Inc.
- Mr. Robert Ferguson, Ingersoll-Rand Water Jet Cutting System
- Mr. Ken Curtis, Ingersoll-Rand, Inc.
- Mr. Marion Roberts, MSFC
- Mr. Steven Cosby, United States Boosters International

Cost to NASA

Cost to NASA for a project with Ingersol is estimated to be $130K over 2 years. Ingersoll has indicated a willingness to cost-share in excess of $230K. A feasibility study for Kennametal's Hyperson project might be augmented by funding from NASA HQ.

Status

Contacts initially were made with LaRC and JPL. A literature survey was completed. Contact was made with the TU Office at MSFC concerning water jet nozzle design, and the RTI Team was put in touch with appropriate experts in water jet machining and nozzle design at MSFC. MSFC concepts for converging-diverging nozzles and a "flow-screen" annulus approach were considered very appropriate. The Team arranged a conference call between Ingersoll-Rand and MSFC, and a tentative agreement was reached to proceed with a project plan in FY88. A project plan was submitted and project funding awarded in FY88. The Team received progress reports on the project at review meetings at the MSFC TU office in February and July of 1988. The RTI Team met with Ingersoll and MSFC at MSFC in April, and a more detailed plan of mutual responsibilities and action has been formulated. United States Booster joined the team effort in September 1989. United States Booster is to complete a white paper on their proposed solution.

7.0 TRAVEL

October 14, 1988: John Cleland participated in a meeting of the **National Technology Transfer Center (NTTC) Planning Committee** at Washington, D.C. to format and establish objectives contained in congressionally mandated NASA document.

October 18, 1988: S.A. Lehrman visited **Champion International's** pulp and paper mill in Canton, NC to review corrosion problems.

October 19, 1988: S.A. Lehrman met with Robert Cohen **(SCANA)** John Hall (SCANA), Robert Henderson **(SC Research Authority)** and Paul Brockman in Columbia, SC. The purpose of the meeting was to discuss developing Application Engineering Projects with SCANA in the areas of power and communication.

October 25, 1988: Dan Winfield attended the **NIH-Industry Collaboration Forum** in Washington, DC. The Forum is NIH's approach to implementing the Federal Technology Transfer Act.

October 25-27, 1988: J. Cleland accompanied H. Clarks and P. Brockman to meetings at **Maine** research facilities in Bangor, Brunswick, and Portland; Maine.

October 26-27, 1988: Dan Winfield attended the 1988 **Neural Prosthesis Workshop** sponsored by the National Institute on Neurological and Communicative Disorders and Stroke.

November 1, 1988: Dan Winfield travelled to Philadelphia to discuss technology needs in cardiology with Dr. Nathaniel Reichek, **University of Pennsylvania.** He also discussed development of new problem statements with Dr. Joel Nobel of **ECRI.**

November 2, 1988: Doris Rouse met with Ray Gilbert and Len Ault at **NASA HQ** to discuss Applications Engineering Projects.

November 2, 1988: Dan Winfield met with a task force at **Reading Rehabilitation Hospital,** Reading, Pennsylvania to discuss ideas for rehabilitation technology projects.

November 4, 1988: J. Cleland attended a **NTTC** meeting at NASA Headquarters in Washington, DC to review and discuss draft report materials. He also met with TU staff on current projects.

November 9-10, 1988: S.A. Lehrman and D.J. Rouse met with Tom Hammond and several engineering staff at **KSC** to discuss developing new Application Engineering Projects.

November 15, 1988: S.A. Lehrman met with Ralph Ferraro, Dr. Jack Lawler, and Roger Taylor of **EPRI's Power Electronics Application Center (PEAC)** in Knoxville, TN. The purpose of the meeting was to discuss transferring LeRC 20 khz power distribution and management technology to the electroplating industry.

November 16-17, 1988: Doris Rouse travelled to LaRC to meet with representatives from the **Paralyzed Veterans Association** and LaRC to discuss a possible project for improved access to commuter airlines by the mobility disabled.

November 29, 1988: S.A. Lehrman and Doris Rouse attended a meeting at the **Princeton Plasma Physics Laboratory (PPPL)** in Princeton, NJ. The purpose of the meeting was to discuss commercial applications for the NASA/MSFC sponsored, PPPL developed neutral atomic oxygen beam generator.

November 29-30, 1988: J. Cleland participated in a **NTTC** meeting at NASA SSC to review and discuss draft report and action items. Cleland presented NTTC Organization and Management Plan. He also met with SSC TUO to discuss low-cost housing technology and on-going projects.

November 29-30, 1988: R.J. Wallace attended the joint **AIAA/NASA First International Symposium on Space Automation and Robotics** in Arlington, VA and explored TU project opportunities with other attenders.

November 30, 1988: S.A. Lehrman and D.J. Rouse met with representatives of **International Paper Company** at their corporate research center in Tuxedo Park, NY. The purpose of the meeting was to discuss developing an Applications Engineering Project(s).

December 7-8, 1988: D.J. Rouse made a presentation at a meeting of the Florida STAC State Affiliates in Tampa, FL.

December 20, 1988: J. Cleland attended a meeting of the **NTTC Planning Committee.** Final draft preparations were made for a report to the congressional committees. A task group finalized objectives, organization, and methods.

January 9-10, 1989: Team member John Cleland traveled to Washington, D.C. and participated in a review and report editing meeting of the **National Technology Transfer Center (NTTC) Task Team.** Technology transfer projects planning were also discussed with NASA Technology Utilization managers.

January 17, 1989: John Cleland attended a **NTTC Task Team** meeting in Washington, D.C. for the final draft study report review.

January 18-19, 1989: John Cleland accompanied Ray Gilbert of NASA OCP and B. Wolverton and L. Tilton on a tour of **Biosphere I project site** and support facilities in Oracle, Arizona. Discussions and planning were conducted related to NASA technology transfer to Space Biosphere Ventures. A workshop was recommended to be held in Fall 1989.

January 18, 1989: Team member Stephen Lehrman attended a meeting at **LeRC** with Ralph Ferrano of the Power Electronics Research Center and Doyle Skinree of Basic Industries Research Lab to discuss a new applications engineering project on electroplating.

January 23-24, 1989: Team member Daniel Winfield coordinated two meetings with industry (Medical Engineering Corporation and Life-Tech, Inc.) at **NASA LaRC** to discuss commercialization of the **Urodynamic Pressure Catheter.**

January 23, 1989: Stephen Lehrman attended a meeting at **NASA HQ** with Henry Clarks, Len Ault, Ray Gilbert of NASA OCP, Jim Rogers of the U.S. Navy, John Samos of LaRC, Tom Hammond of KSC, Paul McWilliams of NIAC and Ron Thornton of STAC. The purpose of the meeting was to discuss joint NASA and U.S. Navy technology transfer projects.

January 25, 1989: John Cleland traveled to **Washington, D.C.** to participate in a televideo conference between NASA HQ, Gallaudet University, MSFC TUO and engineers, and the RTI Team to resolve issues on the **Emergency Vehicle Alert System** (EVAS) project. Other TU business was also addressed by Cleland at OCP offices.

January 29 - February 1, 1989: Dan Winfield attended and gave two presentations to a national conference, **Explorations: Technological Innovations for an Aging Population**, in Orlando, Florida.

February 2, 1989: Dan Winfield met with representatives at the **American Cancer Society** - Florida Division, NASA KSC and NASA HQ in Orlando, Florida to discuss new projects with ACS.

February 7, 1989: Dan Winfield travelled to Baltimore for meetings with Don Friedman at the **University of Maryland Medical School** (Melanona Screening) and the **Veterans Administration Prosthetics Center.**

February 8-10, 1989: John Cleland made a presentation at the **NASA MSFC Technology Transfer Orientation for Alabama - Tennessee State Leaders.** Cleland also met with NASA, Martin Marietta, and USBI engineers/managers on the FARMS, Waterjet, and EVAS projects. A teleconference with Gallaudet University was also held about EVAS.

February 15, 1989: Dan Winfield traveled to **Washington, D.C.** for TU project meetings with Ray Gilbert and Don Friedman.

February 16-17, 1989: Dan Winfield took part in a meeting at **Johnson & Johnson, New Brunswick, New Jersey** on commercialization of the **Bladder Fullness Monitor.** He also discussed other project opportunities with their Manager of Business Development.

February 28 - March 1, 1989: Stephen Lehrman attended a presentation at **NASA Johnson Space Center of the Intelligent Physics Tutor.**

March 13, 1989: Dan Winfield and Janet Dunham (RTI) traveled to Washington, D.C. along with George Finelli of NASA LaRC to make a presentation in software reliability to the **Joint HIMA/NEMA Medical Device Industry Computer Software Committee.**

March 22-23, 1989: Dan Winfield travelled to **Houston** to participate in a meeting with R. Juday, T. Fisher (JSC), D. Rickman (SSC), and B. Massof (Wilmer Eye Institute) on the

applications of the **Programmable Remapper in low vision research**. While in Houston, Mr. Winfield also met with staff of the Texas Medical Center.

March 27, 1989: Stephen Lehrman attended a meeting at **NASA HQ** with Ray Gilbert and Jim Rausch and Dick Donahue of the **U.S. Army Corps of Engineers**. The purpose of the meeting was to discuss a collaborative applications engineering project between NASA and the Corps of Engineers in Oklahoma.

March 29-31, 1989: John Cleland met with **Ingersoll-Rand, U.S. Boosters Inc./UTC,** and the MSFC TU Office in Huntsville, to finalize mutual objectives under the **Water Jet Nozzle Design Project**. Meetings were also held with the TUO, Martin Marietta and MSFC Productivity Center to review the Technical Directive for the FARMS project.

April 18, 1989: Doris Rouse met in Washington with Ted Maher of the **U.S. Department of Agriculture** to discuss potential projects involving risk management in rural areas. Projects would be conducted under a Kellogg Foundation grant to USDA.

April 19, 1989: John Cleland met with R. Gilbert, NASA TU, and M. Nelson, **Space Biospheres Ventures** to discuss the mutual workshop and technology transfer plans. Cleland also discussed TU priorities with James Rose and H. Clarks, NASA OCP.

April 27-28, 1989: Doris Rouse visited **Kennedy Space Center** to attend pre-launch briefings and attempt to view the STS-30 launch. During this time, she met with Dick Davis on the Digital Hearing Aid and Otto Fedor on the Cold Engine projects for rehabilitation.

May 8-9, 1989: Dan Winfield gave a presentation on the NASA Technology Applications Program to the Mid-Atlantic Regional Meeting of the **National Rehabilitation Association** in Charleston, WV.

May 29-30, 1989: Dan Winfield travelled to Houston for technology applications meetings with the **Houston Area Research Center, International Biomedical, Inc., and the Limbs of Love Foundation.**

May 31, 1989: S.A. Lehrman participated in a meeting at Lewis Research Center with **DuPont Electronics** and the LeRC Materials Division. The purpose of the meeting was to discuss using advanced materials to improve trim and swage tools.

May 31-June 1, 1989: Dan Winfield participated in the **In-Flight Flow Cytometer Workshop** at Johnson Space Center. The workshop obtained final input from the science community for an instrument development RFP.

June 12, 1989: S.A. Lehrman participated in a meeting at **Kennedy Space Center** concerning the liquid airpack applications engineering project.

June 19-20, 1989: Doris Rouse participated in the **NASA TU Technology Transfer Executive Committee Meeting** in Washington, D.C.

June 20, 1989: Doris Rouse met with John Carnes, Manager of Port Operations Programs in the **Maritime Administration** to discuss possible use of Marshall Space Flight Center turbopump technology in oil spill cleanup.

June 23, 1989: Dan Winfield coordinated two exploratory technology applications meetings at **NASA-Goddard**: 1) Augmentative Communication Device with ACS, Inc. and Dr. Murzy Jhabvala and 2) Adaptive Gripping Device with Reading Rehabilitation Hospital and Mr. John Vranish.

June 22-25, 1989: John Cleland met with the **MSFC TU Office** and technical representatives on the FARMs project, on state initiatives and on potential new starts. Cleland worked with D. Kornfeld to discuss data analysis and plans to wrap up the rotary reactor optimization project.

July 14, 1989: Dr. Rouse participated in a meeting at **NASA HQ** to discuss NASA TU's education initiative.

July 24-28, 1989: Dan Winfield attended the **19th Intersociety Conference on Environmental Systems** in San Diego, CA. While on the West Coast, he met with engineers from Cortrex Electronics on progress toward development of the Wanderer Notification System.

July 12, 1989: Dan Winfield and Catherine Canada met with the staff of the **National Easter Seal Society Headquarters** in Chicago to initiate a program to identify technology transfer opportunities with the Easter Seal Society.

August 1, 1989: Stephen Lehrman met with Dr. Roosevelt Fernandes (**Southern California Edison Company**) and Ray Arnold (Code EC) and Dean Olmstead (Code EC) at NASA HQ to discuss commercial applications for JPL's Mobile Satellite Communications Program.

August 7, 1989: Catherine Canada met with rehabilitation staff at the Meeting Street School in Providence, RI (an **Easter Seal Affiliate**) to discuss problems which they suggested for the TU program.

August 8, 1989: Dr. Rouse participated in a meeting at **NASA HQ** with **MSFC** and **Space Foundation** representatives to discuss the NASA TU education initiative.

August 8, 1989: Dr. Rouse met with NASA HQ staff to review the manuscripts for the **International Aeronautics Federation Conference.**

August 8-9, 1989: Catherine Canada met with staff and volunteers at the Tarrant County **Easter Seal Society**, Ft. Worth, TX to discuss numerous technology transfer opportunities suggested by their staff.

August 10, 1989: Dan Winfield met with the LaRC TU staff and representatives of the **Virginia rehabilitation community** to discuss mechanisms to identify and pursue technology applications to priority rehab problems.

August 16, 1989: Doris Rouse and Dan Winfield participated in a meeting at NASA HQ on a proposed **Space Medicine Institute** located adjacent to Kennedy Space Center.

August 17, 1989: John Cleland visited LaRC and participated in **Arnold Systems Inc.** wind tunnel tests. He also met with Jim Robertson on EL flat panels and reviewed other LaRC projects with John Samos and Jim Rose.

August 22, 1989: Stephen Lehrman participated in a meeting with **Air Products and Chemicals Inc.**, LeRC Electro Physics Office, and LeRC TU Office to discuss a new Applications Engineering Project to produce scratch resistant diamond-like carbon coatings for ophthalmic lenses.

August 28-30, 1989: Stephen Lehrman attended the **International Association of Fire Chiefs (IAFC)** annual conference in Indianapolis, IN as part of a NASA Team presenting the KSC Liquid Airpack. Four manufacturers and over 100 fire departments were contacted.

September 18-19, 1989: Dr. Rouse participated in the meeting for the **Technology Transfer Executive Committee** in Washington, D.C.

September 21, 1989: Stephen Lehrman participated in a presentation by Phil Winkler **(Air Products)**, Bruce Banks (LeRC) and Harvey Schwartz (LeRC) to Ray Gilbert on a new Applications Engineering Project to produce scratch resistant diamond-like carbon coatings for ophthalmic lenses.

September 21, 1989: John Cleland traveled to **NASA HQ** in Washington, D.C. to meet with Ray Gilbert and officials from LeRC, ARC, and industry to discuss several projects and project plans.

September 21, 1989: Dr. Rouse made a presentation to the **Virginia Economic Development Council** and representatives from the Virginia Center for Innovative Technology.

APPENDIX A: NASA TECHNOLOGY APPLICATION TEAM STAFF, CONSULTANTS, AND STUDENT INTERNS

STAFF MEMBER	BACKGROUND	PROJECT RESPONSIBILITY
Dr. Doris J. Rouse	*B.A., Chemistry / Ph.D., Physiology* Thirteen years in NASA Program. Five years research and management in industry.	Project Director: Assignment of project tasks to staff and consultants. Program planning, review for all Team projects.
Dr. John Cleland	*B.S., Aerospace Engineering / Ph.D., Mechanical Engineering* Five years in NASA Technology Utilization Program. Twelve years' industry and U.S. Army research and management experience in process engineering.	Coordination of manufacturing and industrial projects. Areas of specialization include materials and robotics.
Stephen A. Lehrman, M.S.	*B.S., Mechanical Engineering / M.S., Mechanical Engineering* Two years in NASA Technology Utilization program. Thirteen years' experience in mechanical design and analysis for manufacturing industries.	Coordination of manufacturing and industrial projects. Areas of specialization include machine design, precision engineering, and metrology.
Robert J. Wallace, M.S.	*B.A., Environmental Design / M.S., Industrial Engineering* Six years in NASA Technology Utilization Program. Eight years' experience in CAD/CAM and automated factory simulation.	Coordination of manufacturing and industrial projects. Area of specialization includes automation and flexible manufacturing systems.

APPENDIX A: NASA TECHNOLOGY APPLICATION TEAM STAFF, CONSULTANTS, AND STUDENT INTERNS

(continued)

STAFF MEMBER	BACKGROUND	PROJECT RESPONSIBILITY
Daniel L. Winfield, M.S.	*B.S., Engineering Analysis / M.S., Biomedical Engineering* Five years in NASA Technology Utilization Program. Eight years' experience in product development and manufacturing in the medical device industry.	Management of biomedical projects. Areas of specialization include ophthalmology and orthopedics
Stephen D. Mangum, M.P.A.	*B.S., Political Science / M.P.A., Master of Public Administration* Serving his second year in NASA Technology Utilization Program. One year experience at NASA Headquarters' International Relations Division assessing the impact of the export of technology on U.S. industry and commercial competitiveness.	Serves as a Program Analyst. Areas of concentration include organizational management, budgeting and finance, and data-base management. Assists project managers in background, marketing/industry studies and development of cofunding opportunities. Also serves as the Technology Utilization Network System (TUNS) supervisor for the Team.

APPENDIX A: NASA TECHNOLOGY APPLICATION TEAM STAFF, CONSULTANTS, AND STUDENT INTERNS

(continued)

CONSULTANT	BACKGROUND	PROJECT RESPONSIBILITY
William Meade, M.B.A. *Chapel Hill, NC*	B.S., Marine Engineering and M.B.A. with concentration in Marketing. Three years as RTI consultant.	Assist in developing commercialization strategies and presenting the Technology Utilization Program to industry.
Bernard Maggin *Washington, DC*	B.S., Aeronautical Engineering. Over 35 years' experience in aerospace and energy engineering. Technical and senior management positions in 28 years with NASA. Five years as a consultant to RTI Applications Team.	Management of Public Safety Helicopter project. Management of Tilt Rotor project. Consultation with RTI staff on development of Automation and Robotics projects.
Dr. Francesco Iannetti *Raleigh, NC*	B.S. Chemical Engineering and M.S., Ph.D., Materials Engineering	Assists Applications Team in preparing NASA Thermal Protection Materials (JSC) and materials problem statements.
Reed Barnett *Melbourne Beach, FL*	B.S., Aeronautical Engineering. Forty years' experience in NASA, serving five of those years as the KSC Technology Utilization Officer. Three years as an RTI Consultant.	Assisting Application Team in coordinating Application projects in the southeastern United States. Providing Applications Team support to KSC TU Office.

APPENDIX A: NASA TECHNOLOGY APPLICATION TEAM STAFF, CONSULTANTS, AND STUDENT INTERNS

(continued)

STUDENT INTERN	BACKGROUND	PROJECT RESPONSIBILITY
Catherine Canada *Duke University and University of North Carolina Medical School*	B.S., Biomedical Engineering. Experience as a research assistant in Duke University Biomedical Engineering Department. Second-year medical student at the University of North Carolina, Chapel Hill. Second summer as RTI Student Intern.	Assisted Team staff in background research and development of problem statements in biomedical and rehabilitation areas.
Perry W. Cornelius *North Carolina A&T State Universtity and Duke University*	B.S., Electrical Engineering / M.S., Candidate, Electrical Engineering. Experience as a research and teaching assistant in Duke University Electrical Engineering Department.	Assited team staff in background research and preparation of problem statements in electronics and automation.
Jeffrey T. Antley *North Carolina State University*	B.S., Candidate, Aerospace Engineering.	Assited Team staff in background research and preparation of problem statements in materials and electronics.

APPENDIX B: GLOSSARY OF TERMS

GLOSSARY

A&R	automation and robotics
ACS	American Cancer Society
AFB	Air Force Base
AFOSR	Air Force Office of Scientific Research
AI	Artificial Intelligence
AISI	American Iron and Steel Institute
AMRF	Automated Manufacturing Research Facilities
AoA	Administration on Aging
AOPS	Arnold Oscillating Power System
ARC	Ames Research Center
ATAC	Advanced Technology Advisory Committee (NASA)
ATL	Advanced Technology Laboratories
BPRC	Bioprocessing and Pharmaceutical Research Center
CAD/CAM	computer-aided design/computer-aided manufacture
CCD	closed-circuit display
CCTV	closed-circuit television
CRT	cathode-ray tube
CVD	chemical vapor deprivation
CWRU	Case Western Reserve University
D/A	digital/analog
DoD	Department of Defense
EPI	Emulsion Polymers Institute
EPRI	Electric Power Research Institute
FBI	Federal Bureau of Investigation
FLC	Federal Laboratory Consortium
FLIR	forward-looking infrared
FOCS	fiber-optic chemical sensors
FTS	flight telerobotic system
GC/MS	gas chromatography/mass spectrometry
GSFC	Goddard Space Flight Center
HF	hydrofluoric (acid)
HIMA	Health Industry Manufacturers Association
HQ	Headquarters (NASA)
IAC	Interactive Analysis Capability
ICP	intracranial pressure
IR	infrared
ITT	Institute of Textile Technology
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
KATE	Knowledge-based Automated Test Engineer
KSC	Kennedy Space Center
LaRC	Langley Research Center
LCD	liquid crystal displays
LeRC	Lewis Research Center
LLTV	low-light television

MCV	Medical College of Virginia
MICOM	U.S. Army Missile Command
MOU	Memorandum of Understanding
MSFC	Marshall Space Flight Center
MTI	Mechanical Technology, Inc.
NASA	National Aeronautics and Space Administration
NIST	National Institute of Standards and Technology
NEI	National Eye Institute
NIA	National Institute on Aging
NIDRR	National Institute on Disability and Rehabilitation Research
NIH	National Institutes of Health
NTTC	National Technology Transfer Center
OCP	Office of Commercial Programs
ONR	Office of Naval Research
OSU	Ohio State University
P^2L^2	pulsed phase-locked loop
POP	Program Operating Plan
PSH	public-service helicopter
PSHTT	public service helicopter technology transfer
PTI	Particles Technology, Inc.
PVA	Paralyzed Veterans of America
PVI	pressure-volume index
RFP	request for proposal
RTI	Research Triangle Institute
RTOP	Research and Technology Operation Plan
SDI	Strategic Defense Initiative
SSC	Stennis Space Center
TOMS	Topographical Optical Mapping System
TPS	thermal protection system
TU	Technology Utilization
TUNS	Technology Utilization Network System
VA	Veterans' Administration
VLSI	very large scale integrated