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John F. Kennedy Space Center

About the Cover

The cover depicts the transfer of technology from aerospace to private industry.

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NASA Technical Memorandum 109200

Research and Technology 1993 Annual Report of the John F. Kennedy Space Center

FOREWORD

As the NASA Center responsible for preparing and launching space missions, the John F. Kennedy Space Center is placing increasing emphasis on its advanced technology development program. This program encompasses the efforts of the Engineering Development Directorate laboratories, most of the KSC operations contractors, academia, and selected commercial industries — all working in a team effort within their own areas of expertise. This edition of the Kennedy Space Center Research and Technology 1993 Annual Report covers efforts of all these contributors to the KSC advanced technology development program, as well as our technology transfer activities.

W.J. Sheehan, Chief, Technology Development and Transfer Office (TDO), (407) 867-3017, is responsible for publication of this report and should be contacted for any desired information regarding the advanced technology program.

Robert L. Crippen
Director, John F. Kennedy Space Center

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TECHNOLOGY TRANSFER ACTIVITIES AND OPPORTUNITIES

INTRODUCTION

During 1993, the Kennedy Space Center (KSC) experienced considerable growth in activities and opportunities under its Technology Transfer Program. These activities and opportunities are providing new technology and problem solutions to industries throughout the country. The transfer of this new technology serves to strengthen the nation's economy and benefit the general public. KSC's Technology Transfer Program is being performed and managed under the Technology Development and Transfer Office (DE-TDO) of the Engineering Development Directorate (DE).

TechTracS DATABASE

A special patent and new technology database, TechTracS, has been developed to appropriately monitor various activities and actions regarding technology transfer. Since becoming operational in March of this year, this database now accounts for 646 items of new technology reported since 1980 and 796 action items that have been completed since 1992. Database records for a total of 411 contracts and grants containing patent rights and new technology clauses have also been developed over the past year. This database has a unique feature that automatically generates 63 separate standard letters (as they become due) for processing the new technology items and monitoring the contracts and grants.

The TechTracS database also provides for the administration and processing of inventions under the NASA Patent Program. It serves as an excellent system for monitoring the docketing, evaluating, and processing of patent applications for inventions developed by civil service and contractor employees. TechTracS was developed for KSC by the Research Triangle Institute. Its success has prompted other NASA field centers to also implement this database for their Patent and Technology Transfer Programs.

APPLICATION ENGINEERING PROJECTS

KSC's Technology Transfer Program had eight application engineering projects that were active during 1993. The main purpose of these projects is to demonstrate a specific application of technology that has resulted from the space program. A highlight of this activity for 1993 was the establishment of a cost-sharing Dual-Use Technology Partnership between the State of Florida and KSC for initiating technology transfer projects with commercial manufacturers located in Florida. The application engineering projects are:

1. Automated Citrus Tree Assessment

   The automated citrus tree assessment project is the result of a Memorandum of Understanding between KSC and the Charlotte County Property Appraiser to establish a computerized system of counting citrus trees. Several Florida county property appraisers teamed with Charlotte County to help fund this project. This system will make it possible for property appraisers to more quickly and more accurately count citrus trees for tax assessment. The first system, including both hardware and software, was delivered to Charlotte County for operational testing and use. (Refer to the Research and Technology 1992 Annual Report.)

2. Oxygen Concentrator

The oxygen concentrator project is being developed with the Florida Solar Energy Center (FSEC) under the University of Central Florida. The objective is to conduct research toward the development and commercialization of a superoxide ion-conducting electrolytic device for the production of medical-grade oxygen from air. The Research Triangle Institute located a commercial manufacturer that has now agreed to further fund the development of this unique oxygen concentrator.

3. ATP Assay for Susceptibility Testing

The purpose of this project is to develop a new method of determining drug susceptibility of mycobacteria using an adenosine triphosphate (ATP). Mycobacterium Avium Complex is one of the most common opportunistic infections in AIDS patients. The ATP assay uses a bioluminescence method to measure ATP, which provides a means to measure metabolic changes. Application of this assay to drug susceptibility testing will offer a method with high specificity requiring shorter assay times than current methods.

4. Digital Hearing Aid

The objective of the digital hearing aid project is to develop a new digital hearing aid and companion hearing assessment and device-fitting procedure that would result in a much improved acoustic amplification for the hearing-impaired. The Central Institute for the Deaf (CID) of Washington University has led the development effort for this digital hearing aid in conjunction with KSC and the Department of Veterans Affairs. The 3M Corporation has served as the industrial collaborator and will manufacture the hearing aid under an exclusive, worldwide patent license to the patents owned by CID. The fabrication of a commercial prototype is now being considered by the 3M Corporation. (Refer to the Research and Technology 1990 Annual Report.)

5. Conductive Polymer Coatings

In a joint effort with the Department of Energy (DOE), KSC has initiated a project to be implemented at DOE's Los Alamos National Laboratory (LANL) for developing an electrically conductive polymer which can be used in coating systems that protect metal from corrosion damage. This is the first cooperative project under the DOE/NASA Memorandum of Understanding on Federal Technology Transfer Efforts signed by the NASA Administrator and the Secretary of the Department of Energy on July 9, 1992. A joint NASA/DOE CRADA is currently being pursued. (Refer to the Research and Technology 1992 Annual Report.)

6. Infrared Video Survey System

This is a co-sponsored project initiated with the State of Florida's Technological Research and Development Authority (TRDA) to develop evaluation procedures and ground-truth data needed to verify and promote the commercial use of a space-age, infrared video system for detecting and locating leaks or other anomalies in gas and electric power transmission lines. The project is being accomplished under a team effort involving KSC, the University of Florida, major gas and electric power companies, and an aerial survey equipment company. Two major electric power companies have expressed an interest in utilizing this type of system in conjunction with a geographical information system. In view of this expanded interest regarding how the system should be utilized, the present project will not be continued into the second year.

7. Ground Processing Scheduling System (GPSS)

   The GPSS was developed by KSC, Ames Research Center, and Lockheed Space Operations Company to schedule the numerous events involving the ground processing of the Shuttle vehicle and launcher. The GPSS software was demonstrated at the Technology 2002 Conference in Baltimore, Maryland, in 1992. A commercial software development company in California has now entered into a copyright license agreement with NASA to transition this technology to other areas having potential applications. This license constituted the first NASA copyright license for commercializing computer software.

8. Universal Signal Conditioning Amplifier (USCA)

   The USCA will be a rugged and field-installable self-programmable amplifier that works in combination with a tag random access memory (RAM) attached to various types of transducers. This project is the first of many that will involve dual-use technologies to be developed and utilized for both Government and non-Government markets. Under a special Dual-Use Technology Partnership between NASA KSC and the State of Florida, as represented by the Technological Research and Development Authority (TRDA), this project will require a Florida manufacturer to contribute a minimum of 25 percent of the total project cost. The TRDA and NASA KSC will equally co-fund up to 75 percent of the cost.

STATISTICAL STATUS OF NEW TECHNOLOGY ITEMS

The following chart shows the current statistics for 1991, 1992, and 1993 on the new technology items being processed. These new technology items reflect the extent of creative developments at KSC.

Status	No. of Items		
	1991	1992	1993
Items reports	38	49	77
Items awaiting evaluation	24	29	39
Technical briefs awaiting publication	48	25	42
Technical briefs published	7	32	43
Industry requests for TSP's*	1,143	4,492	9,083
Monetary awards in process	59	46	138**

* Technical support packages (TSP's) provide additional information on technical briefs.

** The 138 monetary awards of $150 each will result in a total of $20,700 being granted to both civil service and contractor employees.

These statistics further indicate a substantial increase in participation in KSC's Technology Transfer Program, especially with an eight-fold increase in industry inquiries that went from 1,143 in 1991 to 9,083 in 1993.

Materials Science

The Materials Science Technology program at the John F. Kennedy Space Center (KSC) supports advanced technologies directed toward improving launch site safety, operability, and maintainability. The program includes application materials engineering, materials testing, chemistry, and other science disciplines. The near-term program focuses on Shuttle ground processing improvement by providing materials and coatings that afford better corrosion control, materials with better hazardous systems compatibility, and improved testing methods and instrumentation. The long-term program will investigate materials technology that can be used to develop new launch and processing facilities for future vehicles and payloads, will reduce the cost of maintenance, will provide higher safety and reliability, and will provide more environmentally compatible systems.

Environmentally Compliant Coating Systems for the Shuttle Launch Sites

In recent years, environmental regulations have sought to restrict the use of paints and coatings containing high concentrations of solvent. The use of the solvent-based, inorganic, zinc-rich primers currently tested and approved could be prohibited at KSC in the near future due to their volatile organic content (VOC) levels. These materials all have VOC levels of 450 grams per liter (3.75 pounds per gallon), whereas the maximum levels allowed in some areas (such as California, certain counties in Florida, and many other urban areas of the United States) are 420 grams per liter (3.5 pounds per gallon) or lower. Legislation has dictated that this level be reduced to 350 grams per liter (2.8 pounds per gallon). Therefore, the possibility is very real that the inorganic, zinc-rich primers and topcoat systems presently approved at KSC will be prohibited and unavailable for use.

In response to this circumstance, the current study has been expanded to search for inorganic, zinc-rich coatings and topcoat systems that provide superior protection to KSC launch structures and ground support equipment and that fully comply with environmental regulations. Currently, the protective coating manufacturing industry is producing environmentally compliant, inorganic zinc coatings such as high-volume solids and water-based systems. New topcoat systems are also being developed to conform to the anticipated strengthening of environmental air quality standards.

The application of these environmentally compliant coating systems was completed in April 1991, and the test panels were exposed in May 1991 to atmospheric contaminants at the KSC beach corrosion site with concurrent applications of an acid slurry to simulate the conditions experienced at the launch site. The results of the 18-month exposure and the laboratory data have been compiled in a report available under document number FAM-93-2004. The results of this testing have identified many environmentally compliant coating systems to be used on KSC launch structures and ground support equipment. The successful coating materials have been included on the Approved Products List contained in KSC-STD-C-0001. The panels are currently nearing the 30-month evaluation point and a status report detailing the 36-month exposure results will be prepared.

Key accomplishments:

- Successfully applied the environmentally compliant coating systems to over 300 test panels and exposed them at the KSC beach corrosion test site.
- Conducted laboratory tests on the zinc primers to determine heat resistance and the level of adhesion to carbon steel.
- Evaluated the coating systems at the 18-month point and prepared a report detailing the beach exposure and laboratory data.

Key milestones:

- Continue to monitor the test panels for the required 5-year exposure period and apply the acid slurry at regular intervals to simulate launch site conditions.
- Produce a status report at the 36-month point and a final report at the end of the 60-month exposure period to document the performance of the coating systems.

Contact: L.G. MacDowell, DM-MSL-22, (407) 867-3400

NASA Headquarters Sponsor: Office of Space Flight

KSC Corrosion Test Site

KSC's Material Safety Data Sheets

Regulations for the maintenance of Material Safety Data Sheets (MSDS's) for hazardous chemicals used by employees of a company include the requirement that employers (1) maintain MSDS's for each hazardous chemical in the workplace and (2) ensure the sheets are readily accessible during each work shift to employees when they are in their work areas [29 CFR 1910.1200(g) (8)]. Due to the nature of procurement and logistics at KSC, most products arrive at central receiving or warehousing areas and, from there, are distributed for storage and use in KSC work areas. MSDS's are received with shipments of hazardous chemicals or are mailed separately to the recipient supply organization. A mechanism for computerizing these MSDS's in order to manage and make them readily accessible to work area personnel was desired.

The Base Operations Contract (BOC) Environmental Health Division was tasked with identifying a feasible solution, and the support of the BOC Computing Services Department was enlisted. Responses to a request for information on available technology for both mainframe and microcomputer systems were reviewed, and a microcomputer platform utilizing currently available off-the-shelf hardware was adopted as the best and most cost-effective means to accomplish the task. BOC Logistics purchased a workstation and commenced scanning MSDS's.

The KSC MSDS System is resident on the KSC Data Network and uses state-of-the-art optical disk technology and SQL Base database management software. The system software utilized is a combination of the Identitech, Inc. (a Melbourne, Florida, based company) software packages FYI (For Your Information) and AIMS (Advanced Information Management System). MSDS's are entered into the system using a scan workstation and are stored as images on the optical disks. The images are concurrently related to a combination of database keys for subsequent access and printing. These keys include a number of data elements, along with a control number assigned by the BOC database administrator and validation of the input. This control number is the common-denominator data element among a group of hazardous chemical databases, which include the MSDS System. Database security and image integrity is maintained using standard system log-on security features such as user identification and password, database backup to an alternate medium, and mirror imaging of data sheets on a separate optical disk. User access to MSDS's is accomplished via a scan or view workstation or a phone/facsimile (Dial-A-File) facility. A scan or view workstation operator may request that an MSDS data sheet be printed locally or that it be transmitted to a specified FAX machine.

The Dial-A-File facility allows a user without a workstation to phone in a request for an MSDS from any touchtone telephone using the TSRS control number as the key and to have the MSDS sent to a designated FAX machine. Designation of the FAX telephone number is accomplished as a step of the system voice and user touchtone phone dialog that occurs during the Dial-A-File session. Dial-A-File is a useful tool for fire and rescue activities since it provides access to MSDS data utilizing commercially available cellular phones and FAX equipment. Control numbers (TSRS numbers) are obtained from the GP23-1 report, "Biomedical Operations and Research Office, Toxic Substances Registry System Index of Material Safety Data Sheets," which is produced and distributed by the BOC MSDS database administrator. These indices are provided in trade name, manufacturer, and stock number sequences and are physically placed at strategic locations throughout KSC and Cape Canaveral Air Force Station as defined in each NASA support contractor's hazard communication plan.

For access to the MSDS System, the following minimal commercially available computer equipment and communications are required:

1. 386/33-megahertz personal computer with 4-megabyte RAM
2. VGA monitor (oversized recommended)
3. MS DOS 5.0
4. Windows 3.1
5. Mouse/drivers
6. Communications access to one of the following networks:
    a. Kennedy Data Network (KDN)
    b. Shuttle Operations Data Network (SODN)
    c. Payload Operations Network (PON)

Other subsequently developed database users of this technology include BOC Logistics, BOC Waste Management, and BOC Security.

Key accomplishments:

- MSDS System implemented at KSC on June 1, 1993.
- MSDS System currently contains approximately 11,000 entries.
- Optical jukebox storage media and system software upgraded in September 1993.

Key milestones:

- Capability for non-BOC organizations to directly update the database with MSDS's.
- Additional database key field capabilities for maintenance of organization-specific data.
- Scanning of additional MSDS's as new products that require them are acquired for use at KSC.

Contact: M.A. Cardinale, MD-MED-1, (407) 867-4237

Participating Organization: EG&G Florida, Inc. (D.B. Churchwell and M.A. Cochcroft)

NASA Headquarters Sponsor: Office of Space Flight

Environmental Cracking of Engineering Materials

Stress corrosion cracking (SCC) of metal alloys can have a devastating impact on the safety and reliability of all types of structures, mechanisms, and high-pressure gaseous systems. Many times, this type of failure is unexpected and occurs at the worst possible moment in a schedule of critical operation of a system. Obviously, when dealing in high-technology areas such as Shuttle launch and space travel, exotic metallic materials are used because of their high strength and lower weight. Typically, these types of materials are the most susceptible to the SCC phenomenon.

In response to this potential problem, work is being conducted under a grant with the Department of Ocean Engineering at Florida Atlantic University. The alloys currently under evaluation include several austenitic stainless steels such as 904L and 1925-6Mo. The materials are being evaluated using the slow strain rate technique (SSRT) or constant extension rate technique (CERT) in a corrosive solution that simulates the Space Transportation System (STS) launch environment. The SSRT test has been accepted as a reliable method to evaluate a material's SCC resistance in a reasonably short period of time.

The alloys in this study have been stressed at an extension rate of $4.7x10^{-6}$ centimeters per second in the corrosive medium and compared to identical materials tested in air. SSRT experiments were also conducted on the alloys at elevated temperatures (38 and 60 degrees Celsius). Differences in ductility (percent reduction of area and percent elongation), stress levels, time-to-failure, and fracture surface morphology are compared in both the corrosive and innocuous (air) environments and used to assess a material's susceptibility to SCC. Experiments to determine the effect of atmospheric exposure resulting from periodic spraying with the corrosive medium were also conducted. Additionally, experiments will be conducted to determine which parameters in the corrosive medium present at KSC have the greatest effect on the SCC susceptibility of these materials. The parameters to be investigated include temperature, hydrogen, and chloride ion concentrations. Pitting and crevice corrosion susceptibility will also be evaluated for the alloys to fully characterize their behavior.

Key accomplishments:

- Evaluated the strain rate and temperature dependency for SCC of the selected engineering alloys.
- Conducted atmospheric exposure tests with concurrent acid sprays on the selected alloys to determine SCC susceptibility.
- Determined the most critical parameters and threshold values for the corrosive environment that lead to SCC.

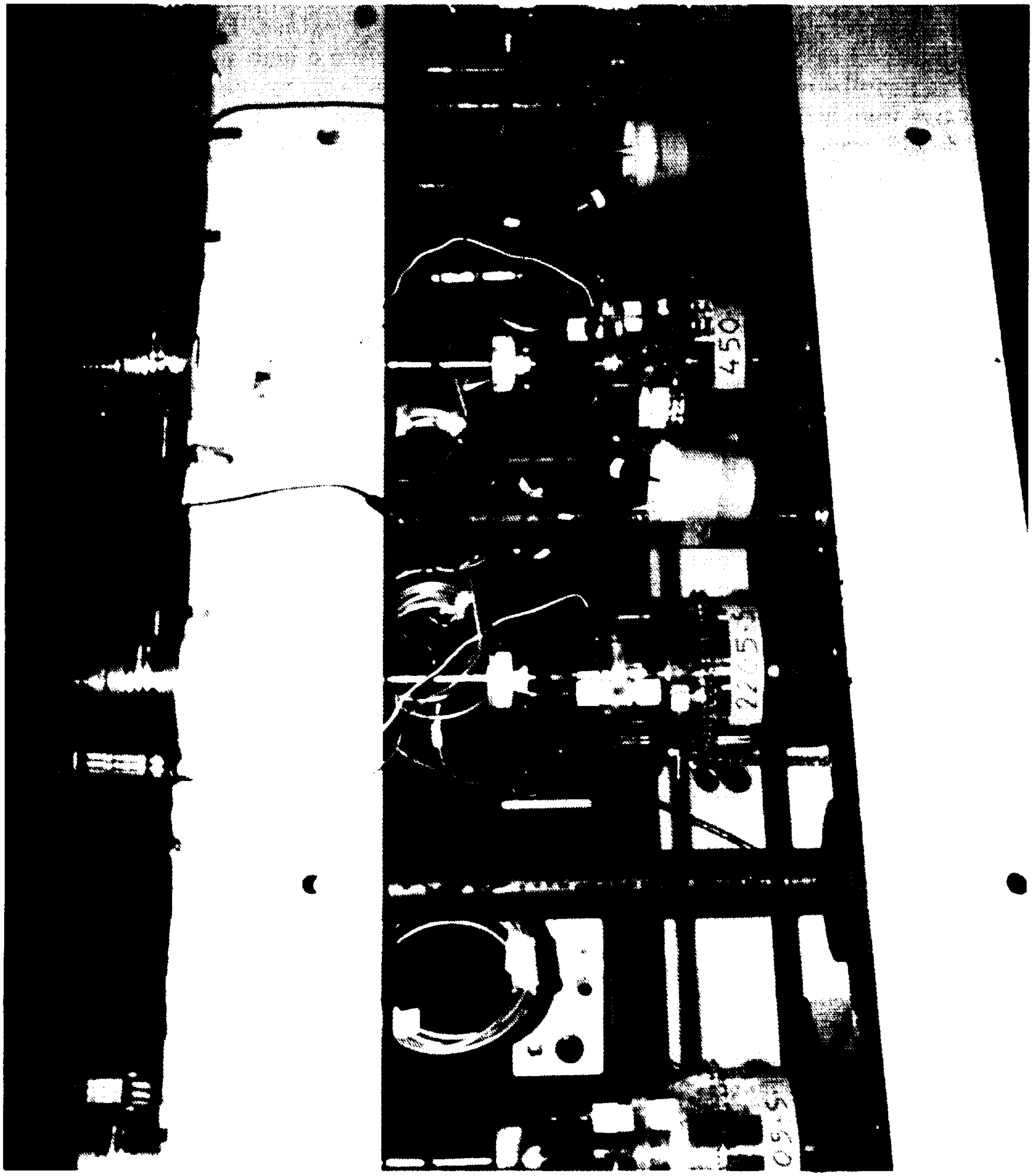
Key milestones:

- Evaluate the pitting and crevice corrosion performance of the identified materials subjected to the STS environment.
- Fully characterize the corrosion behavior of 904L and 1925-6Mo stainless steels for use on KSC launch structures and ground support equipment.

Contact: L.G. MacDowell, DM-MSL-22, (407) 867-3400

Participating Organization: Florida Atlantic University, Department of Ocean Engineering

NASA Headquarters Sponsor: Office of Space Systems Development



Slow Strain Rate Testing Apparatus

Flexible Insulation System Using Ultralow-Density Aerogels

Currently, highly evacuated multilayer insulations (MLI's) and evacuated powder insulations are the most widely used insulation methods for cryogenic equipment. MLI's are the most effective means of insulating. However, because of the highly anisotropic nature of MLI on actual equipment, it requires careful attention and results in generally awkward structural complexities. Furthermore, MLI is very expensive, bulky, and heavy and requires constant care to maintain a high vacuum state (10^{-4} torr or better) to realize its full advantage. Evacuated powder insulation is approximately one order of magnitude less effective than MLI but is isotropic, generally easier to handle, and requires only a moderate vacuum (10^{-2} or 10^{-3} torr). One potential drawback with powder insulations is their tendency to settle and form voids when subjected to vibration or thermal cycling, thus resulting in heat leaks in the areas of the voids. The objective of this project is to produce a flexible insulation system consisting of ultralow-density aerogels (ULDA's) interstitially formed in a low-density fiber matrix. The resulting composite structure is designed to combine the extremely low thermal conductivity of the ULDA's with the flexibility, durability, and engineerability of the fiber matrix.

Recent advances have resulted in the production of ULDA's. Their highly porous structure implies an order of magnitude or more reduction in solid conductivity compared to aerogels currently used in cryogenic insulation systems. Powdered aerogels conform to the shape of an insulation space but are limited in application and can be messy, especially in maintenance situations. While the powdered ULDA can be easily tailored to the geometries of cryogenic equipment, an innovative concept must be developed for the effective utilization of this new material without encountering the typical problems involved with powder insulations. Recent advances in the development of fiber materials have resulted in the production of organic and inorganic fibers useful as thermal insulations over a wide range of temperatures. Fiber-based cryogenic insulations offer the benefits of flexibility (both at room and cryogenic temperatures) and ease of installation. The thermal conductivity of these fiber materials is relatively high (about 30 milliwatts per meter kelvin in vacuum), due to the direct solid conduction through point contacts.

The new flexible insulation system provides ease of handling, improved thermal efficiency, and full flexibility for both evacuated and nonevacuated forms. By producing the ULDA in an opaque, low-density, low-conductivity fiber matrix, a flexible structure is provided for the containment of the aerogel powder. This configuration lends itself to the development of a self-contained superinsulation that could be easily applied in a wide range of internal and external applications on Earth and in space. There has been a constant demand for a cost-effective and easy-to-handle insulation system for cryogenic equipment, especially for irregularly shaped components such as valves, pipe joints, and sensors.

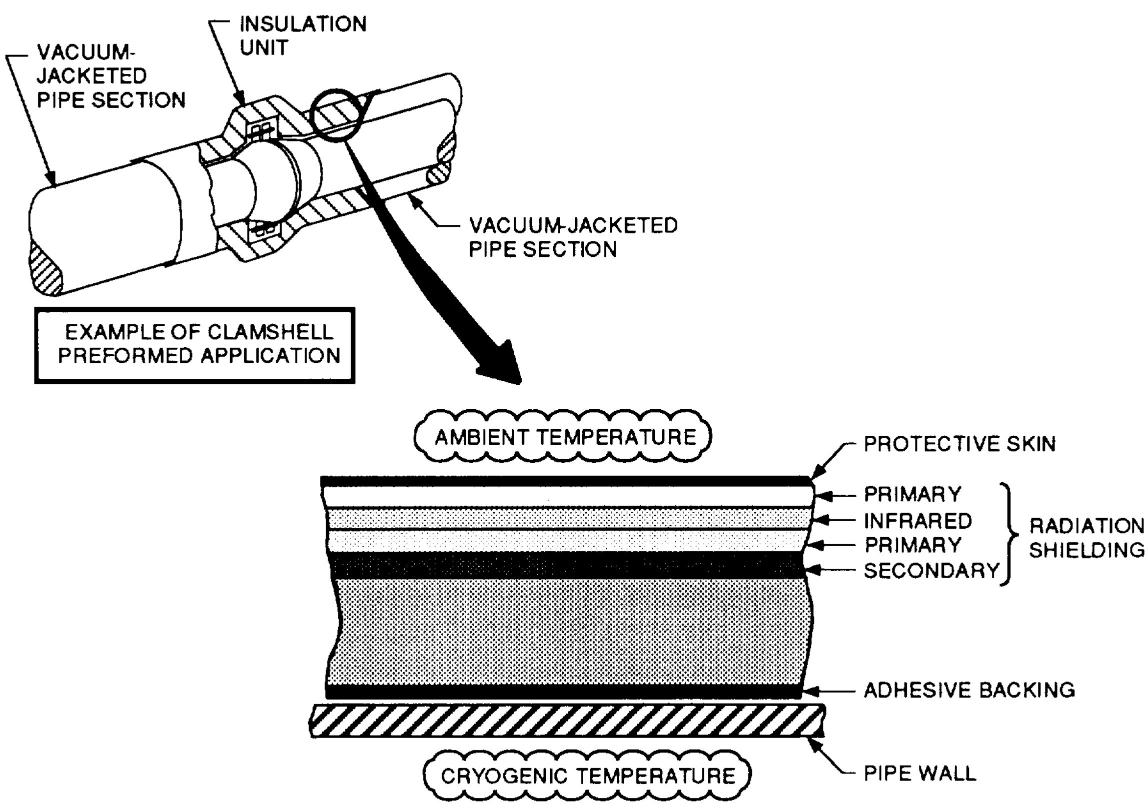
The Phase I work for the development of the flexible insulation system was completed by Aspen Systems, Inc. The bulk densities of the aerogels were measured to be 12 to 35 milligrams per cubic centimeter or several times less than those of conventional aerogels (80 to 120 milligrams per cubic centimeter). Performance testing of the core of the system (the aerogel/fiber composite) showed high insulating effectiveness, low sensitivity to gas pressure, and flexibility under all conditions. The composite was also investigated for material stability with excellent results. The concept for the superinsulation, which includes integrated layers of radiation shielding materials, has now been identified.

The targeted application of this superinsulation is used in cryogenic piping systems where vacuum-jacketing is not practical or feasible. The new insulation would provide an alternative to the costly vacuum-jacketing and MLI in future designs. Flight systems could benefit to an even greater degree by the application of such a high-performance, extremely light-weight, essentially inert, and easy-to-use material. Numerous commercial applications for this superinsulation also exist, including the pressing need for a replacement for chlorofluorocarbon-blown polyurethane foam (as used in refrigerators) by the end of 1995. Further reduction in manufacturing costs would lead to usage in the building industry.

Contact: J.E. Fesmire, DM-MED-41, (407) 867-3313

Participating Organization: Aspen Systems, Inc. (Dr. J. Ryu)

NASA Headquarters Sponsor: Office of Advanced Concepts and Technology



Flexible Superinsulation System

Accelerated Testing of Inorganic, Zinc-Rich Primers

Inorganic, zinc-rich coatings are used for corrosion protection of carbon steel structures at KSC. To be considered for use at KSC, a primer must successfully withstand exposure at the KSC beach corrosion test site. Primers are periodically rated for rusting on a scale of 1 to 10 in accordance with ASTM D610, with a rating of 10 being the best. For preliminary approval, primers must achieve a rating of 9 or better after 18 months of exposure and continue to provide this level of protection for 60 months for final approval. Unfortunately, this process requires a considerable amount of time to place new products on the KSC Approved Products List contained in KSC-STD-C-0001.

Alternating current impedance measurement techniques, also known as electrochemical impedance spectroscopy (EIS), are being studied as a possible method for determining the corrosion resistance of inorganic, zinc-rich primers before exposing them to long-term testing at the KSC beach corrosion test site. A reliable accelerated laboratory test method such as EIS could save time for preliminary approval of primers.

For this method, primers are sprayed on test panels for use in the laboratory experiments. The test panels are exposed at the beach corrosion site for various intervals before being brought back to the laboratory for testing. The panels are immersed in a 3.55-percent sodium chloride solution that is aerated during the test to provide the oxygen necessary for corrosion reactions. Test results should yield information on the polarization resistance, pore resistance, and coating capacitance, which can be used to gain understanding of the complex behavior of these materials. By aging the coatings in a natural atmospheric exposure prior to laboratory testing, it is hoped that a correlation can be found between the experimental results and the long-term field results.

Key accomplishments:

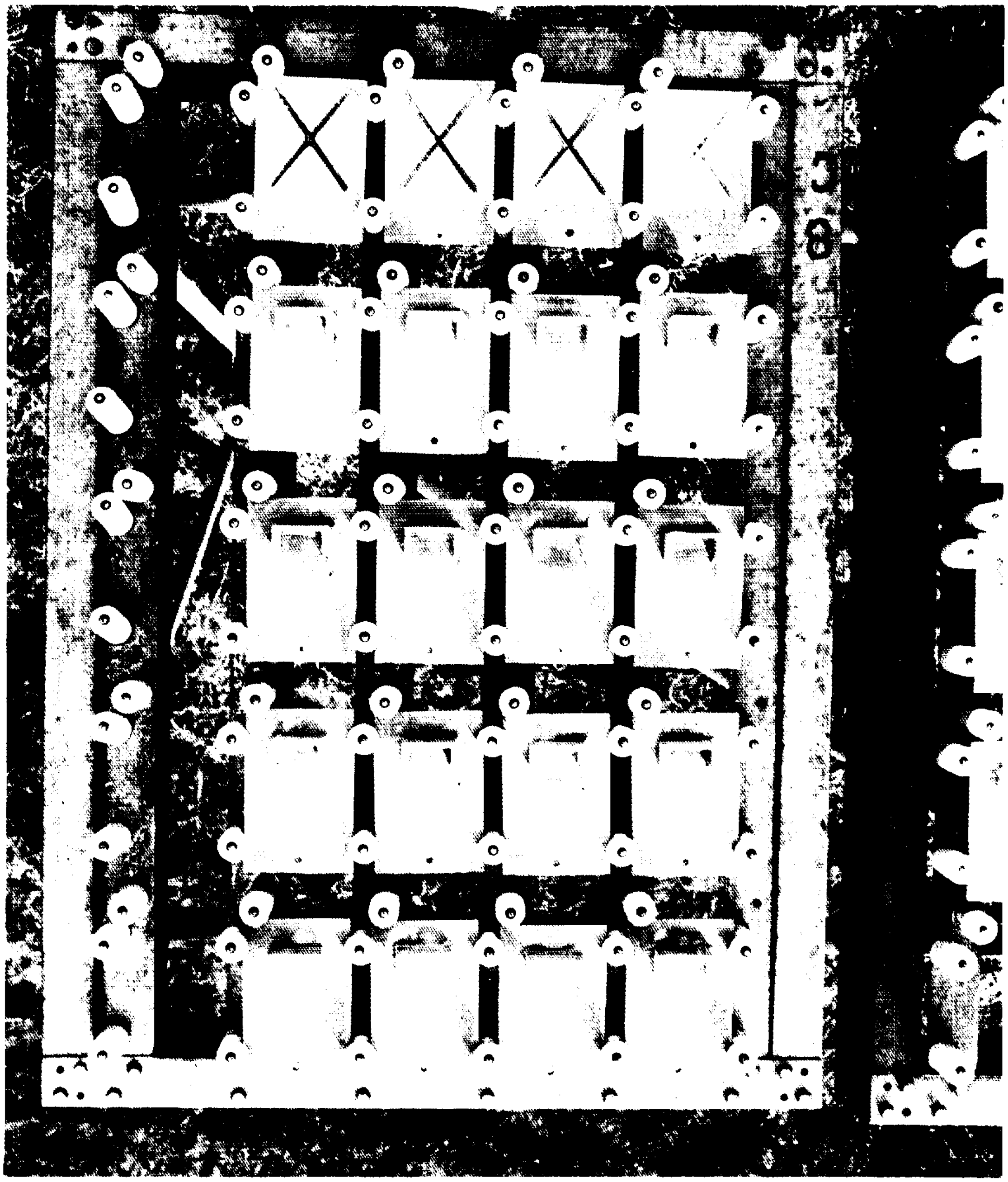
- Test program was started in July 1993 and is continuing.
- Testing is being conducted on primers that have already been exposed at the beach corrosion site for 30 months.
- Results are being compared to similar work conducted in 1989.

Key milestones:

- Atmospheric exposure will be conducted for 12 months with periodic removal for laboratory testing.
- Results will be compared to actual long-term field data for possible correlation.

Contact: L.G. MacDowell, DM-MSL-22, (407) 867-3400

NASA Headquarters Sponsor: Office of Space Flight



Exposure Testing at the KSC Corrosion Test Site

Piping Stress Analysis Software

The Piping Stress Analysis software was developed to eliminate the repetitive calculations required for sizing pipe and calculating allowable pressures. The program was developed over the course of several years. Each time a new way of approaching pipe stress and working pressure calculations was needed, a new module was added to the program. The program includes the ASME/ANSI B31.1 and B31.3 piping codes and the Joint Industry Conference (JIC) code commonly used for hydraulics. These codes are used to set the factors of safety for the yield and tensile strength of the piping material. The users can input their own factors of safety if desired. Several materials are built into the program, and users can input their own if needed.

The program is based on the Lamé equations for analyzing thick-walled cylinders subjected to pressure loads. Failure of piping is assumed to occur due to hoop (circumferential) stress. Radial stress and longitudinal stress are always numerically smaller than hoop stress. Hoop stress is the maximum at the inner wall where the radial stress is numerically equal to p_i. Radial stress is assumed to have a negligible contribution to the failure of piping at low pressures. The ASME/ANSI B31.3 code also uses the Lamé equation. The ASME/ANSI B31.1 power piping code uses an empirical equation with material constants to take into account changes in temperature. When the ratio of the pressure to the allowable stress exceeds 0.385 or when the ratio of the outside diameter to the wall thickness is less than 6, the radial stress can no longer be ignored. The program then considers the Von Mises failure theory to combine the stresses. For greater accuracy, the formula includes the effects of strain hardening if desired. This equation determines the pressure required to yield the outer surface of the pipe. In the program, this pressure is divided by the factor of safety based on ultimate strength since this equation represents the burst pressure. Buckling is considered for external pressure cases using the wall-thickness module. It assumes long, unstiffened cylinders.

The program is written in FORTRAN for the VAX VMS operating system. Versions for the IBM personal computer and the Macintosh platform are presently being developed. The next step for the program will be to develop a graphical user interface.

Key accomplishments:

- KSC pneumatic and hydraulic requirements.
- ASME/ANSI B31.1 Power Piping Code requirements.
- ASME/ANSI B31.3 Chemical Plant and Petroleum Refinery Piping Code requirements.
- JIC hydraulic requirements.
- Incorporated advanced failure theory for piping burst calculations.
- Submitted the program to Cosmic for publication.

Contact: E.A. Thaxton, DM-MED-11, (407) 867-4181

NASA Headquarters Sponsor: Office of Space Flight

Advanced Software

The Advanced Software Technology program at the John F. Kennedy Space Center (KSC) supports advanced computing technologies directed toward decreasing vehicle and payload ground processing time and cost, improving process automation, and enhancing quality and safety. The program includes the application of computer science and computer engineering disciplines, particularly in the areas of artificial intelligence, computer system architectures and communications, database management techniques, multimedia systems, advanced data analysis techniques, and software engineering methodologies. The near-term program focuses on:

1. Shuttle ground processing improvement by automation of vehicle monitoring and diagnosis tasks

2. Intelligent system applications for planning and scheduling

3. Use of multimedia techniques for enhancement of institutional attempts at paperless process management

4. Data analysis techniques to facilitate understanding, cohesion, and real-time access of vehicle and payload data

The long-term program will develop technology for support of future space vehicles, payloads, and launch by investigating distributed system architectures, intelligent vehicle health management, software engineering for legacy systems, intelligent multimedia databases, and advanced data analysis techniques using neural net and fuzzy logic techniques.

Automated Database Design

Although large information systems at KSC have highly trained, skilled designers, smaller projects do not. Users and programmers of small systems typically do not have the skills needed to design a database schema from an English-language description of the problem.

The goal of this project is to help these unskilled users by constructing a system that will design a database from a natural-language description provided by users with no knowledge at all of databases. The output of the system will be an entity-relationship model (E-R model) capturing the design of the database. The approach taken has been to adapt an existing natural-language understanding (NLU) system to this task and to construct a problem solver that builds an E-R model from the output produced by the NLU system. The NLU system builds the semantic interpretation for the sentences, and the problem solver identifies the relations, entities, and the attributes from the user's sentences. The problem solver is a knowledge-based system designed using the principles of classification problem solving. The production rules in it are organized in clusters around the semantic primitives built by the NLU. This performs a full parse, interpretation, formation (the construction of the final knowledge structures), and the integration of the knowledge structures in long-term memory from the user's sentences. At any given moment, the system keeps two views of the description being provided to it by the user: the database view (the E-R model being constructed by the problem solver) and the comprehension view (the knowledge representation structures constructed by the NLU system). Both of these views are used by the system to make sense of the user's sentences, solving intersentential anaphora and identifying and constructing inheritance relationships. A final problem solver, which takes as input the initial E-R model constructed from the sentences, gets rid of inconsistencies and redundancies and normalizes the relations.

The progress made to date includes additions to the NLU system in order to process this task and the initial construction of the problem solver. As of this writeup, a rudimentary system that is producing E-R models from natural-language descriptions of simple database problems has been designed. The system is implemented in a Sparc workstation using Franz Common LISP and Common LISP Interface Manager (CLIM).

Key accomplishment:

- 1993: Began project, made a literature survey, and completed the initial design of the system.

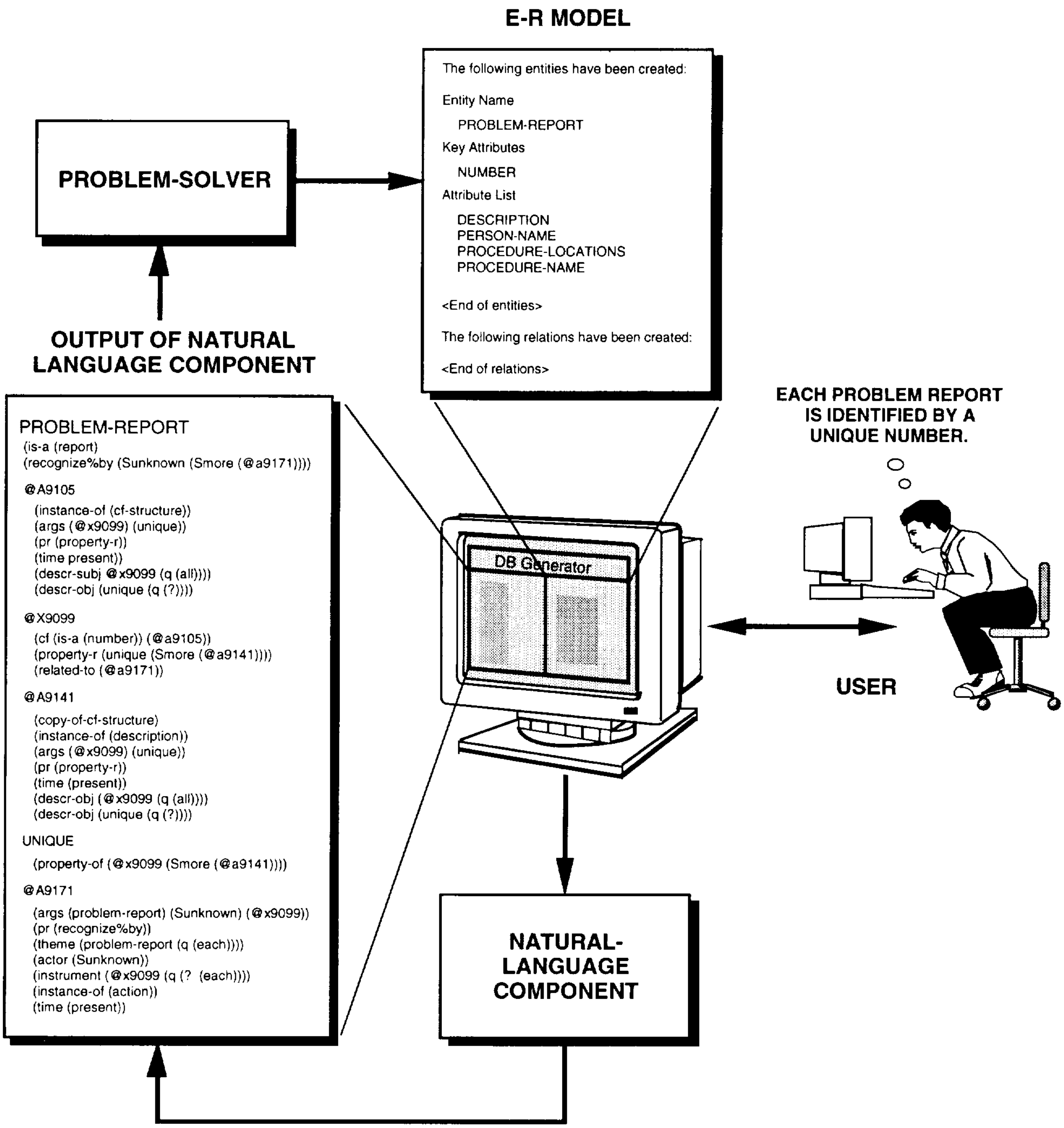
Key milestones:

- 1993: Completion of the first prototype.
- 1994: Refine the prototype and get feedback from real users. Build the final problem solver.
- 1995: Build a knowledge acquisition interface to the system. Perform Beta testing and assessment of the technology.

Contact: N. Sliwa, DE-TDO, (407) 867-2780; and Dr. C. Delaune, CS-GSD-31, (407) 867-8656

Participating Organization: University of Central Florida (Dr. F. Gomez)

NASA Headquarters Sponsor: Center Director Discretionary Fund


E-R MODEL
The following entities have been created:
Entity Name
PROBLEM-REPORT
Key Attributes
NUMBER
Attribute List
DESCRIPTION
PERSON-NAME
PROCEDURE-LOCATIONS
PROCEDURE-NAME
<End of entities>
The following relations have been created:
<End of relations>
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OUTPUT OF NATURAL LANGUAGE COMPONENT
PROBLEM-REPORT
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(recognize%by (Sunknown (Smore (@a9171))))
@A9105
(instance-of (cf-structure))
(args (@x9099) (unique))
(pr (property-r))
(time present))
(descr-subj @x9099 (q (all)))
(descr-obj (unique (q (?))))
@X9099
(cf (is-a (number)) (@a9105))
(property-r (unique (Smore (@a9141))))
(related-to (@a9171))
@A9141
(copy-of-cf-structure)
(instance-of (description))
(args (@x9099) (unique))
(pr (property-r))
(time (present))
(descr-obj (@x9099 (q (all)))
(descr-obj (unique (q (?))))
UNIQUE
(property-of (@x9099 (Smore (@a9141))))
@A9171
(args (problem-report) (Sunknown) (@x9099))
(pr (recognize%by))
(theme (problem-report (q (each))))
(actor (Sunknown))
(instrument (@x9099 (q (? (each))))
(instance-of (action))
(time (present))
DB Generator
EACH PROBLEM REPORT IS IDENTIFIED BY A UNIQUE NUMBER.
USER
NATURAL-LANGUAGE COMPONENT

Integrating and Coordinating Intelligent Planning and Scheduling Tools

Processing orbiter vehicles, rocket boosters, and payloads involves thousands of distinct but interrelated operations, supported by an array of equipment, resources, and support personnel. Until recently, all databases and planning and scheduling tools used to support ground operations for Shuttle missions resided on mainframe computers. Currently, KSC is in the process of modernizing its decision-support capabilities by adding new, more powerful software tools and distributing these tools across a network of computers to improve accessibility and performance.

The goal of this effort is to develop an innovative distributed communication and control software infrastructure that will enable KSC's decision-support tools to exchange information and coordinate activities across different kinds of computers, including mainframes, workstations, and personal computers. A second goal is to ensure that this infrastructure is generic so it can be used in other domains, such as process control and office automation, and in computing environments other than the one that exists at KSC.

The core software technology developed to address these goals is NetWorks!, an innovative communication "middleware" tool. Middleware generally supplies a high-level application programming interface (API), which is a library of function calls for network communication. The API, which is uniform across platforms, shields developers of distributed systems from operating-system dependencies and the complexities of network-level programming.

NetWorks! middleware is unique in that it applies advanced object-oriented technology to the problems of network computing. Using this tool, developers can: (1) nonintrusively integrate existing "legacy" applications designed for stand-alone use, (2) easily reuse and adapt integration code in the form of software objects called Agents, and (3) implement, maintain, and extend complex distributed systems using a library of "building block" Agents. This effort developed two library Agents that provide predefined models for coordinating interactions between independent distributed programs.

The first Agent supports a high-level scripting facility for modeling and automatically executing routines and/or complex sequences of activities (i.e., processes). For example, a script might extract a completed plan for a specified Shuttle mission from a master database, send that data to a remote scheduling application, return the results to the database, and execute a program to detect resource allocation conflicts between the new schedule and other mission schedules. Upon request, the second Agent subdivides a complex service into subtasks, dispatches those subtasks to suitable servers, collects and combines the results, and returns a single response back to the requester. This group-oriented control model shields the requesting program from having to explicitly coordinate the handling of tasks by a group of server applications.

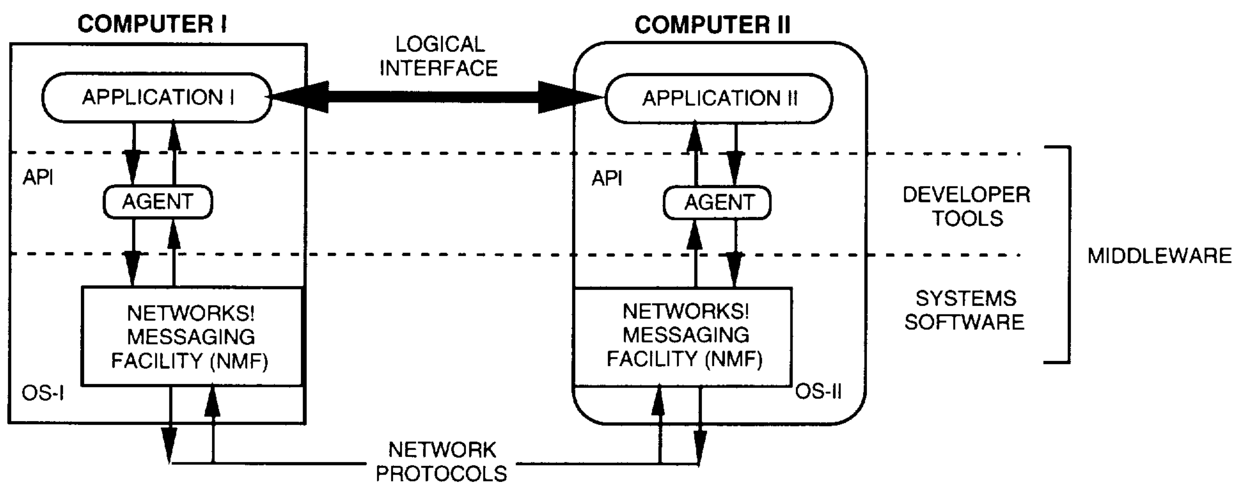
Key accomplishments:

- 1991: Completed a feasibility study and proof-of-concept demonstration.
- 1992: Developed the prototype NetWorks! library Agents for process- and group-oriented distributed control capabilities.
- 1993: Developed NetWorks! versions for the mainframe computer (IBM VM/ESA) and personal computers (OS/2) for both TCP/IP and APPC networking protocols. NetWorks! also runs on workstations (UNIX) and personal computers (DOS/Windows).

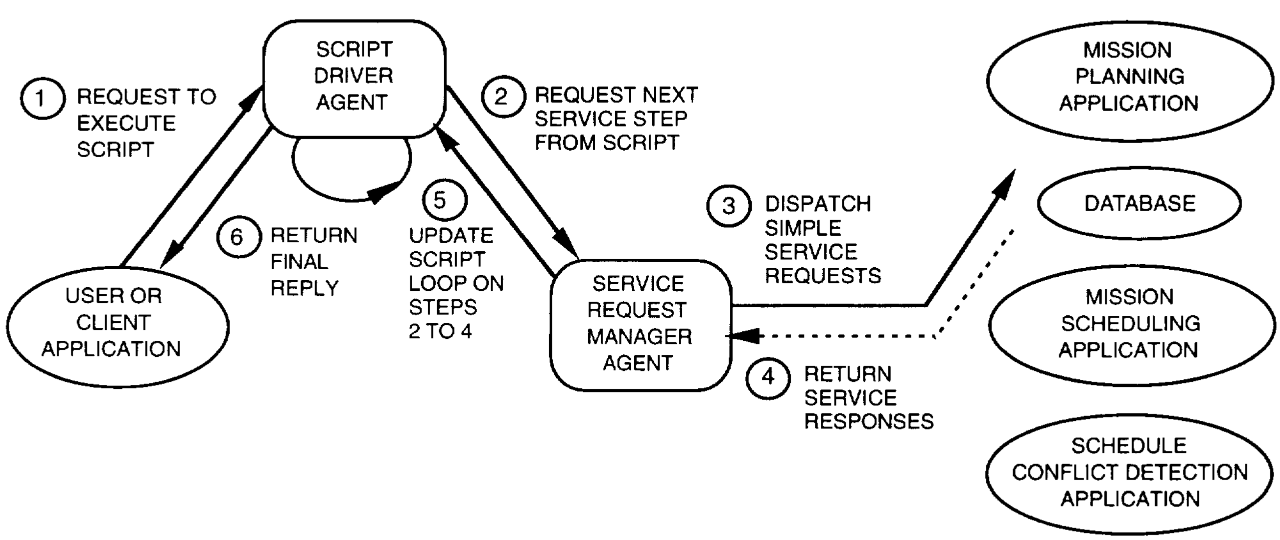
Contacts: N.E. Sliwa, DE-TDO, (407) 867-2780; and R.L. Phelps, TM-LLP-4, (407) 867-1422

Participating Organization: Symbiotics, Inc. (R. Adler)

NASA Headquarters Sponsor: Small Business Innovation Research Program (Office of Advanced Concepts and Technology)



NetWorks! Technology for Distributed Computing



NetWorks! Architecture for the NASA Distributed Decision Support System

Vehicle Health Management System

Shuttle Transportation System processing operations include continuous monitoring of four major systems when an orbiter vehicle is powered up. The basic support configuration requires a minimum of one engineer for each major system [Electrical Power Distribution and Control (EPDC), Environmental Control and Life Support System (ECLSS), and Digital Processing and Instrumentation], along with a Test Project Engineer (TPE) system to integrate the operations. Proposed operation changes include reducing the required support to two engineers at a single console. Such reductions will impose a higher level of responsibility on the supporting personnel. Use of an expert system to provide additional monitoring, fault detection, and troubleshooting capabilities is anticipated to allow this reduction and cost savings without a loss of the knowledge required for rapid and correct response to anomalies.

The goal of the Vehicle Health Management System (VHMS) project is to provide an expert software system to assist engineers in vehicle support monitoring while an orbiter is powered up. The initial approach included an indepth review of two model-based reasoning systems to serve as the basis for VHMS. The product selected, the Knowledge-Based Autonomous Test Engineer (KATE), provides the framework for the VHMS expert system. The VHMS/KATE environment is composed of four basic modules. The Data Acquisition Module decodes the PC-GOAL data stream into KATE data packets. The Reasoner Module executes a simulation of the systems (based on a knowledge-base representation of those systems) and compares simulation data with the real-time data. The Diagnoser Module analyzes any miscomparisons between the simulation and the real world to isolate the most probable cause of the error. The User Interface Module provides a graphical interface for the user to monitor system information. This module is being tailored to fit the specific needs of the TPE customer.

Project progress to date includes the development of six major and five minor detailed graphical displays for the ECLSS, the first major system to be integrated into the project. A mechanism to match the Diagnoser Module analysis results with the proper recommended actions was developed that will assist the user in detailed troubleshooting and anomaly recovery. Utilities to assist the user in analysis and troubleshooting (i.e., data status routines and plot capabilities) were also developed. The first portion of the system knowledge was completed and is in the fine-tuning phase. This portion encompasses the Freon coolant loops of the ECLSS, with connections to the EPDC system and other portions of the ECLSS. Expansion of these connections into the water coolant loop, the air cooling system, and the EPDC system is scheduled for next year.

Key accomplishments:

- 1992: Model-based reasoning system analysis.
- 1993: Integration of VHMS user interface with KATE. Development of the Freon coolant loop knowledge base.

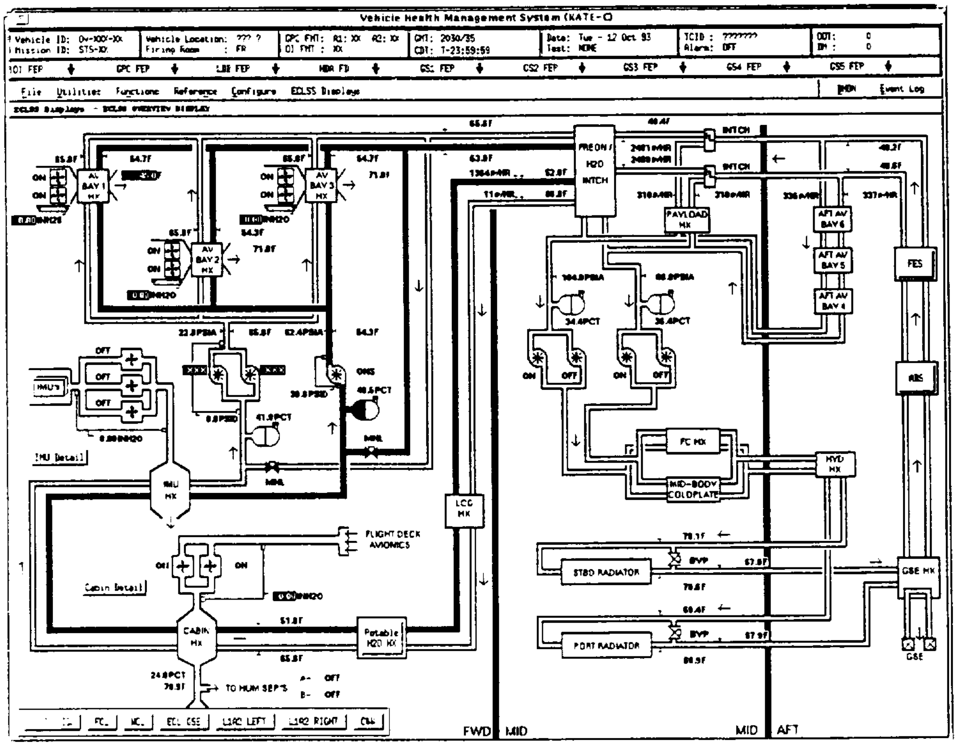
Key milestones:

- 1993: Successful development of the ECLSS Freon coolant loop knowledge base. Proof-of-concept demonstration at KSC.

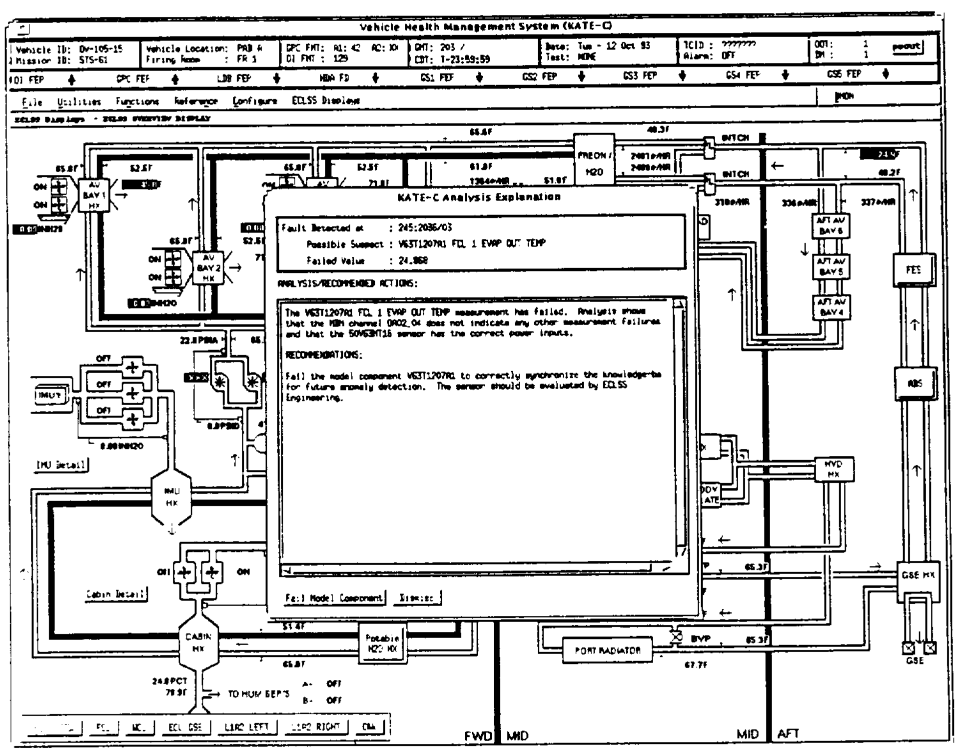
Contacts: N. Sliwa, DE-TDO, (407) 867-2780; and W.K. Lackie, TV-PEO-2, (407) 861-3968

Participating Organization: Lockheed Space Operations Company (R.G. Ikerd)

NASA Headquarters Sponsor: Office of Space Systems Development



VHMS Provides Detailed Graphic Display Monitors for Visual Monitoring and Operator Interaction



Upon Detection of an Anomaly, VHMS Provides the User With an Analysis and Recommended Action To Correct or Work Around the Problem

Automated Manifest Planner

Planning and scheduling of NASA Space Shuttle missions are complex, labor-intensive, iterative processes requiring the expertise of experienced mission planners within the KSC Mission Planning Office (MPO). High-level manifest planning for a specific mission begins 5 to 10 years prior to launch. The goal of this planning is to establish a flight manifest and define the objectives, capabilities, and constraints of each mission. Planning of individual missions must take into consideration other scheduled or anticipated missions. A second important objective of high-level mission planning is to explore alternative planning options. These exercises determine how the flight manifest is affected when program ground rules are changed, launch delays are anticipated or experienced, available resources are affected by budget changes, or new vehicles or facilities are introduced.

The goal of the Automated Manifest Planner (AMP) was to reduce the time required by expert planners to perform planning and speculative schedule studies. The approach was to use a combination of artificial intelligence techniques, including object-oriented representations, application of rules, intelligent entities, explicit user control of the object hierarchy, and the capability to allow the user to mix and match planning and display methods. To achieve flexibility, users are allowed to edit the schedule, edit the planning methods, or change planning methods in the middle of the schedule.

A feasibility study was completed that included extensive knowledge engineering of the MPO and implementation of a software prototype to prove the concepts developed. The prototype was demonstrated and refined, which led to a detailed design of the full-scale system. A full-scale AMP is being developed as a series of incremental releases. Three major releases, AMP 1.0, 2.0, and 3.0, have been delivered as well as many subreleases. These releases cover extensive planning, plotting, and editing options as well as methods to customize the system to virtually any domain. The MPO has used the AMP to perform alternative planning studies. The AMP will soon be used to perform the less speculative manifest planning.

Future plans are to implement a learning capability as well as optimization techniques based on genetic algorithms. Other planning groups within NASA will be involved. Finally, the system will be commercialized and sold publicly.

Key accomplishments:

- 1991: Feasibility study, prototype development, and demonstration.
- 1992: Planning, editing, and printing capability developed.
- 1993: AMP 1.0, 2.0, and 3.0 delivered; AMP 3.0 included planning, plotting, tailoring, capability, and data link to Artemis.

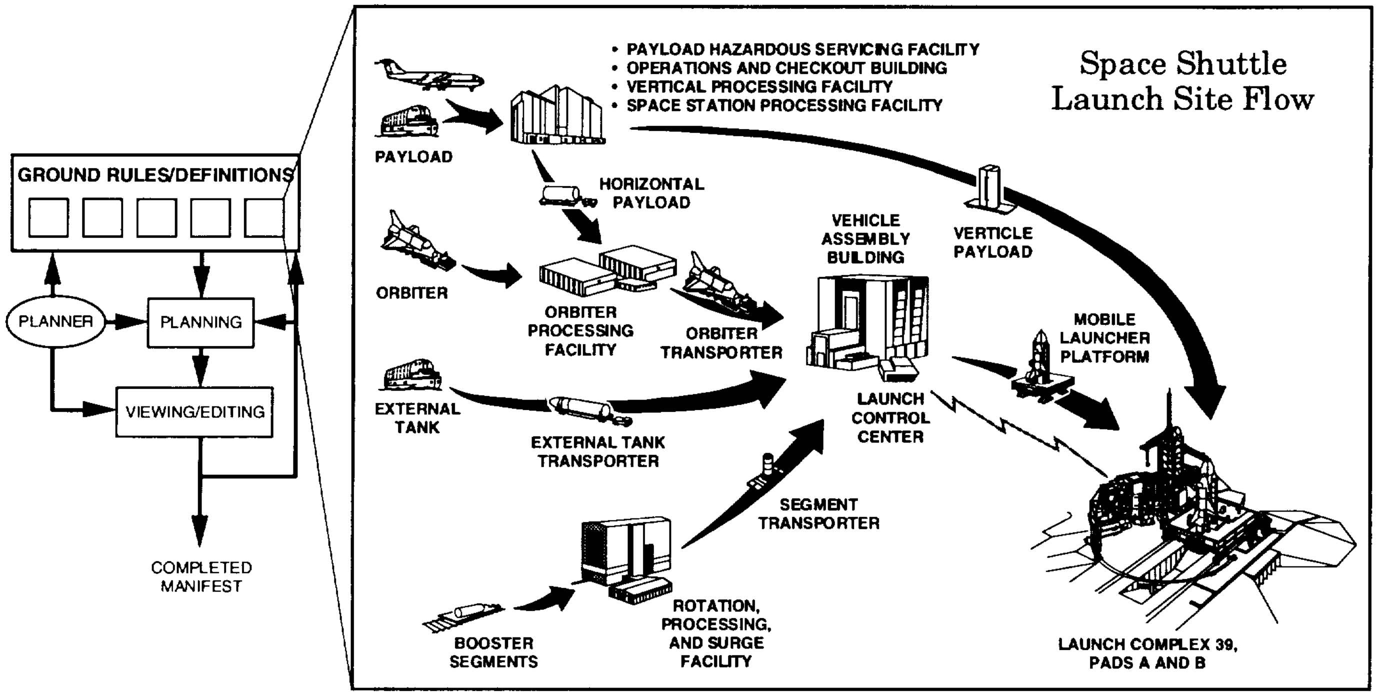
Key milestones:

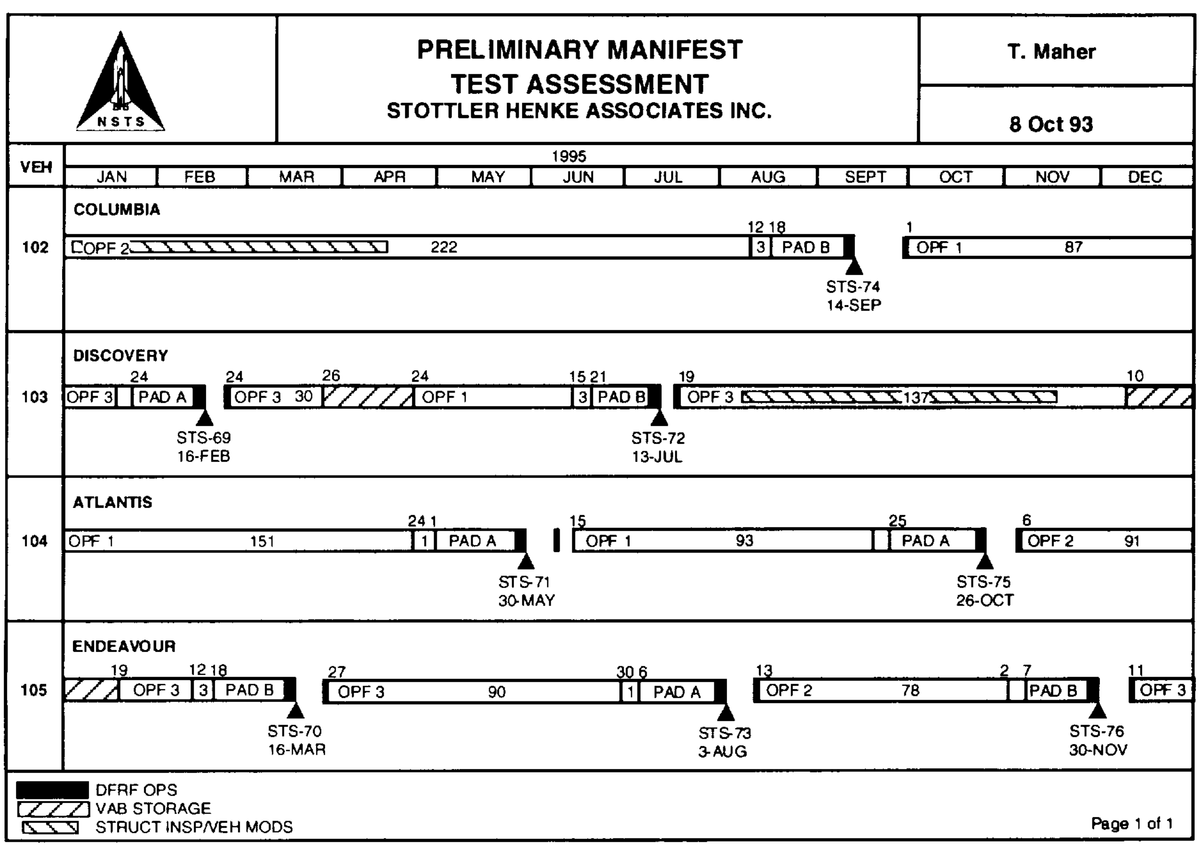
- 1994: Deliver AMP 4.0 and 5.0. AMP 5.0 will include learning capabilities and involvement of other NASA planning groups.
- 1995: Generalize and sell the AMP commercially.

Contact: R.H. Thornburg, TM-LLP-5A, (407) 861-5732

Participating Organization: Stottler Henke Associates, Inc. (T. Maher)

NASA Headquarters Sponsor: Office of Advanced Concepts and Development


GROUND RULES/DEFINITIONS
PLANNER
PLANNING
VIEWING/EDITING
COMPLETED MANIFEST
Space Shuttle Launch Site Flow
• PAYLOAD HAZARDOUS SERVICING FACILITY
• OPERATIONS AND CHECKOUT BUILDING
• VERTICAL PROCESSING FACILITY
• SPACE STATION PROCESSING FACILITY
PAYLOAD
HORIZONTAL PAYLOAD
VEHICLE ASSEMBLY BUILDING
VERTICLE PAYLOAD
ORBITER
ORBITER PROCESSING FACILITY
ORBITER TRANSPORTER
MOBILE LAUNCHER PLATFORM
EXTERNAL TANK
EXTERNAL TANK TRANSPORTER
LAUNCH CONTROL CENTER
SEGMENT TRANSPORTER
BOOSTER SEGMENTS
ROTATION, PROCESSING, AND SURGE FACILITY
LAUNCH COMPLEX 39, PADS A AND B


NSTS
PRELIMINARY MANIFEST
TEST ASSESSMENT
STOTTLER HENKE ASSOCIATES INC.
T. Maher
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1995
JAN FEB MAR APR MAY JUN JUL AUG SEPT OCT NOV DEC
COLUMBIA
102
OPF 2 222 12 18 3 PAD B 1 OPF 1 87
STS-74 14-SEP
DISCOVERY
103
24 OPF 3 PAD A 24 OPF 3 30 26 24 OPF 1 15 21 3 PAD B 19 OPF 3 137 10
STS-69 16-FEB
STS-72 13-JUL
ATLANTIS
104
OPF 1 151 24 1 1 PAD A 15 OPF 1 93 25 PAD A 6 OPF 2 91
STS-71 30-MAY
STS-75 26-OCT
ENDEAVOUR
105
19 OPF 3 12 18 3 PAD B 27 OPF 3 90 30 6 1 PAD A 13 OPF 2 78 2 7 PAD B 11 OPF 3
STS-70 16-MAR
STS-73 3-AUG
STS-76 30-NOV
DFRF OPS
VAB STORAGE
STRUCT INSP/VEH MODS
Page 1 of 1

Intelligent Interactive Visual Database Management System

For each Space Shuttle ground processing cycle, approximately 35,000 chemically developed 8- by 10-inch still photographs (including copies) document all significant prelaunch and postlanding activities. These pictures are an integral part of NASA's quality control and reliability program that assists Space Shuttle systems engineers in verifying "go for launch" and the condition of the orbiter after landing. Presently, this large collection is manually catalogued and stored in numerous notebook binders, file cabinets, and storage boxes. Retrieval is difficult and time consuming. This effort is repeated at other NASA and contractor locations around the country. As should be evident, the cost of misplaced or lost Shuttle photographs is high when compared to a study indicating that even a misfiled document in an average business costs $125, and each document costs $350 to $700.

Because of the importance of these photographs, the goal of the Intelligent Interactive Visual Database Management System (IIVDBMS) project is to investigate more cost-effective methods of system improvement, including the use of expert systems for the critical classification and retrieval phases of the IIVDBMS life-cycle process. Researchers at the University of Central Florida's Intelligent Multimedia Applications Laboratory interviewed KSC classification and retrieval domain experts. Resultant image processing paradigms, decision criteria, descriptor attributes, and heuristics were structured, modeled, and converted into code using LEVEL5 OBJECT (an object-oriented expert system development tool). As a result, a prototype system for multimission NASA Space Shuttle color image classification and retrieval tasks was developed. The system consists of two modules: one for image classification, the other for image retrieval. They are named NAPSAC for NASA Photograph System to Aid Classification and PRAISE for Photo Retrieval and Identification System Expert [see the figure "Photo Retrieval and Identification System Expert (PRAISE)" for a screen display].

Progress to date includes the design and partial development of a state-of-the-technology digital PC and LAN-based high-resolution (1024 x 768 pixels), 24-bit true-color (16.7 million color shades) IIVDBMS (see the figure "PC-LAN IIVDBMS Architecture"). The prototype system includes a production station for image digitization, classification, and compression; a file server for image and data storage; and local and remote user workstations for image decompression, retrieval, and display. Hardware Joint Photographic Experts Group (JPEG) and software (JPEG and fractal) digital compression was demonstrated, and empirical testing at the university and at KSC is underway to investigate display screen resolution versus color pixel depth tradeoffs.

Key accomplishments:

- 1990: Literature research and conceptual studies.
- 1991: Investigation and interfacing of knowledge-based and digital image systems.
- 1992: Prototype networked digital system design and development.
- 1993: Empirical resolution versus color depth testings and fractal compression studies.

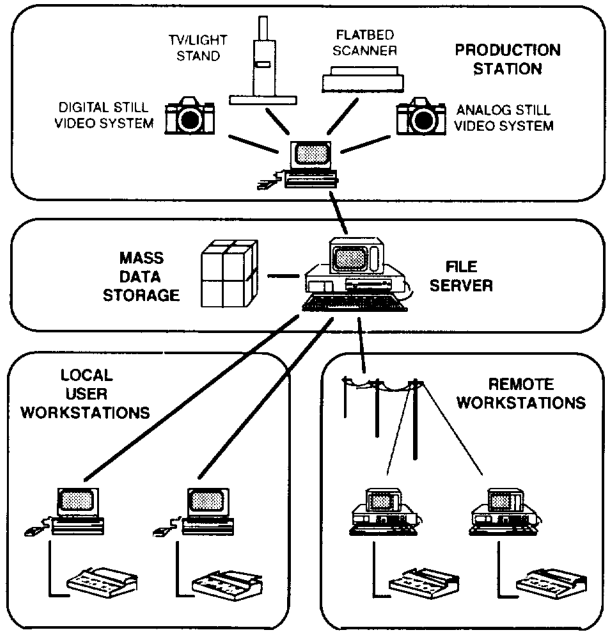
Key milestones:

- 1994: Prototype system demonstration at KSC and indepth empirical resolution testing.

Contact: N.E. Sliwa, DE-TDO, (407) 867-2780

Participating Organization: University of Central Florida (Dr. J.M. Ragusa)

NASA Headquarters Sponsor: Center Director Discretionary Fund



PC-LAN IIVDBMS Architecture

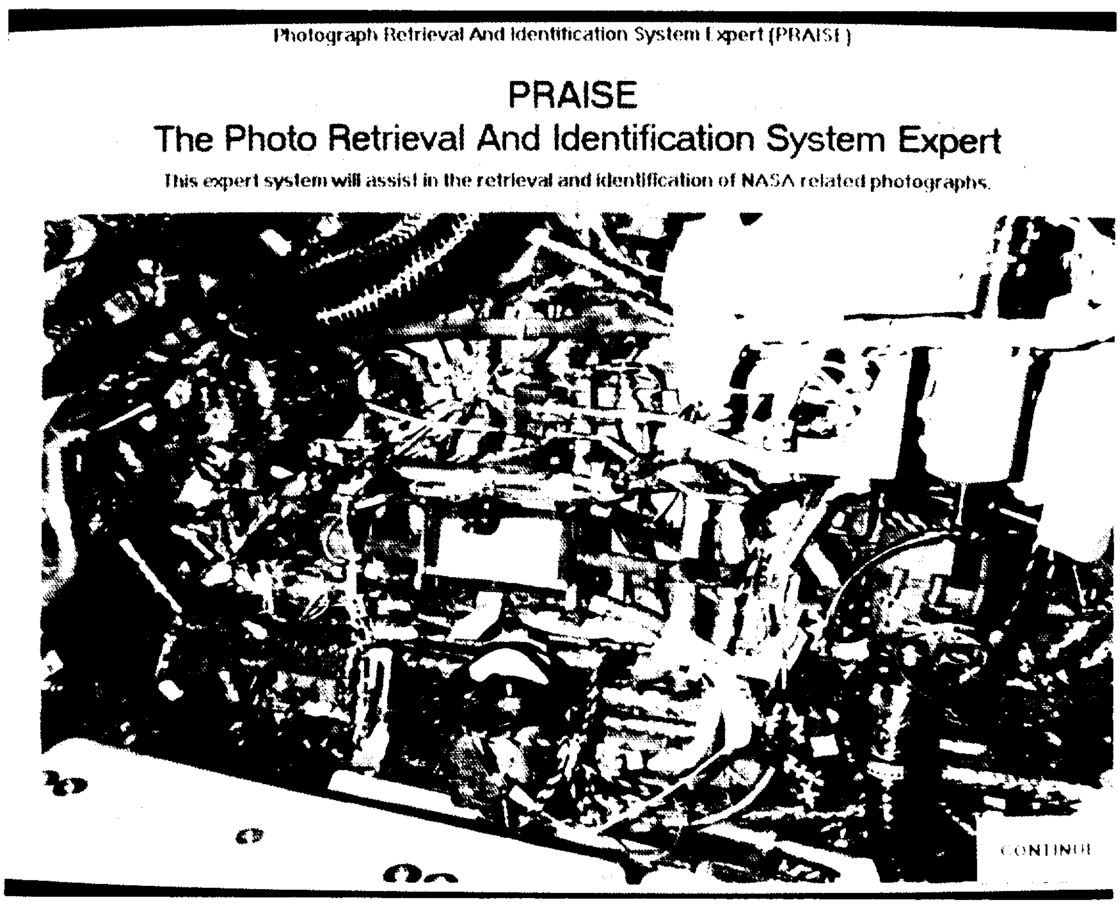


Photo Retrieval and Identification System Expert (PRAISE)

Launch Site Processing and Facilities for Future Launch Vehicles

KSC is often called upon to perform quick-response launch site impact assessments for new launch vehicles. The assessments must be conducted in a timely and comprehensive manner, often for multiple competing design or operational concepts.

McDonnell Douglas Space Systems (MDSS) is contracted to develop a computer-aided tool for evaluating launch site space vehicle ground processing impacts, including operability, facilities, ground support equipment processing requirements, timelines, and resources for future launch vehicles in a quick-response assessment environment. A user friendly, object-oriented artificial intelligence application will be used.

MDSS is developing an artificial intelligence tool called the Operations Impact Assessor (OIA) that features modeling tools and automated databases. The OIA employs object-oriented modeling technology with quick turnaround assessment capability. It will be able to draw together diverse pieces of information from past and current flight hardware programs and available launch site resources in the development of a unified assessment of the future launch hardware processing.

The project was initiated April 21, 1993, and a kickoff meeting was conducted. A document defining the OIA architecture (requirements, system concepts, and products) was provided to NASA in July 1993. Current efforts include development of intelligent assistants and model management utilities. Future plans include development of the analysis engine, reporting tool, and knowledge bases. The effort will culminate with OIA verification and delivery to NASA in October 1994.

Key accomplishments:

- May 1993: Presented OIA overview at the kickoff meeting.
- July 1993: Delivered to NASA the OIA architecture document.

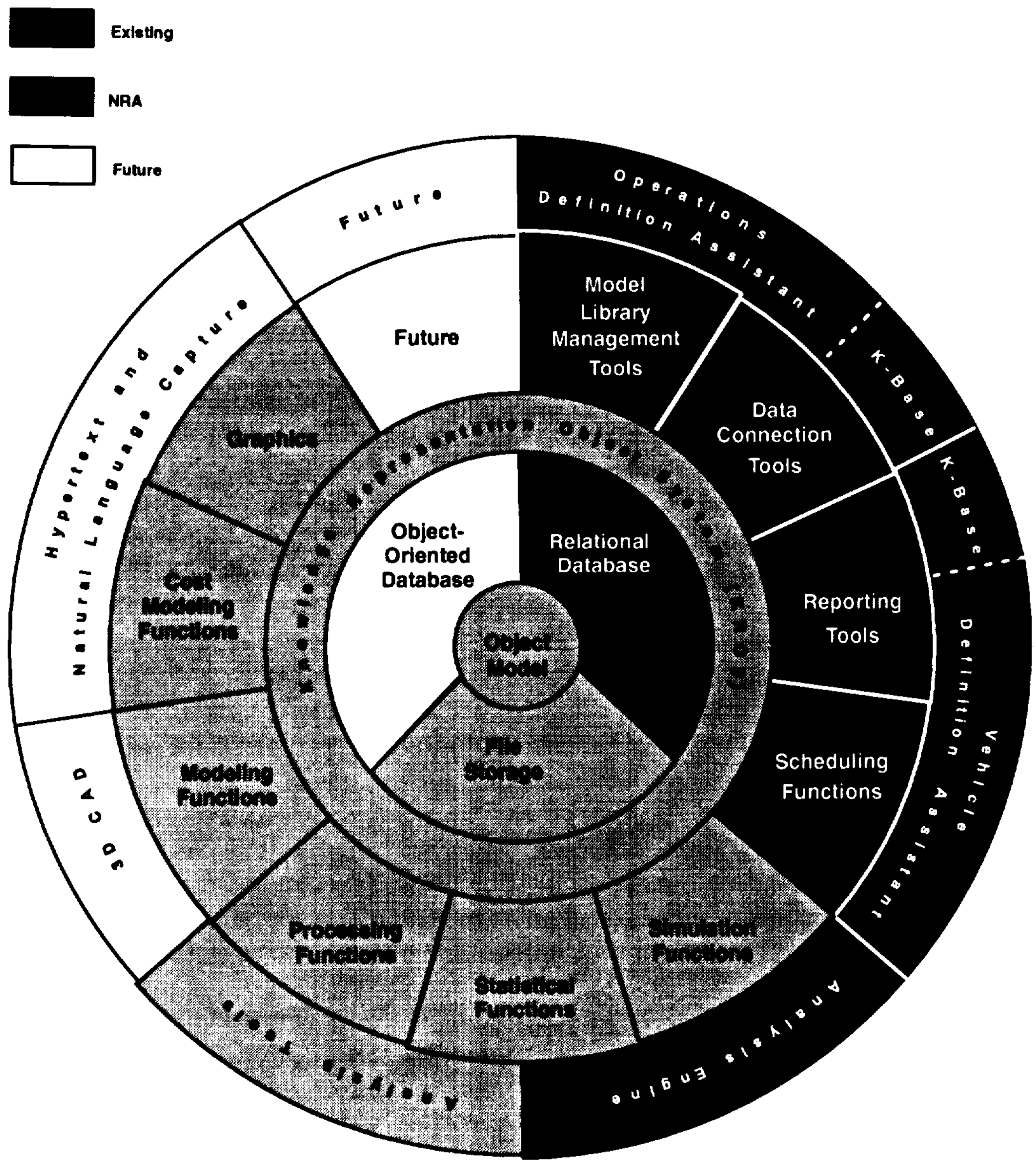
Key milestones:

- January 1994: Midterm review.
- October 1994: Final review and OIA final delivery.

Contact: B.W. Larson, DE-FLS, (407) 867-7705

Participating Organization: McDonnell Douglas Space Systems (R. Shaffer and D. Headley)

NASA Headquarters Sponsor: Office of Space Systems Development



OIA Architecture

Space Station Freedom (SSF) Advanced Processing Operations Study

Langley Research Center's (LaRC) Advanced Programs Office utilizes Kennedy Space Center payload processing expertise to support development of Space Station logistics resupply scenarios for the SSF Level 1 Engineering Division at NASA Headquarters.

A number of Space Station ground processing action items were assigned to the study team, each requiring its own approach. Generally, each action item investigation began with the collection of data such as payload requirements and facility utilization plans. Results usually included processing flows and timeliness derived from well-established analogous KSC operations, issues, and recommendations.

This study is currently in its second year. Major accomplishments during 1992 included:

- Combining the 1992 Civil Needs Database, KSC SSF Multiflow, and LaRC User Mission Database into a single database manifesting all SSF payloads planned for 1999 to 2005.
- Identifying over/under utilization of 26 major KSC Space Station resources (facilities and ground support equipment), which required the development of a customized software tool for analyses.
- Evaluating Shuttle and expendable launch vehicles (actual launch rates, processing times, surge capabilities, etc.) to support the launch-on-need resupply of the Space Station.
- Evaluating the planned SSF propulsion module turnaround at KSC, identifying the need for spare prop modules in the fleet, and making prop module design recommendations to facilities recovery from failure scenarios.

Major accomplishments during 1993 included:

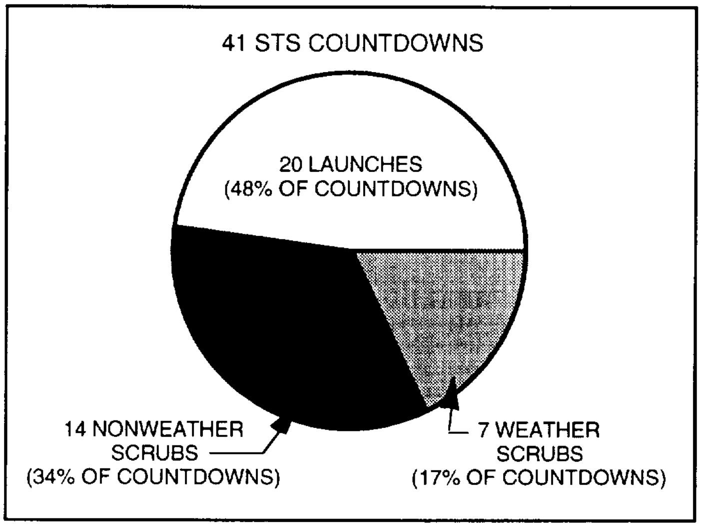
- Evaluating the Space Station resupply and return design reference missions utilizing expendable launch vehicles, including the development of logistics element interface requirements.
- Evaluating the launch of Space Station logistics elements from French Guiana and Russia, including transportation options, foreign launch site ground support equipment and personnel requirements, and anomaly impacts and recovery scenarios.
- Reviewing the European Space Agency automated transfer vehicle designs for launch on the Shuttle and U.S. expendable launch vehicles.
- Investigating Shuttle middeck capabilities to support Space Station resupply and return.

As of mid-October 1993, it is anticipated that funding will be made available to continue supporting the definition of Space Station resupply scenarios, including integration of Russian elements as payloads on the Shuttle and U.S. expendable launch vehicles.

Contacts: P.A. Ahlf, NASA Headquarters, Space Station Advanced Studies Program Manager (202) 358-0708; B. Cirillo, NASA LaRC, Advanced Programs Office, (804) 864-1938; and C. Bachstein, NASA KSC, Space Station Project Office (407) 867-4802

Participating Organization: McDonnell Douglas Space Systems (R. Vargo)

NASA Headquarters Sponsor: Office of Space Systems Development



Weather Effects on Shuttle Launches (November 1987 to January 1992)

LAUNCH RATE PER YEAR	NOMINAL (SERIAL DAYS)	SURGE CAPABILITY* (SERIAL DAYS)
STS - 8	105	99
TITAN - 4	90	79
DELTA - 12	30	23
ATLAS - 8	65	55

* Surge capability requires extensive overtime and guaranteed resources. These estimates were derived from generic flows and future anticipated ETR enhancements. Only one LON mission was assumed.

ELS Launch-on-Need Capabilities

	Number of Shifts
Return propulsion module to PSTF-R for LRU removal and replacement	22 to 29
Return propulsion module for wet LRU removal and replacement (partial deservicing/decontamination)	29 to 52
Return propulsion module to PSTF-R for deservicing and loading propellant	52 to 71
Return propulsion module to PSTF-R for deservicing, functional testing, and loading propellant	71 to 80

Propulsion Module Anomaly Recovery Timelines

Space Transportation System (STS) Manifest Generation Model

The Shuttle Management and Operations Directorate (TM) at KSC recognizes the need for developing a flexible planning system that generates mixed fleet ground processing timelines faster and cheaper. As new launch vehicles are proposed or budget cuts are imposed, options to build or deactivate facilities are assessed. Methods currently used to formulate responses to these options are labor intensive, even with present day automation capabilities.

The STS Manifest Generation Model (MGM) project was initiated to apply advances in modeling and simulation realized through development of the Ground Operations Simulation Technique (GOST) featured in the Research and Technology 1992 Annual Report. GOST provides a powerful technique for assessing facility utilization-based "forward-driven" process flows as found within the launch vehicle processing domain.

Since GOST was developed as a generic modeling and simulation tool for developing ground processing models, it does not contain any information pertaining to orbiter processing in the Launch Complex 39 area. The MGM seeks to encode a model of orbiter processing from which other GOST models could be defined. The first task was to apply GOST's object-oriented modeling methodology to the orbiter processing domain. As a result, a number of objects were identified as being central to the construction of ground processing flows for manifest generation. Test management policies were then encoded as ground rules within the model, and an output facility was developed that produces Gantt chart reports in a format familiar to manifest planning personnel.

Once the TM planners began using GOST to maintain the orbiter processing model, it became evident that a customized user interface for model maintenance would be advantageous. During the project's second year, the output facility used to display results of a simulation was augmented so planners could change task durations directly from the output window. This feature minimizes the amount of time required to affect changes in task duration due to real-world processing events. In an effort to make the technology more accessible to planning personnel, the developers began to port the MGM application over to the C++ version of GOST released in mid-1992. Currently, the group is recreating the model using the C++ version and has developed an improved manifest reporter that can display any combination of launch vehicle and facilities on the same Gantt chart report. A data import facility was also created to read task duration data contained within Artemis projects for update MGM models.

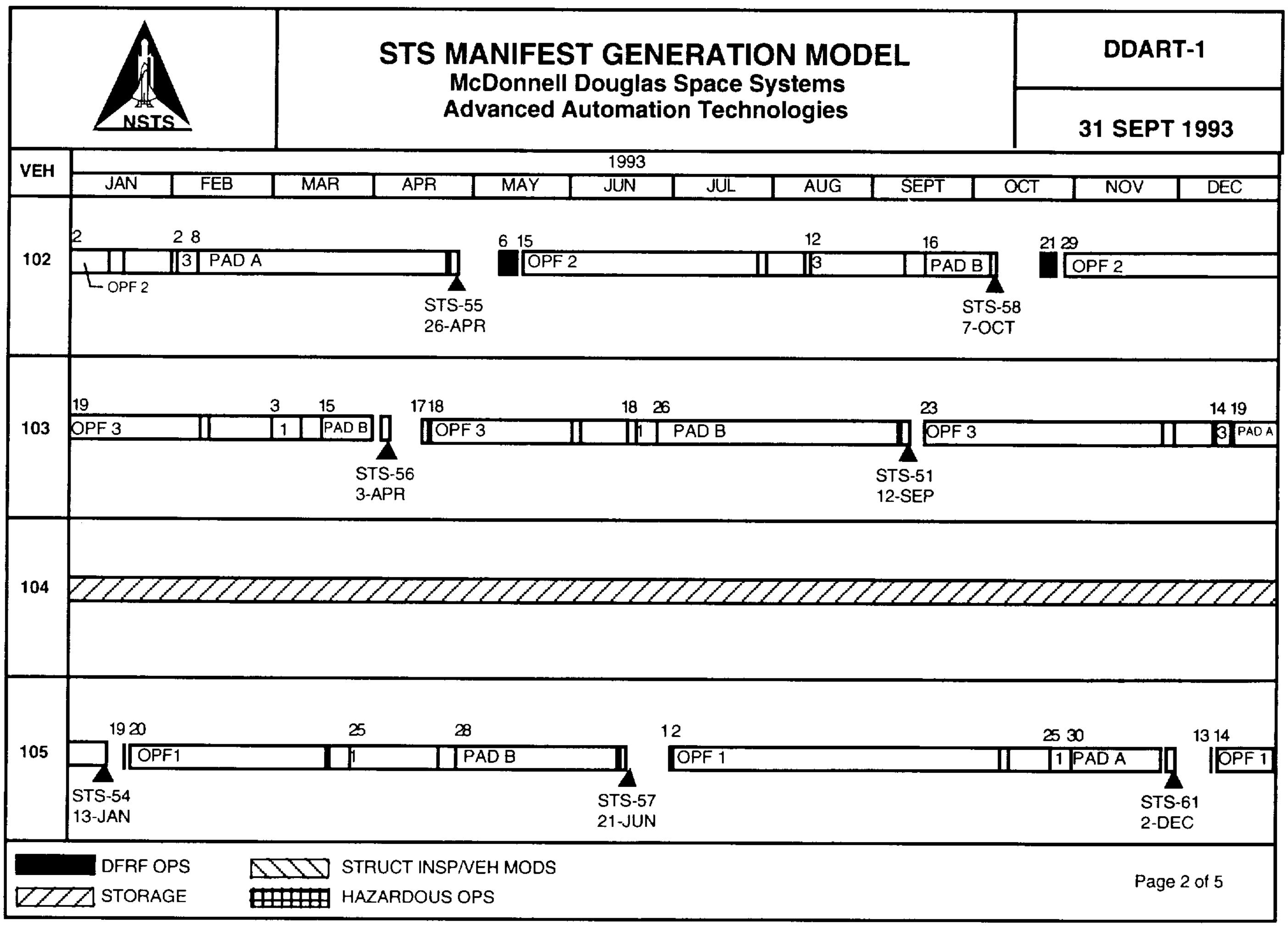
Key accomplishments:

- 1991: Developed a realistic orbiter and external tank/solid rocket booster processing model using prevailing policy ground rules.
- 1992: Developed a mouse-sensitive manifest reporter to display and modify simulation results.
- 1993: Ported the model to C++ GOST.

Key milestones:

- August 1991: Delivered the application and model (LISP) to TM planners on a Symbolics MacIvory.
- September 1992: Delivered the mouse-sensitive manifest reporter (LISP).
- December 1993: Proposed delivery of the PC-accessible application and model (C++/Motif) on DecStation.

Contact: R.H. Thornburg, TM-LLP-5A, (407) 861-5732
Participating Organization: McDonnell Douglas Space Systems (J.P. Rollins)
NASA Headquarters Sponsor: Office of Space Systems Development



Advanced Technology for Space Station Ground Processing Study

The ground processing of Space Station elements at KSC is expected to have an extremely high cost. The design, testing, and implementation of numerous ground support systems is labor intensive. Most processing operations are currently planned to be performed manually. The extensive planning, scheduling, and retrieval of technical information on the operations floor is cumbersome and labor intensive. In an effort to reduce overall Space Station costs, a study to identify improved processing methods through the use of advanced technology was initiated. The purpose of this effort was to identify needed technologies and advanced systems and take the necessary steps to implement improved, less costly systems and methods for Space Station processing wherever possible.

A team of technologists, operating personnel, and management from both NASA and the Payload Ground Operations Contractor at KSC was formed to pursue this effort. Initial opportunity areas were identified by key personnel who are overseeing and integrating all Space Station processing requirements at KSC. Next, extensive interviews were held with numerous Space Station management, engineering, and operations personnel teams. Due to the similarities to Spacelab processing, a number of Spacelab engineers were also interviewed to identify existing bottlenecks and potential improvements.

Technologists with experience in the required areas then performed an independent assessment of the technologies required and developed more descriptive improved processing systems concepts. The identified processing opportunities were then evaluated via a numerical criteria evaluation. The key factor in this evaluation was the total potential cost savings attributable to each opportunity. Independent of this analysis and ranking, key NASA Space Station managers at KSC were interviewed to determine the most attractive opportunities to be pursued. Their inputs were based on their own assessment of the need and savings for each opportunity and on the feasibility of successfully developing and using the proposed advanced systems. The KSC Space Station office, along with the study team, then selected the top opportunities to be pursued at the current time.

Key accomplishments:

- Identification and proposed enhancement of 32 Space Station processing tasks.
- Consensus recommendation of five top opportunities to pursue.

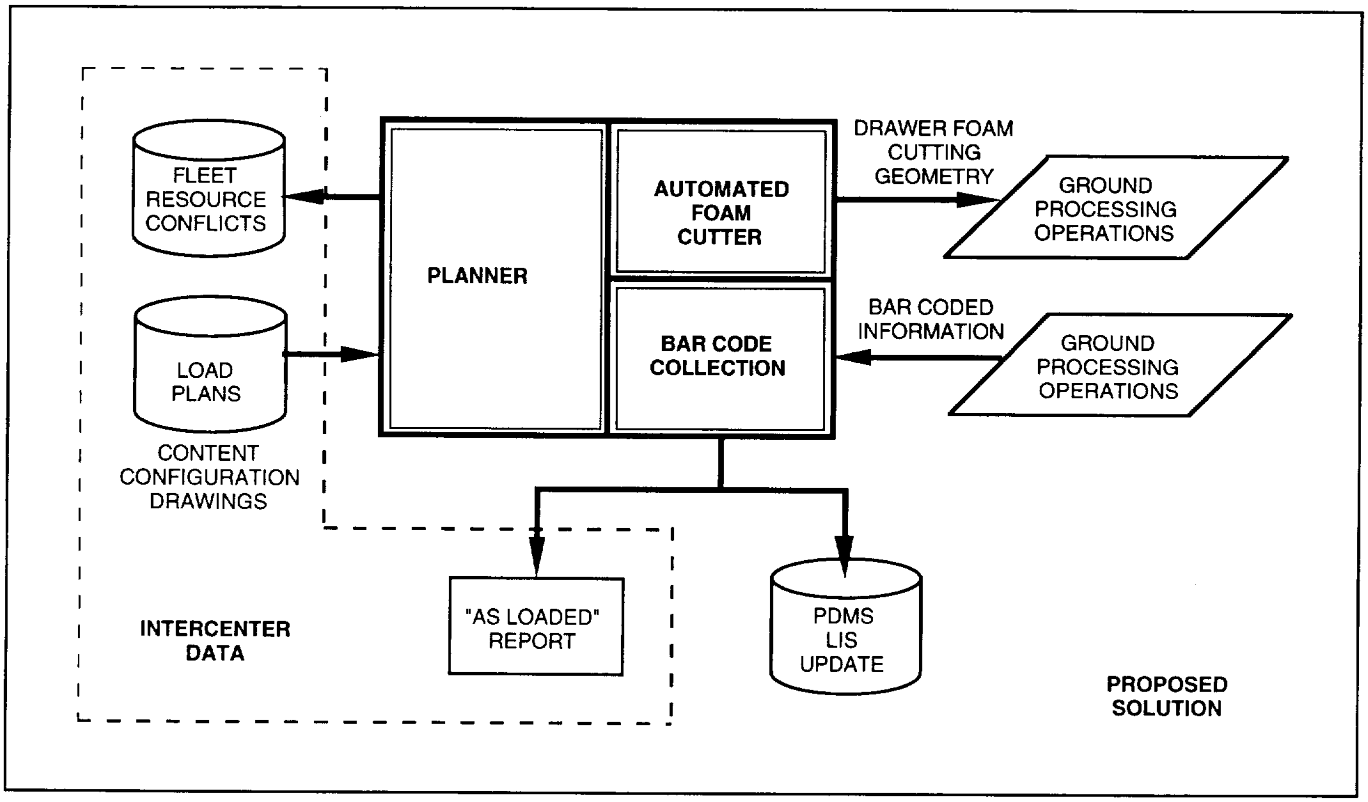
Key milestones:

- Continue to identify additional improvement opportunities.
- Develop prototype automated rack and drawer processing system.

Contact: N. Sliwa, DE-TDO, (407) 867-2780

Participating Organization: McDonnell Douglas Space Systems (K. Jernigan, C. Bessette, M. Huckabee, T. Weyant, N. Herren, D. Matson, M. Sklar, R. Vargo, D. Davis, and J. Taylor)

NASA Headquarters Sponsor: Office of Space Flight



Space Station Resupply and Return Automated Ground Operations

Knowledge-Based Autonomous Test Engineer (KATE)

KATE is a model-based monitoring and/or control system used to support Shuttle launch operations. KATE uses a mathematical model of a system to predict the values of measurements. When a discrepancy between predicted values and actual measurement values occurs, KATE determines and reports possible failed components that would explain the discrepancy. KATE then supplies the operator with recommendations on how to proceed under these circumstances.

The model of a system is represented as a knowledge base (KB), which is loaded into the KATE shell at run time. In this manner, each application differs only by the KB that has been loaded. Basically, a KB consists of descriptions of individual hardware components, equations that map each component's input values to its output values, and connections between components.

KATE's major achievement for 1993 was the successful conversion to C++ and OSF/Motif of the majority of the functionality of its previous LISP-based version. The new version (called KATE-C) was necessary to make KATE compatible with CCMS II and TCMS platforms, thereby allowing deployment for firing room applications. During the reimplementation, object-oriented design methodologies were used to maximize code modularity, reuse, and maintainability. Significant effort was also made to simplify the process of integrating KATE-C with custom user displays, specialized diagnostic algorithms, and new data sources.

For example, the User Interface was decoupled from the rest of the KATE-C shell to simplify KATE-C's future migration to the CORE AP/DP environment. In addition, generic widget handlers and interface services were provided to allow users to construct their own process overview panes and specialized dialog managers. Other improvements provided by KATE-C were: (1) the diagnostic engine of KATE-C was implemented as a toolbox, allowing the incorporation of highly divergent diagnostic algorithms into a common environment; (2) the real-time data interface was standardized so all data providers (including the three already developed) are interchangeable; (3) KATE-C's monitoring and simulation tasks were implemented as completely separate steps in the KATE-C reasoning process and their interaction between themselves and other reasoning tasks can now be managed directly from the user interface; and (4) KATE-C's fault detection process was extended to allow for future inclusion of advanced monitoring techniques such as trend perception and statistical process analysis.

Since the low-level KB structure was changed significantly to simplify its integration with KATE-C, KATE's KB editor was also reimplemented in C++. This new editor, while still in the prototype stages, provides a graphical interface to a template-based, context-sensitive text editor. With it, objects can be selected from a standard component library, named, specialized, and inserted into the application KB. Tree displays are provided to allow the user to visualize the connections between objects. Help menus and consistency and validity support tools are planned for the future.

1993 ended with a successful proof-of-concept demonstration of KATE-C for one subsystem of the Shuttle Vehicle Health Monitoring System (VHMS). The subsystem selected was the Active Thermal Control System (ATCS) for the Environmental Control and Life Support System (ECLSS) of the VHMS. This demonstration was presented by the Lockheed Shuttle Processing Contract personnel who acted as the user and knowledge expert liaison for this project and developed the majority of the user interface displays. For this application, KATE-C will be providing monitoring and diagnostic support for payload bay and instrumentation cooling while the Shuttle is powered up on the pad or in a processing facility.

Key accomplishments:

- Reimplementation of KATE core functionality in C++.
- Successful proof-of-concept demonstration of KATE-C for the ATCS subsystem of the VHMS.

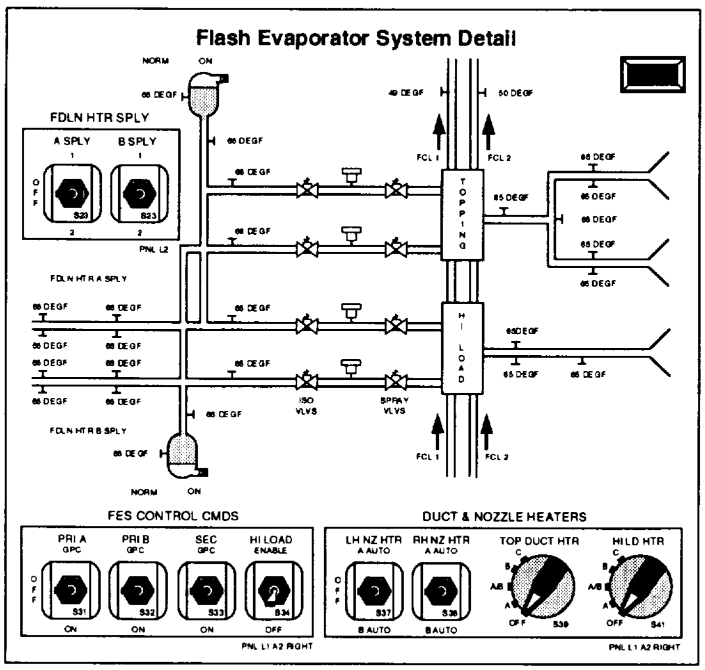
Key milestones:

- Completion of KATE's C++ translation.
- Apply KATE-C to two other VHMS subsystems.
- Trend analysis of real-time data for classification, performance trending, and signature recognition.

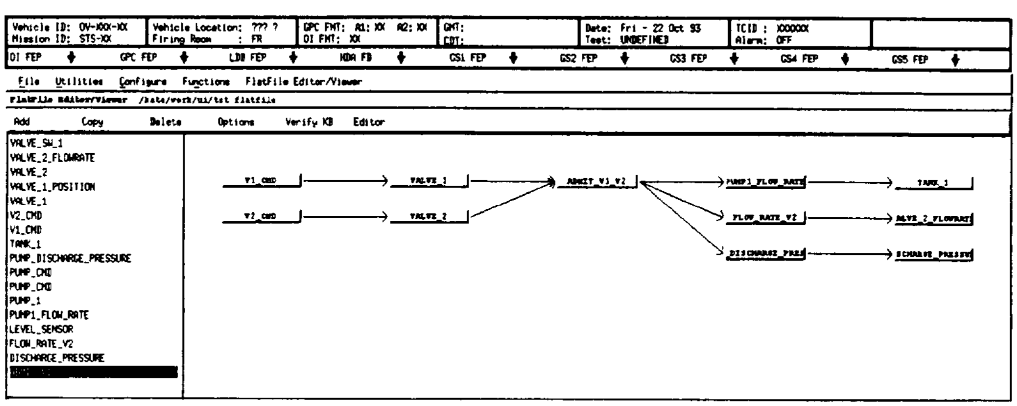
Contacts: N. Sliwa, DE-TDO, (407) 867-2780; and J.E. Galliher, DL-DSD-23, (407) 867-3224

Participating Organization: I-NET, Inc. (C.H. Goodrich and S.R. Beltz)

NASA Headquarters Sponsor: Office of Advanced Concepts and Technology



Overview Pane



Tree Display

Data Processing System (DPS) Launch Commit Criteria (LCC) Expert System (DLES)

In the course of Space Shuttle countdown operations, the Shuttle DPS is required to comply with predetermined standards of performance known as launch commit criteria (LCC). These criteria outline minimum requirements for a safe launch, as well as predetermined procedures for troubleshooting anomalies that may occur. Often, this kind of troubleshooting requires compiling information from many different sources, including failure histories, reference manuals, and telemetry retrieval data. The data must then be filtered and analyzed to determine the proper course of action. This procedure is often difficult and time consuming, which can be detrimental to time-critical launch operations.

The goal of the DLES project is to provide the DPS engineer with a tool capable of detecting and intelligently diagnosing DPS anomalies in near real time. The use of expert systems technology allows the DLES to monitor Shuttle telemetry data to determine if an anomaly has occurred. Once detected, the DLES uses a knowledge base (CLIPS) to determine a most probable cause and provide a resolution to the problem. The resolution is then presented to the user with all relevant telemetry data, related problem histories, and other information required to understand and resolve the problem. The DLES provides the rationale or "thought process" used to assist in the user's understanding and acceptance of the recommendation. Other features of the DLES include a detailed system monitor that allows daily monitoring of the DPS, a database of reference documentation and historical information, and an automated log book. The DLES has been modified to provide the capability to monitor multiple firing rooms (up to four) simultaneously on the same workstation. This is accomplished using the UNIX Checkout and Monitoring System (UCMS) provided by Expert Systems for Operations Distributed Users (EXODUS).

Development of the DLES began in February 1991 and a proof-of-concept prototype was demonstrated in August 1991. The capability to detect, diagnose, and resolve all DPS LCC violations is complete. The database and database interface is nearly complete. Development of an Open Look GUI version of the DLES is complete. The DLES is being converted to Motif to make it more portable and for potential incorporation into the Checkout, Control, and Monitor Subsystem (CCMS) 2 environment. The DLES was modified in 1993 to allow monitoring of multiple firing rooms with a single workstation.

The DLES has supported launch countdowns in an advisory mode in the management firing room for every launch since STS-46. Future plans call for the conversion to Motif, completion of the database, and formal validation of the DLES to be completed by October 1994. At that time, the DLES is planned to be officially used in the prime firing rooms to support testing and launch.

Key accomplishments:

- 1991: DLES proof of concept.
- 1992: First launch support of STS-46 (management firing room).
- 1993: Development completed on all DPS LCC violations.

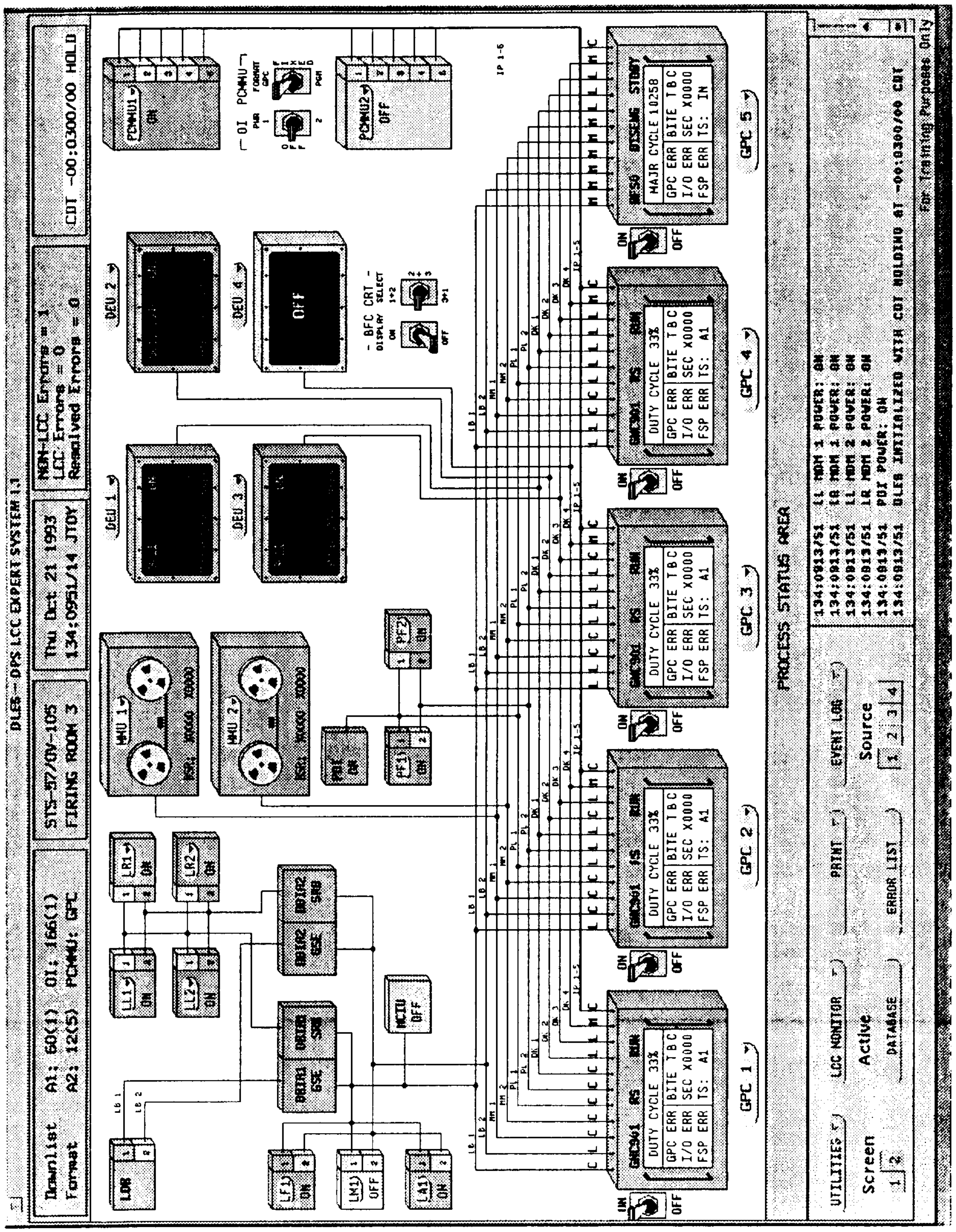
Key milestone:

- 1994: Final deployment of a validated system into the prime firing room.

Contacts: N. Sliwa, DE-TDO, (407) 867-2780; and S.B. Wilson, TV-GDS-23, (407) 861-3846

Participating Organization: Lockheed Space Operations Company (J.M. DeVoss)

NASA Headquarters Sponsor: Office of Space Systems Development


DLES – DPS LCC EXPERT SYSTEM 1.1
Downlist A1: 60(1) OI: 166(1)
Format A2: 12(5) PCMMU: GPC
STS-57/OV-105
FIRING ROOM 3
Thu Oct 21 1993
134;0951/14 JTOY
NON-LCC Errors = 1
LCC Errors = 0
Resolved Errors = 0
CDT -00:0300/00 HOLD
GPC 1
GPC 2
GPC 3
GPC 4
GPC 5
DEU 1
DEU 2
DEU 3
DEU 4
MMU 1
MMU 2
PROCESS STATUS AREA
UTILITIES
LCC MONITOR
PRINT
EVENT LOG
DATABASE
ERROR LIST
Screen
Active
Source
For Training Purposes Only

Reasoning Based on Intelligent Computation and Networking

Several workstation-based software projects currently under development at KSC perform automated fault detection and vehicle health management (VHM). These systems monitor Space Shuttle telemetry and continuously check for off-nominal conditions. When such occurrences are detected, the system attempts to determine the cause and advise the firing room engineer of its findings. Advisory systems can thereby provide efficient and consistent analysis of vehicle anomalies.

Advisory systems were developed for various orbiter systems by various organizations (e.g., data processing and main propulsion). To date, these projects were developed independently of one another to diverse standards and requirements. The systems are consequently single-purpose, requiring their own individual workstations, telemetry processors, and supporting software procedures.

As these projects move out of the prototype stage into an operational environment, this approach becomes unworkable. Systems developers have to re-invent software previously created. A solution to this problem is to develop a system that will allow the firing room engineer to run any advisory system on any workstation. Experience to date shows many elements that could be provided in common.

It is possible to design an architecture that allows advisory systems to operate and be developed cooperatively by providing these elements. Rubicon (Reasoning Based on Intelligent Computation and Networking) attempts to do this. The project has two goals:

1. To facilitate development of new advisory systems by providing common functions.

2. To permit separate advisory systems to run compatibly at a single workstation.

These goals should be met without placing burdensome requirements on future developers and without adding layers of software that adversely impact system performance.

For fiscal year 1993, Rockwell/LSS developed a prototype that demonstrates these concepts. Two existing advisory systems, MCDS Diagnostic Tool (MDT) and the DPS LCC Expert System (DLES), were integrated under Rubicon and now can be operated simultaneously on a single workstation. Common telemetry and database interfaces and several utility functions were incorporated. Communications protocols among systems are in place.

Rubicon is a step toward operational vehicle health management at KSC. The prototype demonstrates that independently developed expert systems can be integrated into an operational VHM system.

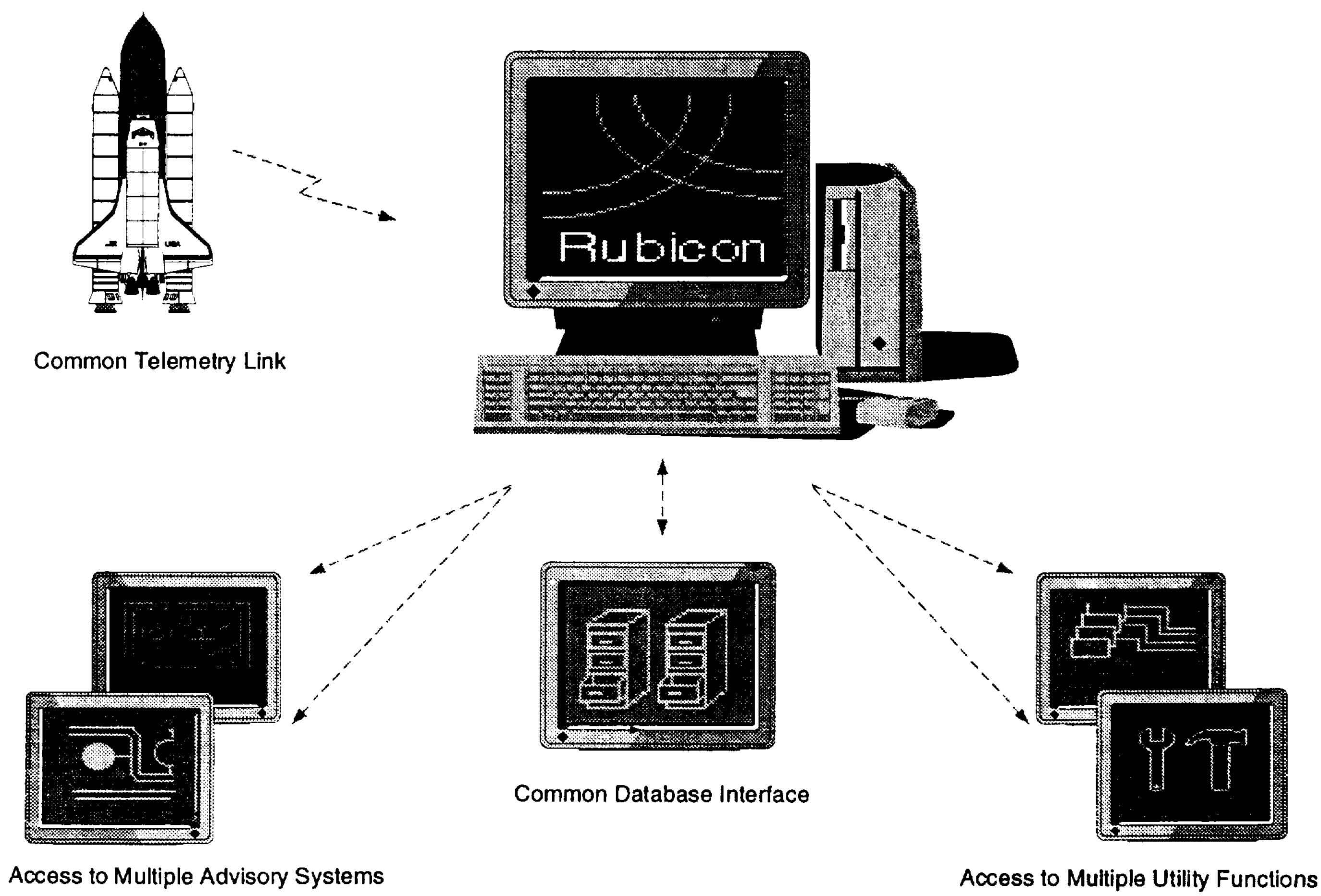
Key accomplishment:

- 1993: Rubicon prototype completed and demonstrated.

Key milestone:

- 1994: Completion of the operational Rubicon system.

Contacts: N. Sliwa, DE-TDO, (407) 2780; and S.B. Wilson, TV-GDS-23, (407) 861-3846
Participating Organization: Rockwell International Corporation, Space Systems Division (T. Fowler)
NASA Headquarters Sponsor: Office of Space Systems Development



Rubicon System Diagram

Expert Systems for Operations Distributed Users (EXODUS)

In an effort to improve monitoring and control of Shuttle processing and launch operations at KSC, expert systems have been developed to augment the current capabilities of the Checkout, Control, and Monitoring Subsystem (CCMS). CCMS is composed of six MODCOMP distributed computer systems located in control rooms across KSC dedicated to Shuttle, payload, and hypergolic systems processing. Expert systems acquire and analyze vehicle and ground measurements from CCMS, alert engineers of anomalous conditions, and suggest courses of action. These systems often retrieve pertinent information from Shuttle documentation and system logs to aid in the decision process. Development of these advisory systems by different engineering groups has led to independent, stand-alone systems supported by different platforms and software implementations. The cost to KSC engineering to develop and maintain these independent systems increases with each addition of a new expert system. If there were common utilities to perform functions basic to all expert or advisory systems, a substantial savings in cost and development time could be achieved as well as standardization among the systems. Since these systems will be monitoring testing on an integrated vehicle, it would be beneficial if the advisory systems were integrated to allow information sharing on events that may affect a given decision.

The goals of Expert Systems for Operations Distributed Users (EXODUS) are to decrease the time and costs of the development of systems and to integrate these systems into a cooperative environment. By providing common utilities for measurement data acquisition and access to a common database containing system documentation, system logs, etc., developers can concentrate on the intelligence of their systems earlier in the development phase. Measurement data acquisition is provided by the EXODUS subsystem known as the UNIX Checkout and Monitoring Subsystem (UCMS). UCMS, written in ANSI C, acquires measurement data from an Ethernet connection to a control room data source. UCMS is designed to support multiple data sources to allow multiple control room monitoring at the workstation. UCMS also provides other services, such as recording and retrieval capabilities, as well as generic measurement information and display utilities. Database services are handled by an Oracle database and database manager, allowing advisory systems and users to access necessary documentation at a common source on a network. Integration of the advisory systems will be achieved by utilizing a communications protocol and a controller workstation. The communications protocol and controller software are being developed under a small business contract and will be available commercially.

Phase one of the UCMS has been completed and demonstrated to the user community. It is being upgraded to support a hardware change in the control room data source. The Oracle database server is to be developed in 1994. The Networks! software is currently under development by Symbiotics Corporation and is due to be released in April 1994.

Key accomplishments:

- 1992: Demonstration of the Networks! communication protocol to the user community.
- 1993: UCMS phase one completed and demonstrated to the user community.

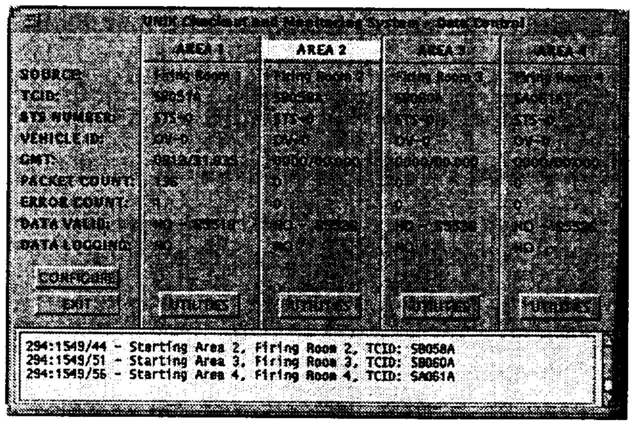
Key milestone:

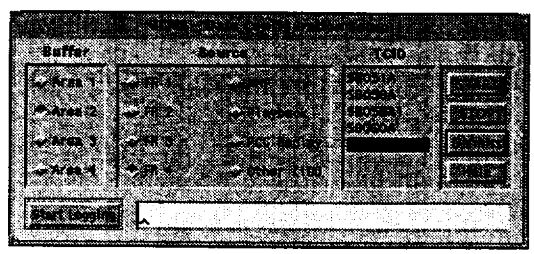
- 1994: UCMS phase two completion and demonstration. Oracle Database Server completion and demonstration.

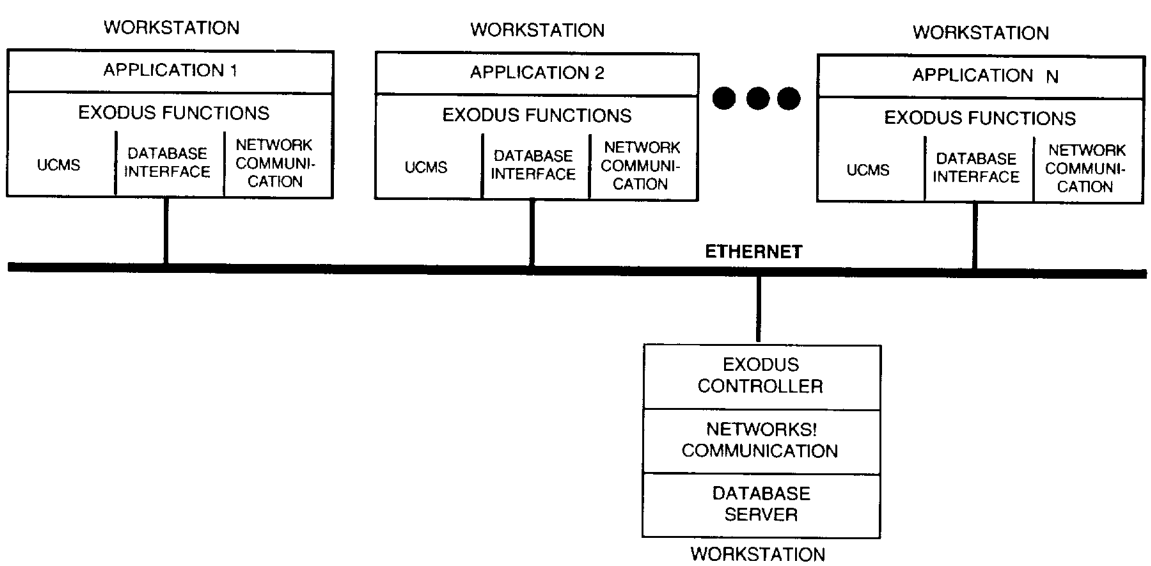
Contacts: N. Sliwa, DE-TDO (407) 867-2780; and J.H. Fluhr, TV-GDS-11, (407) 861-3788

Participating Organization: Lockheed Space Systems (J.M. DeVoss)

NASA Headquarters Sponsor: Office of Advanced Concepts and Technology and Office of Space Systems Development







Exodus Functional Overview

Propulsion Advisory Tool (PAT)

The idea for a Main Propulsion System (MPS) advisory system was born out of the frustration and delays incurred by the launch team at KSC while trying to assemble data for evaluation during the hydrogen leak investigations during the summer of 1990. The current system used to track MPS during launch lacks robustness and speed due to strict configuration controls and the dated equipment. MPS is a major contributor to on-pad scrubs and troubleshooting efforts. It is a driver behind vehicle processing and, like other subsystems, is rapidly losing expertise due to ebbing design center and vendor support. As a result, these pools of knowledge are being lost forever. Hence the need exists for an advisory computer system to track MPS that is a knowledge-based system with user-friendly storage and retrieval of the data and data plotting.

The Propulsion Advisory Tool (PAT) project answers these needs. It is an expert system currently under development to monitor MPS health prior to a Shuttle launch. PAT is a joint development project between NASA/KSC, Lockheed Space Operations Company, Lockheed Sanders, Rockwell International Space Systems Division (KSC), and Rockwell International Space Systems Division (Downey). Some of its features are:

1. Enhanced displays, data manipulation, and plotting techniques
2. Anomaly prediction, detection, warning, and corrective action
3. Trend analysis and system diagnostics

PAT focuses on launch day operations to monitor system health. It follows the transfer of liquid hydrogen and oxygen through the ground systems and orbiter into the external tank. To accomplish this, it relies on data from analog pressure/temperature sensors and discrete valve position indicators fed from the PC GOAL network. In addition, PAT receives the data for the aft background purge effluent for liquid hydrogen, liquid oxygen, and helium leakage.

PAT uses incoming data for two completely parallel operations. One path is used to display the MPS liquid oxygen and liquid hydrogen propellant loading system. The user can display plots of any applicable MPS measurements, in any combination. Historical data can also be plotted with "live" data. The other path feeds the PAT knowledge base. This expert system software uses a rule/model base of knowledge captured from MPS engineering experts to predict and detect anomalies or trends. The user is then warned of the potentially hazardous condition, including a corrective action. The groundwork has been laid for use of neural nets and fuzzy logic in the PAT knowledge base.

Key accomplishments:

- 1992: Initial demonstration of software technology. Implementation of initial liquid hydrogen data reduction/manipulation prototype.
- 1993: Delivery of hardware. Delivery of liquid oxygen data reduction/manipulation software.

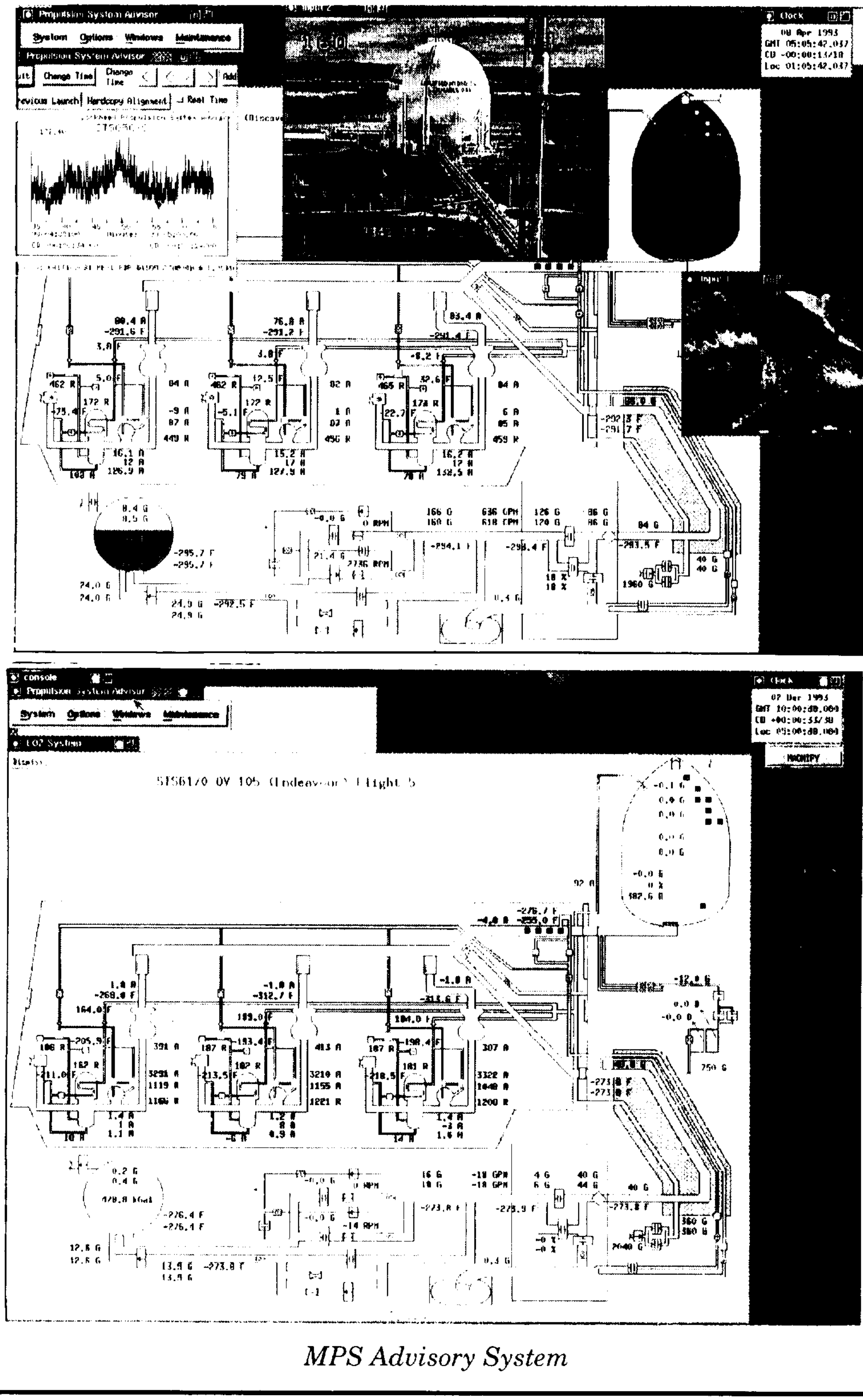
Key milestones:

- 1994: Complete liquid oxygen and anti-geyser expert system software. Complete data reduction/manipulation software for Space Shuttle Main Engines.
- 1995: Expansion to the liquid hydrogen expert system software.

Contacts: N. Sliwa, DE-TDO, (407) 867-2780; and R.J. Beil, TV-FSD-11, (407) 861-3944

Participating Organizations: Lockheed Space Operations (L.T. Bird); Rockwell International Space Systems (L.H. Fineberg); and Lockheed Sanders (B. Houvener)

NASA Headquarters Sponsor: Office of Space Systems Development



MPS Advisory System

Ground Processing Scheduling System

Space Shuttle ground processing at KSC is a complex activity, encompassing the inspection, testing, maintenance, and repair of Space Shuttles in preparation for launch. The Ground Processing Scheduling System (GPSS) is the application of advanced scheduling techniques that have been developed to support the dynamics of scheduling during the Shuttle ground processing phase in the Orbiter Processing Facility (OPF). Scheduling in the OPF demands the integration of the ground processing requirements for 24 major orbiter systems. A majority of this system's processing is worked in parallel, with each system's processing requirements having associated constraint, configuration and resource requirements.

The GPSS is a set of interconnected, software modules that are coded in LISP and C. GPSS is being used in an operational testbed environment to functionally schedule the activities and configuration of the Space Shuttle during its processing phase in the OPF. The software modules manipulate data specific to the Shuttle processing environment and consist of domain constraints and scheduling heuristics for the OPF environment. GPSS also includes a sophisticated user interface and the scheduling engine. The GPSS scheduling engine is based on artificial intelligence technology that uses constraint-based programming methods, combined with iterative repair and simulated annealing techniques, to provide an "anytime" schedule of Shuttle OPF operations.

NASA KSC Shuttle Operations, NASA Ames Artificial Intelligence Research Branch, and Lockheed Space Operations Company are working jointly to develop this dynamic rescheduling system. The GPSS team continues to refine the automated deconflict capability and is preparing for translation of the LISP/C code into C++ for the first operational and user-sustainable version of the system. The GPSS team is also preparing to extend the GPSS functionality by integrating the system with advanced interface tools and providing an innovative and interactive meeting environment for schedule communication and decision support. In 1994 and beyond, it is anticipated that the GPSS will become a fully functional partner within the automated scheduling capabilities supporting KSC ground processing.

Key accomplishments:

- 1989: Introduction of the GPSS project to KSC.
- 1990: Prototype system to support OPF processing ready for testing.
- 1991: Initial OPF knowledge base established via field testing.
- 1992: OPF schedules produced for the orbiters Columbia and Endeavour via operational testing.
- 1993: Compress and conflict resolution capabilities provided to testbed system. GPSS team receives Space Act Award.

Key milestones:

- 1993: Predict and deconflict schedule violations.
- 1994: Provide and implement the first operational and sustainable version of the GPSS to the users. Provide a prototype version of the GPSS-based interactive meeting system.

Contact: N.E. Sliwa, DE-TDO, (407) 867-2780

Participating Organizations: NASA KSC Shuttle Operations (N. Schafer), NASA Ames Research Center (P. Friedland), and Lockheed Space Operations Company (D.L. Kautz)

NASA Headquarters Sponsor: Office of Advanced Concepts and Technology / Office of Space Systems Development

Industrial Engineering

Industrial Engineering at the John F. Kennedy Space Center (KSC) supports the development of advanced technologies for application in vehicle and payload ground processing. This effort is directed toward decreasing processing time and cost, improving operational efficiency and productivity, and improving personnel comfort and safety. Industrial engineering includes the application of statistical control methods, psychology and human factors, operations research techniques, and process modeling and simulation. The near-term focus of this dicipline is Shuttle ground processing. The long-term focus will concentrate more on overall production and process improvement techniques, emphasizing the areas of operations research and process modeling.

Interfacility Benchmarking in Shuttle Processing Operations

An industrial trend known as benchmarking directly supports Continuous Improvement of Processes (CIP) as an integrated organizational objective. It further supports the identification of specific areas of resource concentration and focuses these resources on improvements in daily business practices. This research in interfacility benchmarking is centered around a structured process identification and measurement activity required in competitive benchmarking comparative analyses. These process comparisons will provide useful information for improvement activities within Shuttle processing at KSC. A three-phase, three-year research activity is in progress to evaluate comparison between multiple facilities in the same organization and between facilities in different organizations. These relationships are being studied to establish common performance measures affecting organizations across a broad functional spectrum.

First-year research activities have centered around an analysis of state-of-the-art industrial benchmarking activities and the development of a systematic process disaggregation methodology for use in Shuttle processing to identify high-priority, low-level processes for further, detailed process improvement analyses. Concurrently, a structured use of organizational performance measures for interfirm comparison is being developed. It is designed to consider high-level performance measures that share common attributes across the organizational spectrum at KSC.

The measurement system being developed during phase one and planned for integration in subsequent phases is identified as the Interfacility Productivity and Performance Measurement System (IPPMS). The bilevel approach to process analysis is being developed to better understand the internal processes of Shuttle processing before attempting to benchmark with other organizational elements in following phases of the project. This dual approach is designed to capture operational processes for comparison at both the macro and micro levels.

Phase two will involve the development of initial external benchmarking methods with other organizations.

Key accomplishments:

- Development of a systematic process disaggregation methodology.
- Identification of the top-ranked/common processes (three types of processing facilities).
- Identification of high-level and low-level processes for comparative analysis.
- Development of IPPMS comparative analyses.

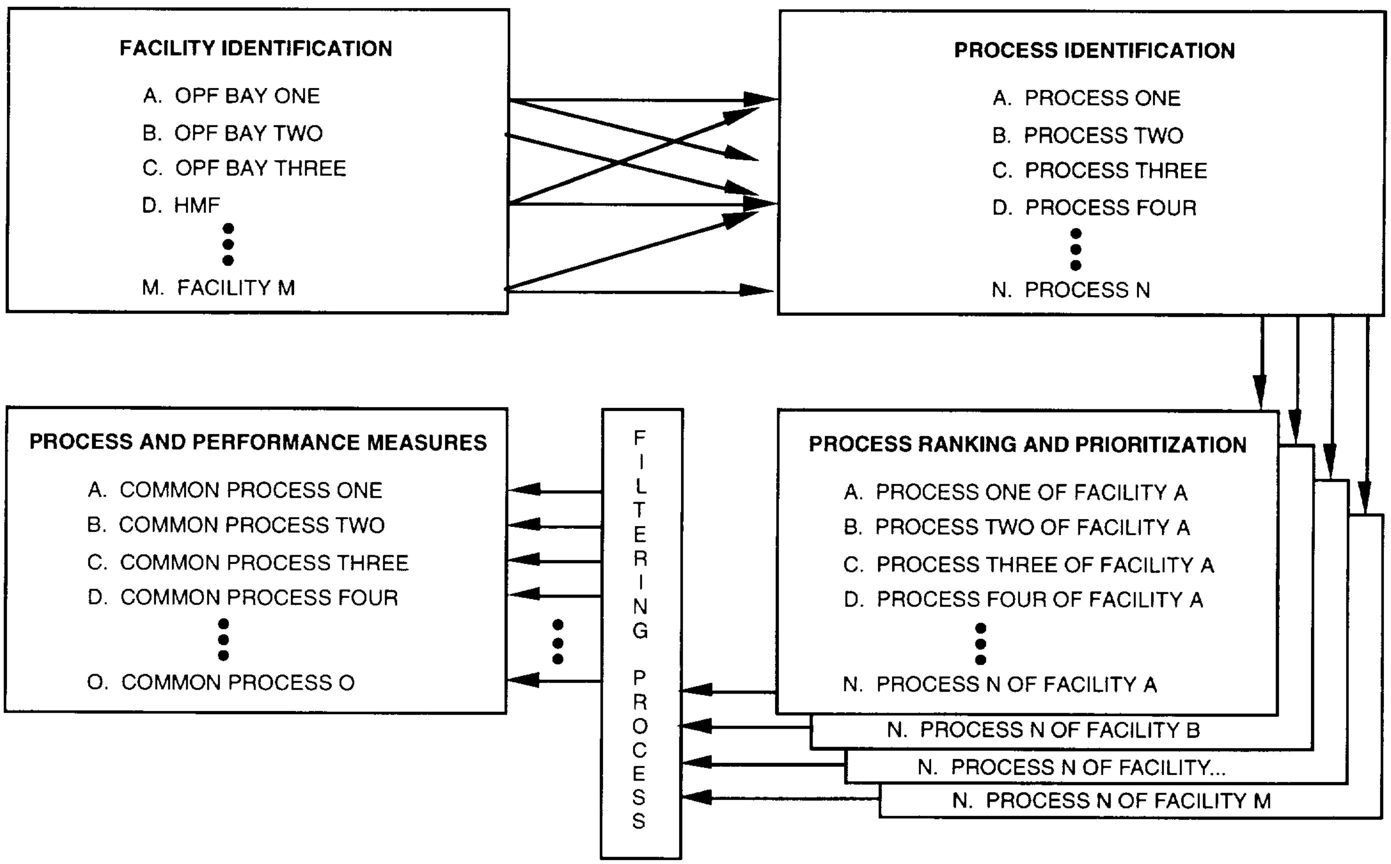
Key milestones:

- Identification of top-ranked/common interfacility processes.
- Identification of low-level interfacility processes.

Contact: T.S. Barth, TP-OAO, (407) 861-7067

Participating Organization: University of Central Florida (R. Safford and A. Jackson)

NASA Headquarters Sponsor: Office of Space Systems Development



Benchmarking Process Disaggregation Flowchart

Automated Recertification Training System

This is the third year of a Small Business Innovation Research (SBIR) project conducted by ENSCO, Inc., to enhance the computer-based training (CBT) process at KSC. The primary focus for this improved training approach is the periodic recertification of technicians to perform specific Shuttle processing tasks. Widely varying job requirements of technicians and the need to coordinate training within the constraints of the work schedule presented challenges to the current classroom-based recertification program.

Phase I of the Automated Recertification Training System (ARTS) project began in 1991 to perform applied research toward the conversion of existing certification courses to CBT. While CBT has been available for many years, improvements in the development and delivery process were needed to allow production of CBT courseware on a larger scale to meet KSC's recertification training needs. ENSCO's goal in Phase II was to apply improved software methods and hardware technology to increase the efficiency and cost-effectiveness of CBT. The technical approach for the project was developed to achieve three major objectives:

- To provide a needs assessment process to ensure the selection of effective CBT applications and to accurately define the content of CBT courseware.

- To develop an integrated authoring system that allows CBT courseware to be developed faster and to make courseware more maintainable.

- To investigate digital audio and video technology that would enable distribution of multimedia CBT over existing computer networks.

The project is on schedule to meet all its major objectives by May 1994. Specific accomplishments during 1993 include:

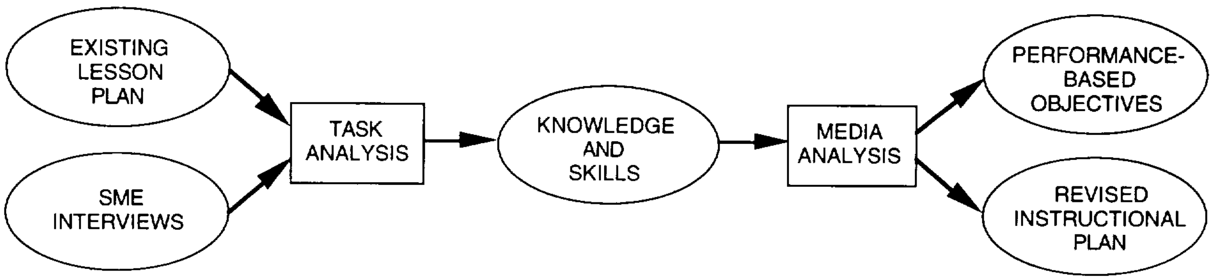
- Development of a two-stage needs assessment process was completed and used to define the requirements for five pilot courses developed as part of the contract. This process was successful in streamlining the content of these courses in order to meet the essential training objectives. (See the figure "Needs Assessment Process.")

- Creation of a courseware authoring system based on a commercial authoring package running in Microsoft Windows that enables the production of customized courseware compatible with KSC design standards. (See the figure "Authoring Workstation.")

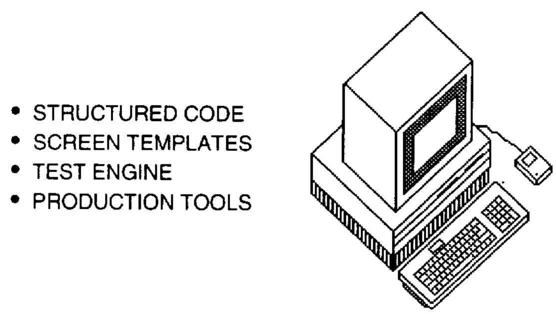
- Completion of a prototype courseware delivery system that stores digitized and compressed video on a file server and then forwards the digital data over a network connection for later decompression and playback on a training workstation. (See the figure "Courseware Delivery Concept.")

Delivery of the CBT hardware and software developed under this contract is planned for March 1994. When the developed tools are fully implemented at KSC, it is expected to reduce the cost of courseware development and have a favorable impact on trainee job performance. Commercializing the technology from this SBIR project is planned for Phase III. Spinoff products anticipated include custom courseware for technical skills training, courseware production software for corporate training organizations of aerospace and other industrial companies, and embedded trainers for software applications.

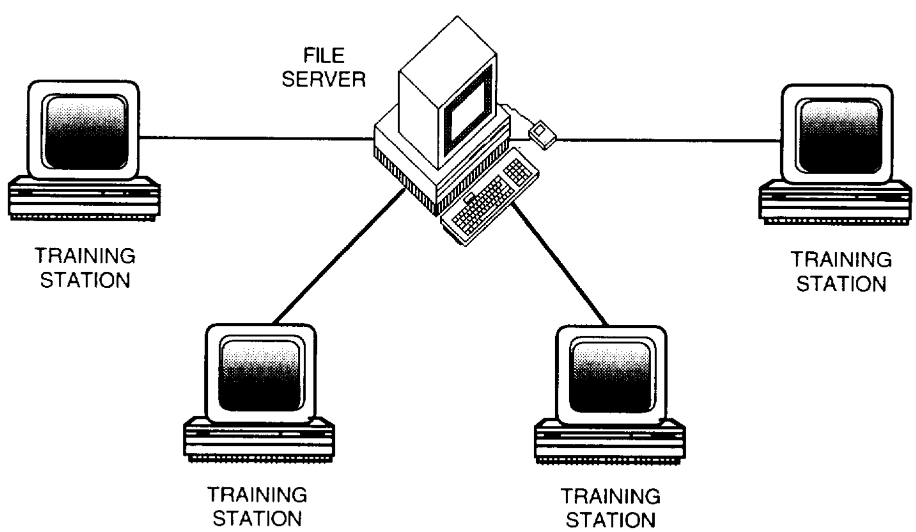
Contact: T.S. Barth, TP-OAO, (407) 861-7067
Participating Orga::zation: ENSCO, Inc., (G. Drape)
NASA Headquarters Sponsor: Office of Advanced Concepts and Technology



Needs Assessment Process



Authoring Workstation



Courseware Delivery Concept

Team Dynamics and Team Performance in Space Shuttle Processing

Teams exist at every level of activity in Space Shuttle processing. At the high levels, NASA personnel work closely with Shuttle Processing Contract (SPC) personnel to specify the flow of processing activities required to prepare an integrated Shuttle for a particular mission. Similar teams come together on the shop floor to prepare elements of flight hardware for launch. At the floor level, a typical team might include processing technicians from one or more contractors, quality technicians from each of the contractors involved in the task, NASA quality personnel, NASA and contractor systems engineers, and others. The unique capabilities of each team member and the ability of the people, many of whom are assembled for the performance of a single task, to act as a team can impact the quality of the task output and the efficiency of the task performance.

Research personnel from the Center for Creative Leadership (CCL), the United States Air Force (USAF), Kennedy Space Center (KSC), Ames Research Center (ARC), and the Department of Industrial Engineering at the University of Central Florida (UCF) joined together to study team dynamics and team performance in Shuttle processing activities at KSC. More specifically the research objectives included:

1. Refinement of team dynamics research models developed by the CCL, USAF, and ARC for use in Shuttle processing.
2. Development of team output performance measures capable of being correlated with team dynamics measures.

The figure summarizes the research objective and primary roles of the project participants in realizing the objectives. The information gained during this study will be used as the basis for recommendations to improve team performance in Shuttle processing operations.

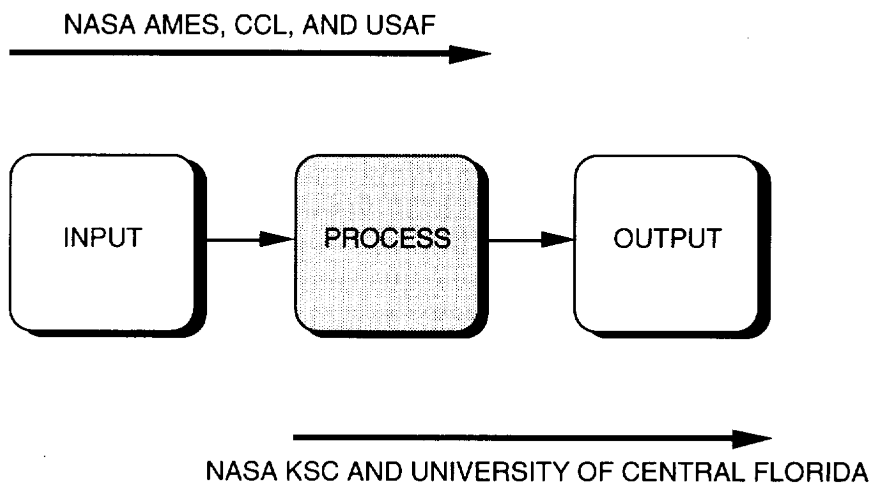
Key accomplishments:

- The development of relationships with the "client" to enable observation of teams composed of client personnel.
- Establishment of logistical procedures for onsite observation of teams performing Shuttle processing activities.
- Observation of approximately 50 different Shuttle processing operations for first and second shifts in the processing facilities [Orbiter Processing Facilities (OPF's), Vehicle Assembly Building (VAB), and Hypergol Maintenance Facility (HMF)].
- Analysis and correlation of results and summary briefings to KSC management.

Contact: T.S. Barth, TP-OAO, (407) 861-7067

Participating Organizations: University of Central Florida (W. Swart, R. Safford, and G. Clark), NASA Ames Research Center (B. Kanki), Center for Creative Leadership (R. Ginnett), and the United States Air Force Academy (J. Austin)

NASA Headquarters Sponsor: KSC Center Director Discretionary Fund



Team Research Model —— a System View

Propellant Handlers Ensemble (PHE) Heating Unit

The PHE is used at KSC and Vandenberg Air Force Base (VAFB) to protect personnel during hazardous hypergol propellant operations for the Space Shuttle and other launch vehicles. The PHE, which consists of an environmental control unit (ECU) and a butyl rubber suit, provides a totally enclosed life support system. The ECU provides breathing air from a cryogenic (liquid) air dewar. During winter months and especially at night, the technician in the PHE may become very cold due to a combination of low ambient temperatures and the cryogenic air source. Several operations have been curtailed because of cold stress on the PHE technicians.

The Propellants and Gases branch (DM-MED-4) of the Engineering Development Directorate used the Small Business Innovation Research (SBIR) program to find a research and development company to develop a method to heat the PHE during cold weather operations. The contracts (phase I and phase II) were awarded to Mainstream Engineering Corporation (MEC) of Rockledge, Florida. MEC's approach was to develop a water/salt reaction device to add heat to the air stream leaving the ECU. The heater unit mixes water and a salt, which reacts to form an oxide, and generates heat. Air from the ECU passes through a tube inside the heater unit where it picks up heat by conduction through the tube wall. A major requirement of this design is to keep weight and size to a minimum while having enough reactants to provide adequate heat for the nominal 2-hour duration of the ECU. Another requirement was to select a nontoxic salt with adequate heat output when reacted with water.

After exhaustive testing of candidate salts, MEC decided to use sodium oxide (NaO). This salt is nontoxic and provides the necessary heat output when saturated with water. The water and NaO are mixed by gravity draining the water through a manifold to the NaO tank. The NaO, mixed with a wicking material, is encased in fiberglass tubes that allow better reaction with the water. The heater unit also features a passive thermostat, consisting of a bimetallic disk placed over the manifold holes. When the temperature of the disk reaches 100 degrees Fahrenheit, the disk deforms to form a seal over the manifold that restricts water flow into the salt tank, thereby reducing the heat generated. As the temperature decreases, the disk will relax to its original position and allow water to flow again. The weight of the heater units has gone from an initial prototype of 10.3 pounds to the final design of 3.9 pounds. MEC delivered four prototype heater units to KSC. These units will be tested in-house by KSC to determine if they meet requirements. The KSC testing is tentatively scheduled for the fall of 1993. If successful, the design will be commercialized in a phase III effort that will provide heater units to KSC and VAFB.

Key accomplishments:

- Use of a salt/water reaction to generate enough heat to raise the temperature of the air entering the PHE.
- Reduce the heater unit size and weight (from 10.3 to 3.9 pounds).
- Use of a bimetallic disk to act as a passive thermostat to regulate the heater unit output temperature.

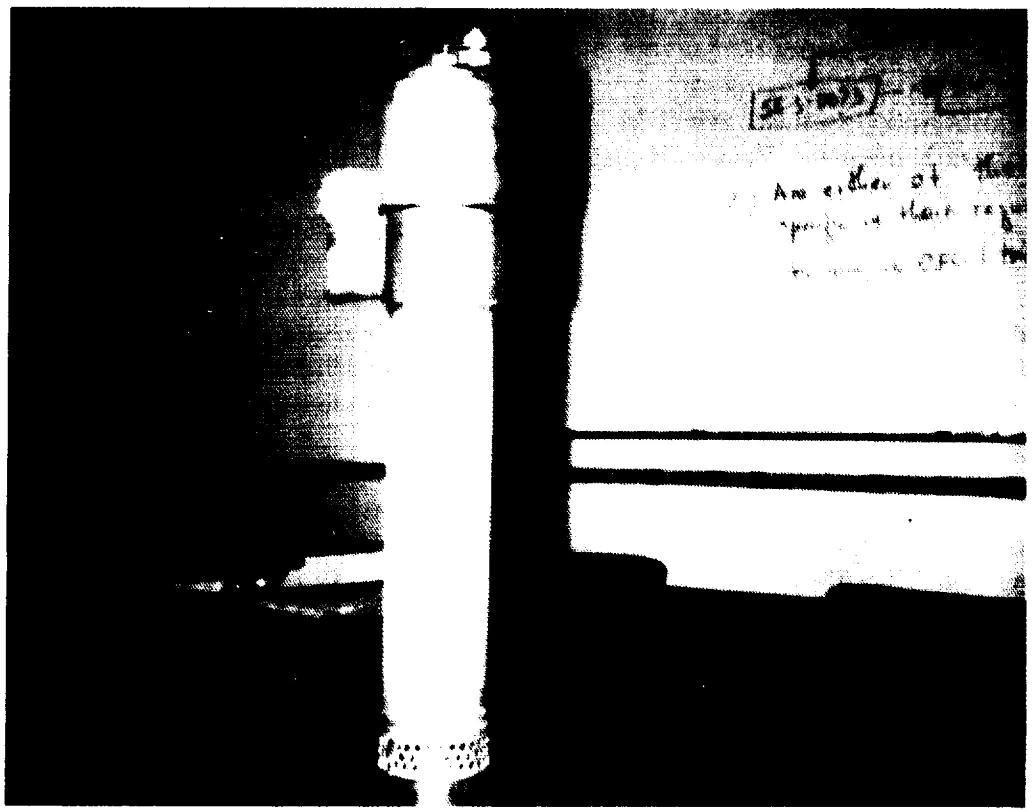
Key milestones:

- 1990: Development of an NaO/water reaction heater design.
- 1991: Development of a water delivery manifold design.
- 1992: Development of a passive bimetallic disk thermostat.

Contact: M.D. Hogue, DM-MED-42, (407) 867-3266; and E. Ernst, DM-MED-41, (407) 867-3201

Participating Organization: Mainstream Engineering Corporation (L. Grzyll)

NASA Headquarters Sponsor: Office of Advanced Concepts and Technology/KSC Center Director Discretionary Fund



PHE Heating Unit

Supercritical Air Respirator

At KSC, the fire rescue team and the closeout crew use the liquid air pack (LAP) in case the need arises to rescue astronauts from the Space Shuttle at the pad. The LAP, as its name implies, provides respirable air from a cryogenic (liquid) air dewar. A problem with the LAP is that when it is operated in horizontal positions, the internal pickup in the dewar is exposed to the ullage. The ullage is the gaseous portion of the air in the dewar that creates system pressure. Two results of outflowing the ullage are that (1) it is rich in gaseous nitrogen, thereby reducing the gaseous oxygen level of the air leaving the dewar and (2) the system pressure drops sharply. Another problem with the LAP is there is no direct quantity measurement of the liquid air. Currently, a timer is used to estimate when the LAP has 25 percent of its air left [per National Institute of Occupational Safety and Health Development (NIOSH) requirements] so the wearer can egress to a safe location.

The Propellants and Gases Branch (DM-MED-4) of the Engineering Development Directorate used the Small Business Innovation Research (SBIR) program to find a research and development firm to develop a replacement respirator for the LAP. Aerospace Design and Development (ADD) of Boulder, Colorado, was awarded both contracts (phase I and phase II). ADD proposed a supercritical air respirator (called the SCAMP for SuperCritical Air Mobility Pack). Supercritical air is almost cold enough to be liquid but is at a high enough pressure to have approximately the same density as the liquid. This would give the SCAMP a size and weight similar to the LAP but without its problems. The supercritical air is still a single-phase gas; so the two-phase problem associated with pulling ullage would not occur. The quantity of the supercritical air can be measured by a capacitance sensor inside the dewar.

ADD has been able to develop a prototype SCAMP design that meets KSC's requirements of size, weight, and attitude-independent operation. The loading system for the SCAMP uses compressed air cooled to supercritical temperature by a liquid nitrogen bath. ADD has fabricated four SCAMP's and two loading systems. Two SCAMP's and one loading system will be retained by ADD for NIOSH testing. The remaining hardware was sent to KSC for an in-house testing program tentatively scheduled for the spring of 1994. If the KSC in-house testing of the SCAMP is successful, a phase III effort will be initiated to procure SCAMP's to replace the current LAP inventory at KSC.

Key accomplishments:

- Development of a supercritical air respirator that overcomes the drawbacks of liquid air respirators.
- Development of a loading system that requires only liquid nitrogen, a source of compressed air, and electrical power.

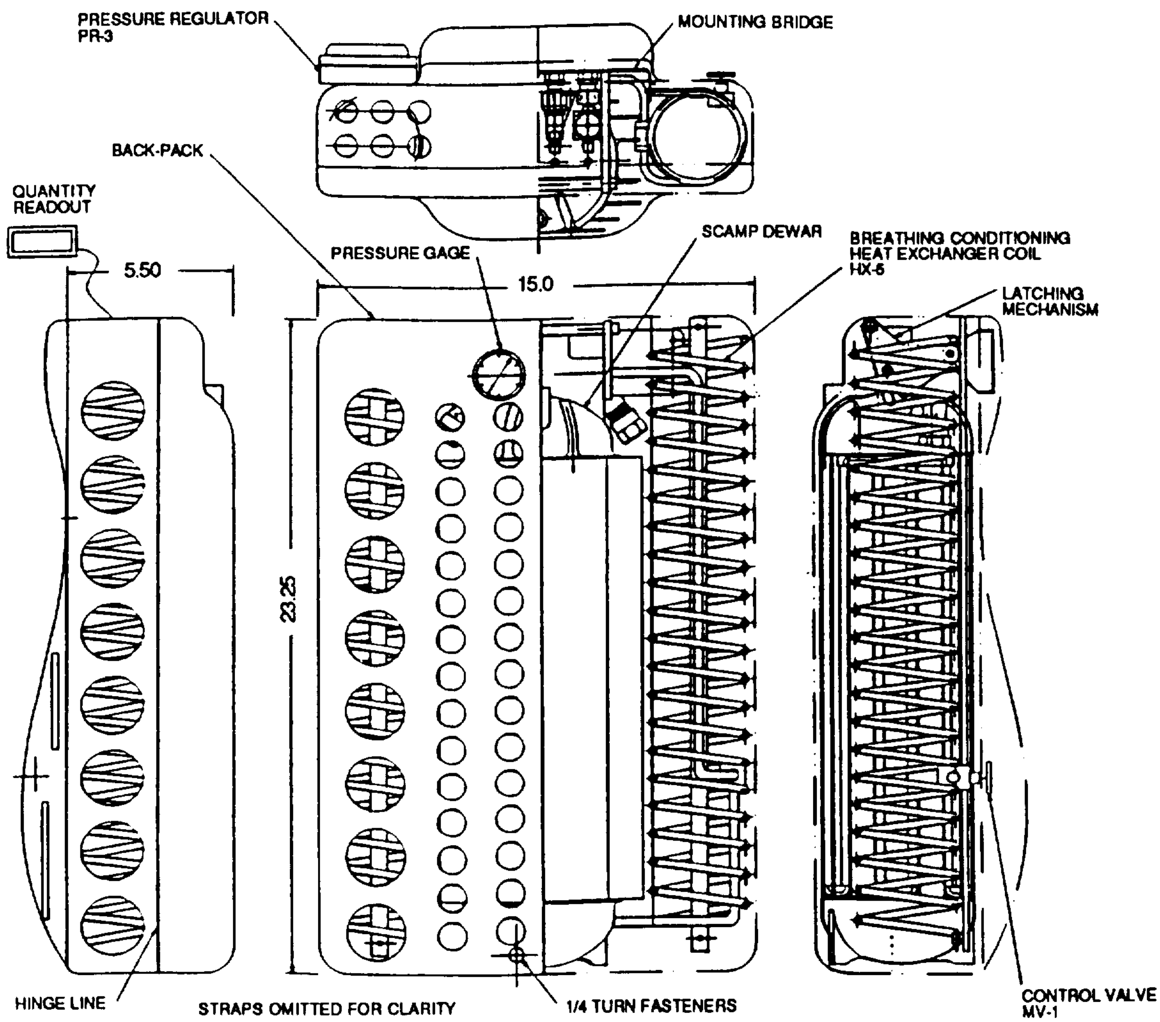
Key milestones:

- 1991: Development of a supercritical air respirator concept.
- 1992: Development of a direct measurement quantity sensor design.
- 1993: Design and fabrication of a SCAMP prototype and a SCAMP loading system.

Contacts: M.D. Hogue, DM-MED-42, (407) 867-3266; and E. Ernest, DM-MED-41, (407) 867-3201

Participating Organization: Aerospace Design and Development, Inc. (Dr. H.L. Gier)

NASA Headquarters Sponsor: Office of Advanced Concepts and Technology, KSC Center Director Discretionary Fund



SCAMP Backpack Configuration

Nondestructive Evaluation

The Nondestructive Evaluation (NDE) Technology program at the John F. Kennedy Space Center (KSC) includes the development of inspection and verification instruments and techniques that can provide information (external or internal) to hardware and component structures in a nonintrusive manner. The technology includes, but is not limited to, the following:

1. Laser
2. Infrared
3. Microwave
4. Acoustic
5. Structured light
6. Other sensing techniques
7. Computer and software systems needed to support the inspection tools and methods

The present effort in this discipline is being directed toward reducing Shuttle processing costs using these technologies. The long-term effort of the program is to develop cost-effective NDE techniques for inspecting and verifying space vehicles and their components during manufacture and to continue validating those items during assembly/launch and on-orbit or during space flight.

Development of a Nondestructive Vibration Technique for Bond Assessment of Space Shuttle Tiles

The objective of this project is to develop a nondestructive, noncontact technique based on the "vibration signature" of tile systems to quantify the bond conditions of the thermal protection system (TPS) tiles of Space Shuttle orbiters. The technique uses a laser vibration pattern imager/rapidscan system, modal measurements, and finite element modeling.

The technical approach followed in this project was:

1. To develop mathematical finite element models to compute the dynamic characteristics of tile/structure assemblies.
2. To conduct vibration testing (using a laser sensor) on multi-tile panels with controlled bond conditions.
3. To correlate experimental and mathematical model results.
4. To develop an inverse solution for direct, real-time assessment of a tile that is not properly bonded (disbonded) and its general location.
5. To further verify the technique by testing tiles on the orbiter itself.

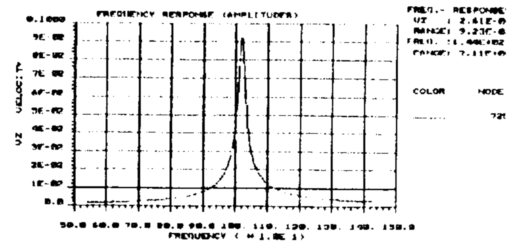
Finite element models were developed for tiles bonded to both the clamped and deformable integrated skin-stringer orbiter mid-fuselage. Results showed that the size and location of a disbonded tile can be determined from frequency and mode shape information. Moreover, a frequency response survey was used to quickly identify the disbonded tiles. The finite element results were compared with the experimentally determined frequency responses of a 17-tile test panel, where a rapidscan laser system was employed. An excellent degree of correlation between the mathematical simulation and experimental results was realized.

An inverse solution for a single tile was derived and is being implemented into a computer program that can interact with the modal testing software. The geometries and material properties of the tile, SIP, and filler bar are included in a data file for each case. The modal parameters (natural frequencies and mode shapes) can be inputted from either the STARS modal system or from the output of finite element solutions. The output of the program is the percentage bonded and a diagram showing the size and location of a disbond. The program has been tested with the results of the finite element solutions as input, and the results are essentially identical to the modeled disbond. Future work on the project will include verifying the technique with experimental data on test panels and the orbiter.

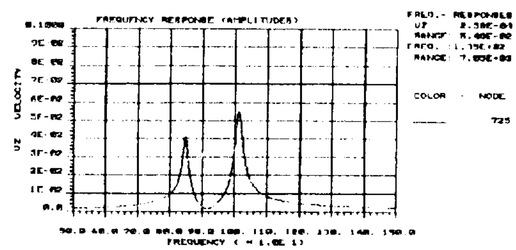
Contact: R.M. Davis, DE-TDO, (407) 867-2780

Participating Organization: University of Central Florida (Dr. F.A. Moslehy, P.E.)

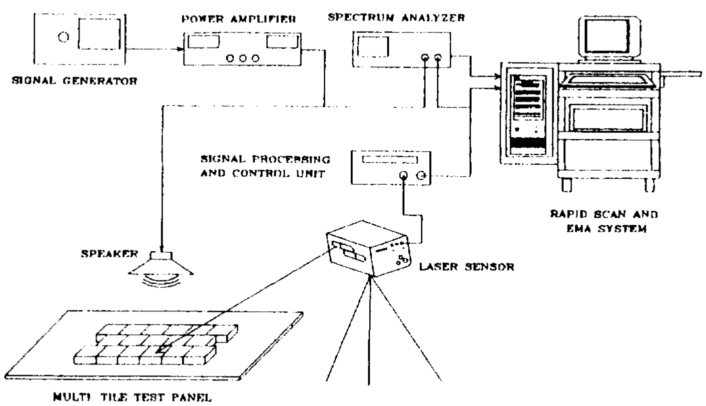
NASA Headquarters Sponsor: Office of Space Systems Development



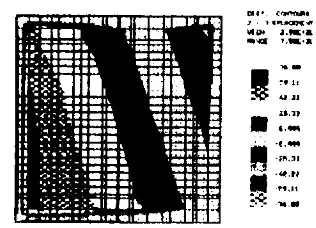
Frequency Response of
100 Percent Bonded Tile
(Center Point)



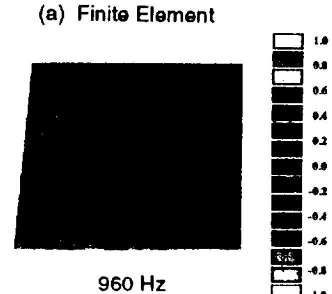
Frequency Response of
80 Percent Bonded Tile
(Center Point)



Experimental Setup for Testing the 17-Tile Panel
Using the RapidSCAN Laser System

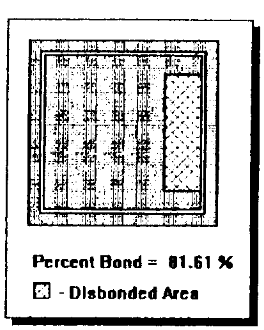


963 Hz
(a) Finite Element

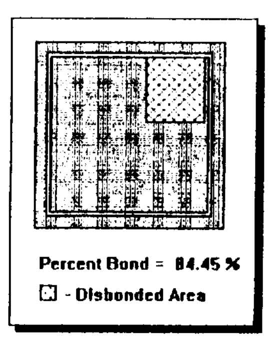


960 Hz
(b) Experimental

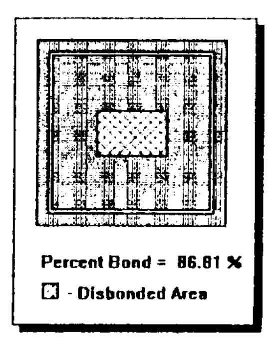
Mode Shape Comparison for Tile 9
of the 17-Tile Test Panel



80 Percent Bonded Tile
(20 Percent Edge Disbond)



84 Percent Bonded Tile
(16 Percent Corner Disbond)



84 Percent Bonded Tile
(16 Percent Center Disbond)

Inverse Solution Results

Tile Cavity Modeling System (TCMS)

Present Space Shuttle configurations have approximately 24,000 thermal protection system tiles bonded to each orbiter. An average of 98 tiles requires replacement after each flight due to damage. When a damaged tile is removed, it leaves a cavity that a replacement tile must fit. Many of the replacement tiles are made by modeling the tile cavity using a resin material. This process is both time consuming and labor intensive, consists of many steps, and averages 12 hours for completion.

The Tile Cavity Modeling System (TCMS) is a new technology that digitally images a tile cavity, processes the image through a computer, and exports the data to a floppy diskette that can, with additional processing, be read by a numerically controlled tile milling machine. This new system takes less than 1 second to gather data and approximately 5 minutes for the computer to process and store on a disk. The TCMS projects optical fringe lines onto the tile cavity surfaces and views the cavity using two electronic cameras. In less than 1 second, the cameras acquire a total of 24 images as the fringe lines are moved or phase shifted four times. These exposure levels are used at each position. The 24 video images are sent to the computer workstation where software processing measures the cavity features and generates a CAD file for automated tile fabrication.

In the spring of 1992, data gathered from two test panels using the TCMS was submitted for fabrication of replacement tiles. The tiles were made and “fit-checked” successfully into the test panel cavities. The TCMS was brought to the KSC Orbiter Processing Facility (OPF) for a demonstration on an orbiter in January 1993, and several geometrically shaped basic tile cavity configurations were successfully modeled. Additional TCMS hardware and software improvements have been made, and the TCMS was turned over to KSC for limited operational use in November 1993.

Key accomplishments:

- Implemented the phase shifting for the fringe line projection.
- Imaged cavities from two test panel cavities.
- Demonstrated modeling of basic tile configurations on an orbiter.

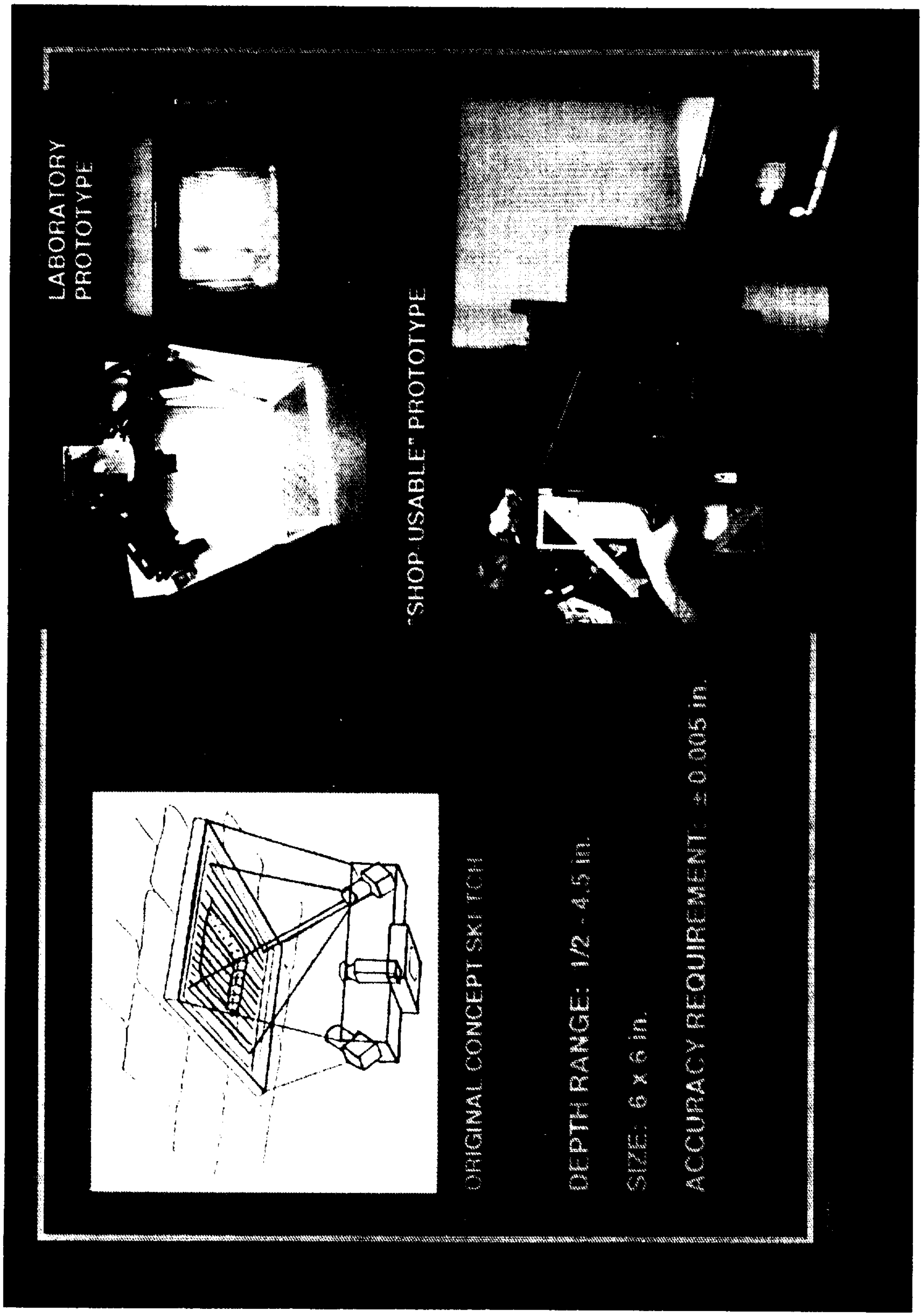
Key milestone:

- Successful testing of the TCMS on an orbiter with various tile configurations.

Contact: R.M. Davis, DE-TDO, (407) 867-2780

Participating Organization: Lockheed Space Operations Company (F.T. Williams)

NASA Headquarters Sponsor: Office of Space Systems Development



Cavity Modeling for Shuttle Tiles

Surface Defect Analyzer

The purpose of this study was to develop a rapid, in-the-field method of evaluating the physical dimensions of microscopic surface flaws, defects, and damage on critical surfaces of the Space Shuttle and related ground support equipment. The instrument developed will provide an alternative to the mold impression techniques being used.

Presently, when a surface flaw (dent, scratch, dig, gouge, raised metal, or fretted area) is found on a critical surface or a surface-finished part (particularly a sealing surface), a mold impression is made to determine if acceptance criteria have been violated. Taking this mold impression is time consuming and sometimes difficult. There is a strong need for an "instantaneous electronic" mold impression device for use at KSC.

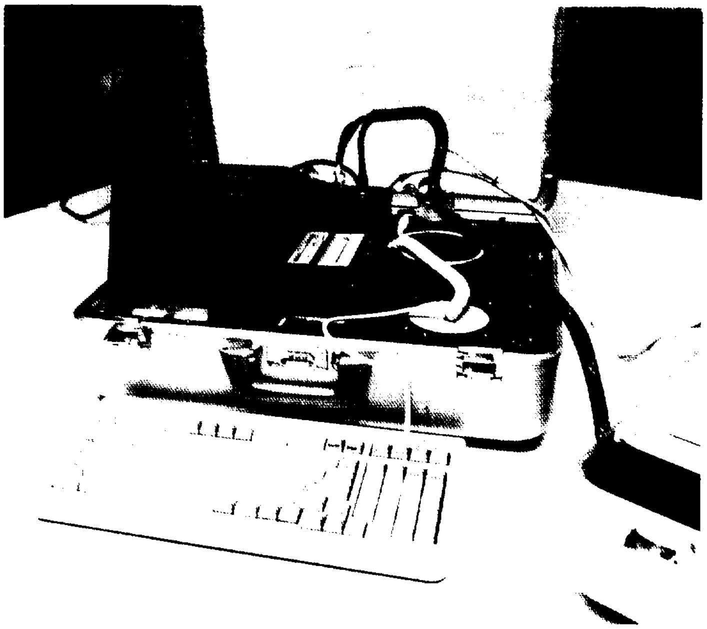
After investigating numerous approaches, the technique of structured light microscopy was chosen as the method to most rapidly yield a working fieldable instrument. In this method, a line or shadow edge is projected obliquely onto the flaw and viewed from a point out of the plane defined by the projected edge on the defect. Thus, a profile of the defect is seen. By using a television camera to provide an image for a computer and providing such software features as a video micrometer to measure the captured image, accurate measurements of the width and depth of the defect can be accomplished quickly.

The field evaluation unit built and tested by Shuttle operations personnel was revised. The unit was miniaturized with ergonomic considerations taken into account. The image processing computer was upgraded from a 386 to a 486 computer that is smaller and lighter than its predecessor. The color display was also replaced with a smaller and lighter version. These components were packaged into a much smaller case that is more readily deployable by Shuttle operations personnel. The optical head was also redesigned. The head is smaller and lighter and fits more comfortably into a single hand. The head's mouse controls were placed on a second hand-held unit, which includes the liquid crystal display (LCD) screen, the cursor mouse controls, and the activation button that causes the computer to capture the image currently being viewed on the LCD screen. In addition, the optics of the head were greatly improved. The previous version was unable to image and measure all 13 of the defects on a sample plate provided by Shuttle operations personnel, but the new version with improved optics was able to image and measure all 13 defects on the sample plate. The overall field of view of the instrument in its present version is about a 0.600-inch square with a resolution on the order of 0.0002 inch.

Contacts: J.D. Collins, DL-ESS-24, (407) 867-4438; R.M. Davis, DE-TDO, (407) 867-2780; and P. Schwindt, TV-MSD-24, (407) 861-3674

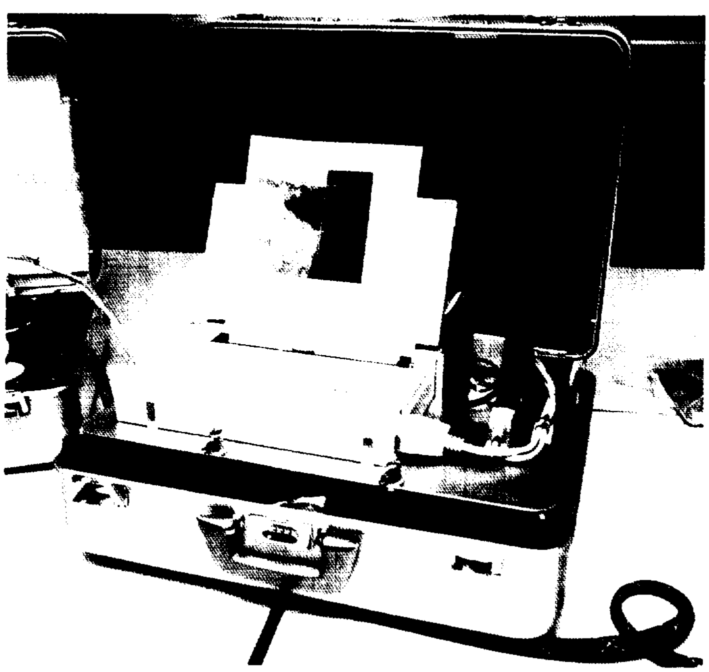
Participating Organizations: I-NET, Inc. (S.M. Gleman, C.G. Hallberg, S.W. Thayer, J.E. Thompson, and D.L. Thompson) and Thiokol Corporation (D.C. Noble and P.F. Vanaria)

NASA Headquarters Sponsor: Office of Space Systems Development



Computer and CTR Display

Optical Head and Control/Display



Surface Defect Report Printer

Bolted Joint Nondestructive Evaluation

A major problem associated with Space Shuttle processing is locating stress fracture cracks in bolted joints. At present, critical jointed structures of the Space Shuttle are disassembled and eddy-current or visually inspected for stress fracture cracks around the bolt head. This is a very time-consuming and costly solution to the problem. A rapid, in-the-field method of nondestructively locating and imaging cracks around bolt heads is needed.

Originally, it was proposed that the objectives be achieved using x-ray technology; however, this was not an immediately feasible solution due to limited funding and time. Ultimately, x-ray techniques were abandoned.

A method of detecting and measuring the extent of stress fracture cracks on bolted joints has been developed using a "pitch-catch" ultrasonic transducer. An ultrasonic pulse-generator/transducer pair is mounted on a rotating and radially translating base that fits over the bolt head. The ultrasonic pulse-generator "pitches" a pulse that travels through the joined material and bounces off the bottom of the material and is "caught" by the ultrasonic transducer. A crack in the joined material stops the ultrasonic pulse traveling through the material and results in a shadow region for that particular position of the pitch-catch transducer. The transducer is spun around the bolt head, generating data for a full 360 degrees. Then, the transducer is moved radially outward slightly and spun again. This process is repeated until the full radial extension of the transducer pair is achieved. The resulting data is composed of two-dimensional projections of the ultrasonic shadows cast by the three-dimensional crack in the top layer of the joined material for all possible angles and radii. A nonlinear data processing technique called Confluent Morphological Simulation is being developed in which the three-dimensional structure of the crack is approximated in an iterative process. Essentially, the computer guesses what three-dimensional crack shape could generate ultrasonic shadow data similar to what was generated with the transducer. The computer then correlates the actual shadow with the shadow that fits the guessed crack configuration. In an iterative process, the computer modifies the crack shape, comparing the two shadows until the closest fit is found.

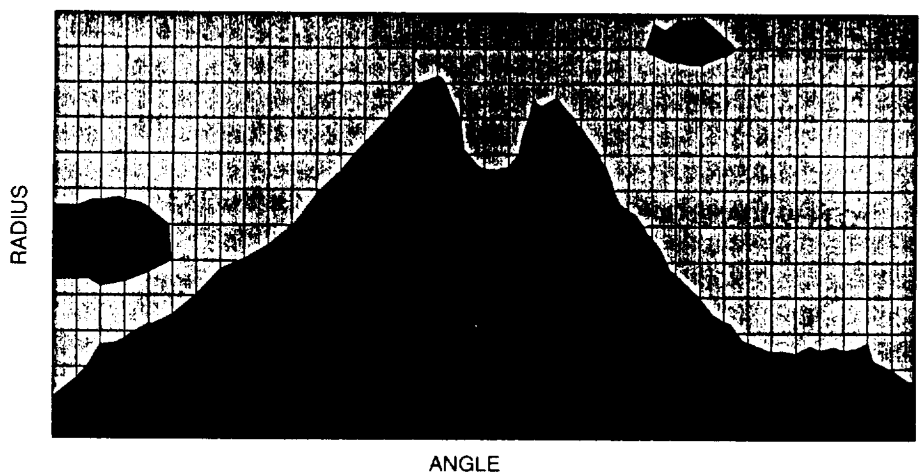
This method for imaging cracks in joined material holds great promise but requires work to bring it to its full potential. One problem with this process is the geometry of the bolt limits the area that can be scanned. The ultrasonic transducer cannot image directly under the bolt head at this time because the joined material would be shielded from the ultrasonics by the bolt head itself. Laboratory personnel have proposed a method of solving this problem that would entail either using a double bounce method for the ultrasonics or adding an additional motion stage to the transducer that would translate it tangentially. In addition, the maximum extension of the ultrasonic transducer would limit the outer radius that could be scanned and imaged. The essentials of imaging stress fracture cracks in joined material have been demonstrated, but more work in this area could possibly yield a fieldable unit that would have wide commercial potential.

Contact: J.D. Collins, DL-ESS-24, (407) 867-4438; R.M. Davis, DE-TDO, (407) 867-2780; and H.N. Delgado, RQ-SAO, (407) 867-3163

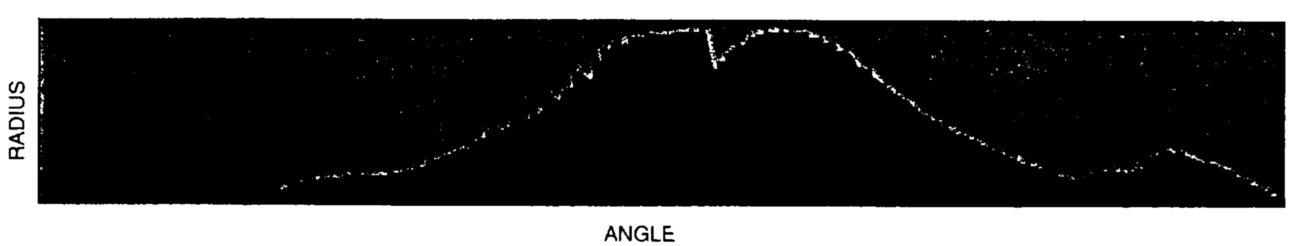
Participating Organization: I-NET, Inc. (Dr. S.M. Gleman, Dr. J.A. Hooker, and S.M. Simmons)

NASA Headquarters Sponsors: Office of Space Systems Development and Office of Safety and Mission Assurance

Rotatable Pitch-Catch Ultrasonic Transducer Assembly



Experimental Data on the Stress Crack



Computer Simulation of a Similar Stress Crack

Fastener Monitoring: An Emerging Technology

On flight-critical fasteners, a proper preload is crucial to their intended function. A lack of required preload levels in a critical joint creates the potential for loss of vehicle and/or life. Conventional torque measurements cannot achieve accurate preload levels due to variations in friction. Additionally, strain gage technology is subject to premature failures.

Fastener preloads are best measured through material strain. The "ultrasonic length" of a fastener is directly related to its material strain. Using ultrasonics on a fastener involves transmitting a sound wave down through the fastener shank. This is accomplished using a transducer and ultrasonic bolt gage. First, an "initial" ultrasonic fastener length is obtained. This initial fastener length is taken in a no-load state. A torque or tension load is then applied to the fastener and another ultrasonic length is obtained. The second ultrasonic length will be greater due to stretching of the fastener. The change in the ultrasonic length of the fastener is associated with the material strain, which is directly correlated to the amount of preload applied to the fastener.

Ultrasonic technology is currently being applied to the following critical fasteners to control the amount of preload:

1. Orbiter external tank umbilical studs
2. Orbiter Shuttle carrier aircraft bolts
3. Orbiter vertical tail bolts
4. Mobile Launcher Platform post studs

Currently, preload and postload ultrasonic lengths are obtained at different times. Future plans are to obtain the two fastener ultrasonic lengths while the fastener is being tensioned/torqued. The ultrasonics will indicate when the proper preload has been achieved in real time. The tensioning/torquing sequence and ultrasonic measurements will be performed once and simultaneously, hence the name ultrasonic real-time monitoring. The approach for implementation is to obtain the capability to place a transducer on one end of the bolt while the tensioning/torquing is being performed. This may be accomplished through redesign of the fastener head and/or transducer redesign.

Key accomplishments:

- 1990: Consolidated Shuttle and other ultrasonic bolting applications (i.e., Mobile Launcher Platform holddown post studs) with the EG&G Nondestructive Evaluation Laboratory for operations support and continued development.
- 1991: Implemented ultrasonic monitoring as a requirement for preload determination on the orbiter external tank umbilical studs and Shuttle carrier aircraft bolts.
- 1992: Commenced a feasibility study of real-time ultrasonics on the vertical tail bolts.
- 1993: Procured new bolt gages for evaluation in optimizing real-time implementation. Completed a conceptual transducer and external tank umbilical stud redesign to support real-time monitoring. Completed a conceptual transducer redesign supporting real-time monitoring on the Shuttle carrier aircraft bolts and implemented the requirement to perform ultrasonic real-time monitoring for preload determination on redesigned vertical tail bolts.

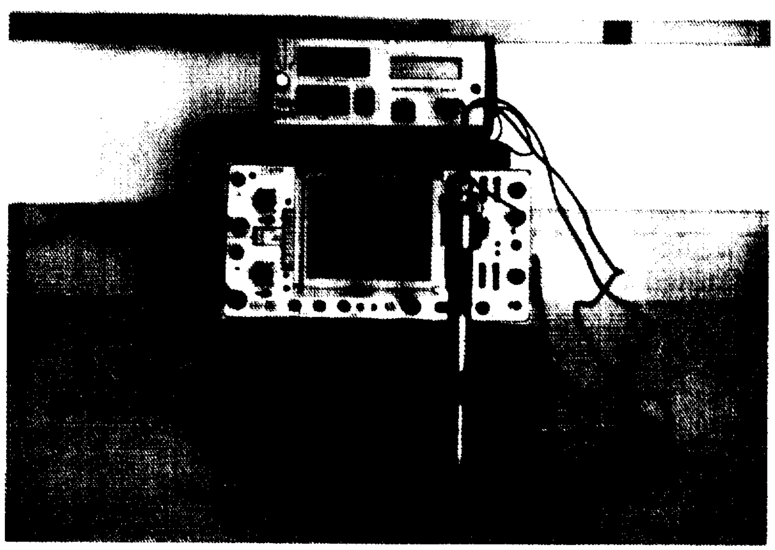
Key milestones:

- 1994: Transition of the new bolt gage system into production support. Implementation of real-time monitoring on the Shuttle carrier aircraft bolts.
- 1995: Implementation of real-time monitoring on the orbiter external tank studs and on the Mobile Launcher Platform holddown post studs.

Contact: C.G. Stevenson, TV-MSD-1, (407) 861-3603

Participating Organization: EG&G Florida, Inc. (M.E. McDaniel and R.M. Sabatino)

NASA Headquarters Sponsor: Office of Space Systems Development



Verification Test Article Project

There are physical phenomena that result in random data whose values cannot be predicted in a deterministic sense. Examples of the phenomena include pressure gusts encountered by aircraft and acoustic excitation by jet or rocket noise. Vibration of pad structures is a consequence of the Shuttle launch-induced environment. Research at KSC has led to the development of innovative techniques to accurately characterize noise and to predict the vibroacoustic response of pad structures. KSC techniques model vibration response due to rocket noise as a random transient event. This avoids structural response overpredictions and overdesign inherent in the traditional steady-state methods. Moreover, KSC-developed techniques can accurately predict responses in the low-frequency (0 to 20 hertz) range where other methods fail.

In 1993, a multiyear test validation project was embarked on to verify the KSC technique. The objectives of this program were to:

1. Design, fabricate, and install a verification test article (VETA) within the pad perimeter [Pad Terminal Connection Room (PTCR)] and measure launch-induced noise (acoustic pressures) and the related vibration response.

2. Characterize acoustic pressures (loads on the VETA) and predict the subsequent vibration response (acceleration and displacement) using KSC techniques.

3. Verify the accuracy of random vibration response analysis predictions, especially in the low-frequency regime.

Key accomplishments:

- March 1993: Designed and analyzed the VETA.
- May 1993: Finalized the instrumentation requirements.
- August 1993: Fabricated and painted the VETA.
- October 1993: Demonstrated the data acquisition system.

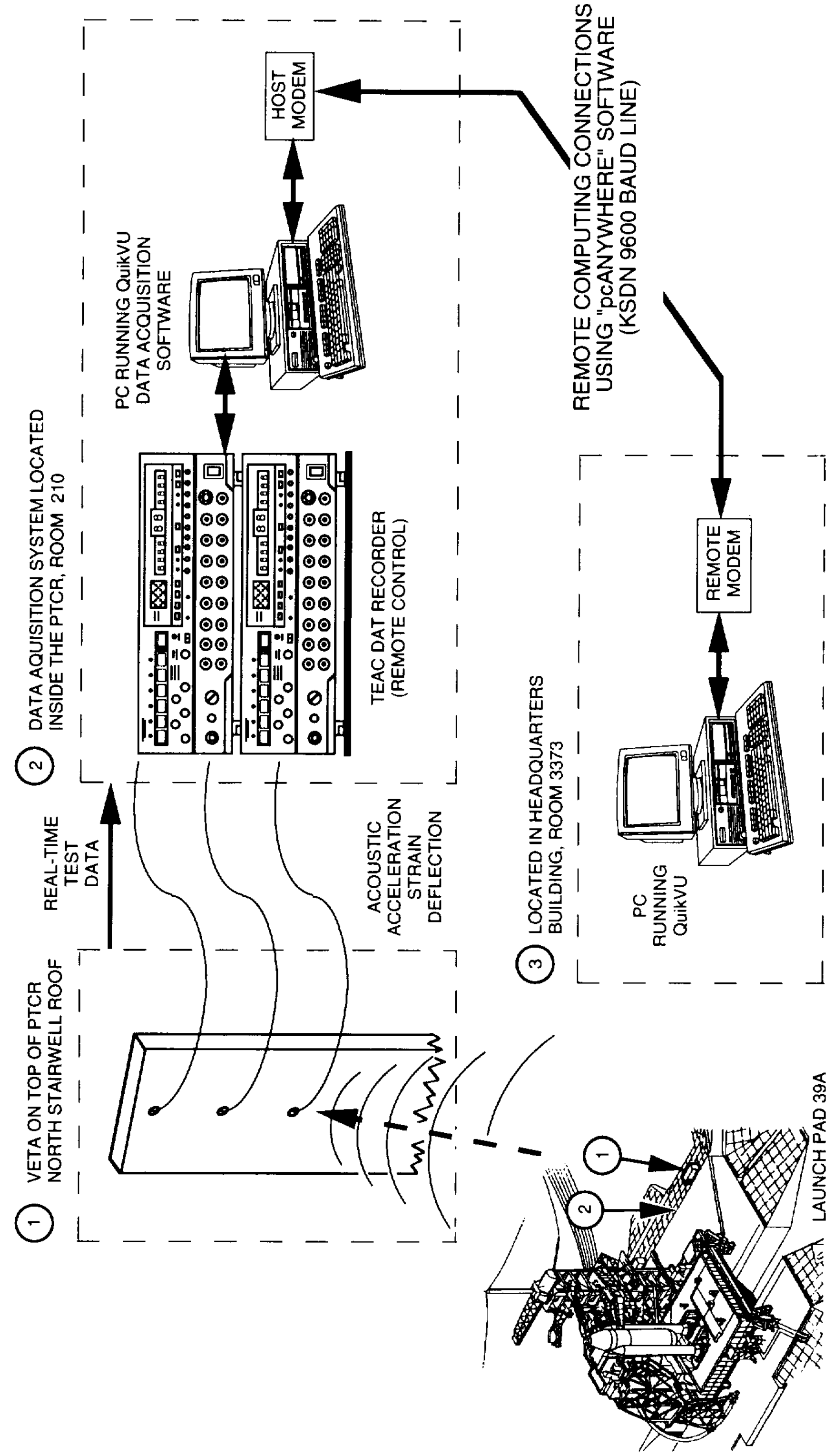
Key milestones:

- November 1993: Perform modal tests on the VETA.
- December 1993: Install the VETA on Launch Pad 39A.
- January 1994: Instrument the VETA and initiate measurements.
- December 1994: Acquire noise and vibration data on the VETA.
- June 1995: Verify the vibration response analysis techniques.

Contact: R.E. Caimi, DM-MED-11, (407) 867-4181

Participating Organization: I-NET, Inc. (R.N. Margasahayam)

NASA Headquarters Sponsor: Office of Space Flight



Verification Test Article Program
Real-Time Data Acquisition and Monitoring Flowchart

Nondestructive Evaluation of Corrosion Using Infrared Thermography

Corrosion deterioration of Space Shuttle flight hardware and ground support equipment (GSE) is becoming of greater concern due to the aging of the systems in the highly corrosive environment at KSC. Damage to the metallic surfaces can lead to safety and reliability issues regarding these systems. Corrosion control on these surfaces is usually accomplished using protective coating systems. These coatings have the potential of masking or concealing the active corrosion on the metal substrates. Nondestructive evaluation (NDE) techniques to detect corrosion under the coating films would significantly enhance the effort to sustain the Shuttle systems in a safe and reliable manner.

In response to this situation, a combined study has begun to evaluate the feasibility of using infrared thermography and infrared gradient thermography to predict and detect corrosion under paint films on metal substrates. Surface corrosion areas would be measured using a structured light microprobe system (the Surface Defect Analyzer). These NDE techniques were also identified as potential methods for detecting and measuring corrosion damage on aging aircraft. Based on methods described below, tests will be conducted to determine corrosion damage to metallic substrates. Further, these methods will require characterization and modification to allow the use of this technology on Space Shuttle systems.

Currently, two sets of tests were performed. Model Space Shuttle riveted panels were prepared and exposed to both a salt-fog chamber and the KSC beach corrosion site conditions to initiate the corrosion process on the coated surfaces. The salt-fog exposure is conducted according to American Society for Testing and Materials (ASTM) B117 for various time intervals to produce differing amounts of corrosion damage. The panels have been photographed using an Inframetrics model 445 infrared camera and stored on a VHS recorder for further analysis. This analysis is conducted using a computer-enhanced imaging system that increases the contrast level to produce a clearer thermographic image. Initial results have detected corrosion damage on uncoated surfaces, and the work is continuing to detect corrosion under coated surfaces. Based on the initial work on coated surfaces, this NDE technique has produced encouraging results.

In the other set of tests, two aluminum test bars (2 by 4 by 0.5 inches) were fabricated using different methods. The first was milled out at a shallow depth and the grooves were filled with Bondo (to provide a known thermal conductivity delta) and then painted with Krylon. The second was a piece of aluminum from the scrap area with preexisting corrosion. This piece was then also coated with Krylon paint. These test bars were then subjected to thermal shock and the resulting thermographic gradients were recorded over time in a digital format. The resulting images were processed to look at pixel-by-pixel gradient structure. This resulted in a set of curves whose structure represented the presence or absence of corrosion in a given finite area. The initial results indicate corrosion can be detected through Krylon paint. Measuring the depth of the corrosion by gradient analysis may be possible but is unproven at this time.

Key accomplishments:

- Produced model Space Shuttle riveted test panels for exposure in both the salt-fog chamber and the KSC beach corrosion test site.
- Conducted salt-fog chamber exposure of the model test panel for infrared analysis.
- Acquired infrared thermography images of the corroded test panel and conducted analysis of the bare and coated surfaces.

- Demonstrated the concept of detection and mapping of corrosion under paint.
- Began preliminary analysis of measuring corrosion depth using gradient analysis.

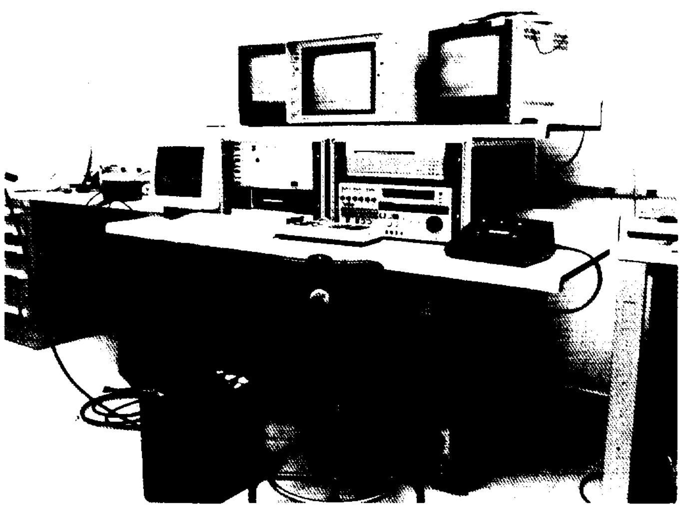
Key milestones:

- Continue acquisition of thermographic images of coated test panels with various amounts of corrosion.
- Develop a systematic approach for the detection of corrosion under paint films on metallic substrates.
- Apply these techniques to actual Space Shuttle flight hardware and GSE for the determination of corrosion damage.
- Build GSE to detect and measure corrosion on flight and GSE hardware.

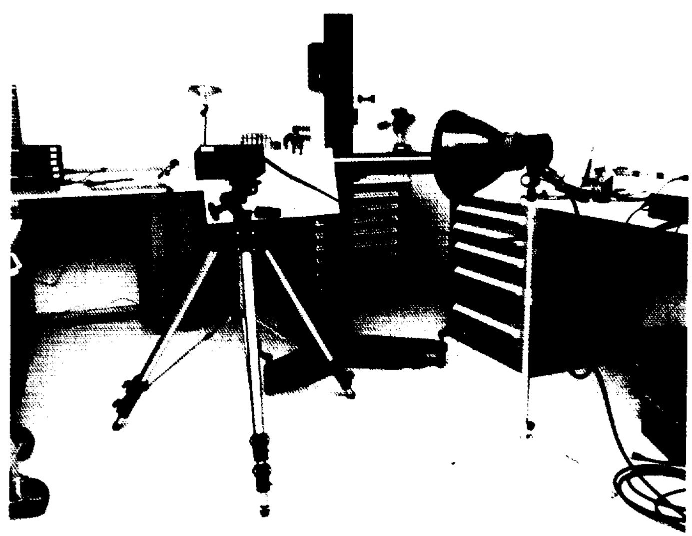
Contacts: L.G. MacDowell, DM-MSL-22, (407) 867-3400; R.S. Johnson, DM-MSL-21, (407) 867-7048; J.D. Collins, DL-ESS-24, (407) 867-4438; H.N. Delgado, RQ-SAO, (407) 867-3163; and R.M. Davis, DE-TDO, (407) 867-2980

Participating Organization: I-NET, Inc. (Dr. S.M. Gleman and S.W. Thayer)

NASA Headquarters Sponsor: Office of Space Systems Development, Office of Safety and Mission Assurance, and Office of Space Flight



Thermography Analysis Equipment



Rudder Speed Brake Mockup Test Panel

Life Sciences

The Life Sciences Technology program at the John F. Kennedy Space Center (KSC) supports the development of advanced technologies for application in long-term human habitation in space. This effort is directed toward ensuring crew health, improving personnel comfort and safety, and improving operational efficiency in Controlled Ecological Life Support System (CELSS) biomass production, food processing, and preparation. The near-term focus of this program is CELSS resource recovery and biomass processing improvement techniques. The long-term focus will concentrate more on production improvement, emphasizing supply-line economics.

CELSS Biomass Production Chamber

Long-term human habitation in space requires a continuous supply of food, oxygen, and water as well as the continuous removal of carbon dioxide and the recycling of waste materials. The supply-line economics indicate that as the distance and duration of a mission increases, the resupply cost from Earth will also increase. Using plants as bioregenerative life-support systems is being considered as an alternative to continuous resupply from Earth.

NASA's Controlled Ecological Life Support System (CELSS) program has studied the use of plants for life support for over 15 years. The Biomass Production Chamber (BPC) at KSC is used to produce candidate CELSS crops and monitor the bioregenerative life support functions of carbon dioxide removal, oxygen production, food production, and water purification.

To date, four wheat, three soybean, four lettuce, and four potato crops have been grown to maturity in the BPC. Results indicate that 20 square meters of plants should meet the oxygen generation and carbon dioxide removal needs of one human, the water needs of five humans, and a little more than half the food needs of one human.

Future research plans include using biologically processed inedible biomass as a primary nutrient source for future crops, producing multiple crops on a continuous basis, and developing technologies to monitor and assess the life-support functions of the crop.

Key accomplishments:

- 1989: Completed two wheat production studies and one soybean study.
- 1990: Completed two soybean studies and two lettuce studies.
- 1991: Completed one lettuce and two potato studies.
- 1992: Completed one lettuce and one potato study. Installed independent atmospheric control for upper and lower compartments.
- 1993: Completed one wheat and one potato study. Determined the effect of atmospheric filtering on plant performance and composition of organic compounds in the atmosphere.

Key milestones:

- 1994: Grow a wheat crop using nutrients recovered from inedible biomass of a previous crop. Continuous crop production in the BPC for 6 months. Transfer environmental monitoring and control to SUN workstations.
- 1995: Continuous crop production with a mixture of crops using recycled nutrients.

Contact: R.M. Wheeler, MD-RES, (407) 853-5142

Participating Organization: The Bionetics Corporation (G.W. Stutte and C.L. Mackowiak)

NASA Headquarters Sponsor: Office of Life and Microgravity Science and Applications

Potato Tuberization in the Biomass Production Chamber

CELSS Biomass Production Research

In support of KSC's Controlled Ecological Life Support System (CELSS) project, ancillary studies were conducted in controlled environment chambers. The information gained from these studies will be used for plant production studies in the Biomass Production Chamber (BPC) (see the article "CELSS Biomass Production Chamber").

Focus is placed on extracting plant nutrients from inedible biomass for recycling into the plant hydroponic systems. This would reduce the need of Earth-based resupply. Information is being gathered on the irradiance needed for optimal potato tuber formation in order to maximize production efficiencies. Prior to trials in the BPC, production trials with sweet potato (a highly nutritious crop) were being baselined.

Nutrient recycling was successful when using wheat inedible biomass and soybean inedible biomass for subsequent wheat production. The photoperiod had a strong effect on the carbon fixation rate for potato. Experiments are being performed to optimize energy efficiency for potato production. Focus on the effects of various nutrient regimes for improved sweet potato production has resulted in an understanding of nutrient requirements for this crop. Optimization of partitioning to storage root formation will continue over the next year.

Key accomplishments:

- 1989: Potato growth and yield in the nutrient film technique (NFT) were published in the American Potato Journal.
- 1990: Proximate composition of seed and biomass from soybean plants grown at different carbon dioxide concentrations was published as a NASA technical memorandum.
- 1991: Soybean stem growth under high-pressure sodium with supplemental blue lighting was published in the Agronomy Journal.
- 1992: Supraoptimal carbon dioxide effects on soybean growth and development in controlled environments were published in the Journal of Plant Physiology.
- 1993: Wheat was grown on minerals recycled from inedible soybean and wheat biomass.

Key milestones:

- 1994: Further test crop production using recycled nutrients from inedible biomass. Baseline hydroponic peanut production.
- 1995: Optimize nutrient recycling by growing crops on nutrients recycled from a simulated human waste stream.
- 1996: Integrate the crop production subsystem with an aquaculture subsystem.

Contact: R.M. Wheeler, MD-RES, (407) 853-5142

Participating Organization: The Bionetics Corporation (C.L. Mackowiak and G. Stutte)

NASA Headquarters Sponsor: Office of Life and Microgravity Science and Applications

Wheat Production Using Recycled Nutrients

CELSS Resource Recovery and Biomass Processing Research

Resource recovery and biomass processing are a major component of a functional Controlled Ecological Life Support System (CELSS), along with system integration, biomass production, and crew. The challenge has been to recycle inedible material into carbon dioxide and mineral forms that can be used by crops and to convert these inedibles into food, thus more efficiently using CELSS energy, volume, weight, and crew time.

The ultimate goal has been to design, fabricate, test, and operate (at a breadboard scale) CELSS biomass processing and resource recovery components. Candidate processes are identified and studied with small, laboratory-scale (0.1-liter size) systems to identify key environmental and process control parameters. Intermediate-scale systems (i.e., 1- to 10-liter size) are then used to optimize these key process parameters and to gain operational experience with the potential hardware, software, process control and monitoring, and biological subsystems. Then, the full-scale components are designed, fabricated/procured, set up and tested, operated, and integrated with the other systems within the CELSS breadboard.

Research this year focused on the use of a mixed microbial community to aerobically biodegrade inedible crop residues (e.g., stems, leaves, roots, chaff/pods, etc.). The major products of this decomposition are: (1) carbon dioxide and inorganic forms of mineral elements that need to be recycled for further growth by the plants and (2) microbial biomass that will be used to produce fish (*Tilapia*) as an additional food source from the crop residues. The laboratory scale research has been completed and focused on pH, temperature, crop residue concentration, and growth rate of the mixed microbial culture. Research with intermediate scale bioreactors was initiated with the design, fabrication, testing, and operation (11 runs) of three 8-liter bioreactors. Results from these first runs were used to design and begin fabrication of the 120-liter breadboard-scale aerobic bioreactor to be integrated with the CELSS breadboard Biomass Production Chamber (BPC) by early 1994. Further process optimization using intermediate scale bioreactors will continue through the next several years, with improvements being implemented on the larger breadboard-scale bioreactor.

Key accomplishments:

- 1986 to 1988: Initial cellulose conversion research.
- 1989: Cellulose conversion process optimization studies.
- 1990: Flask-scale studies of cellulose conversion.
- 1991: Completed biomass processing studies on cellulose conversion with five breadboard-scale runs.
- 1992: Initiated flask-scale studies of microbial aerobic decomposition of crop residues.
- 1993: Design, fabrication, and operation of intermediate-scale aerobic bioreactors. Design and fabrication of Breadboard-Scale Aerobic Bioreactor (B-SAB).

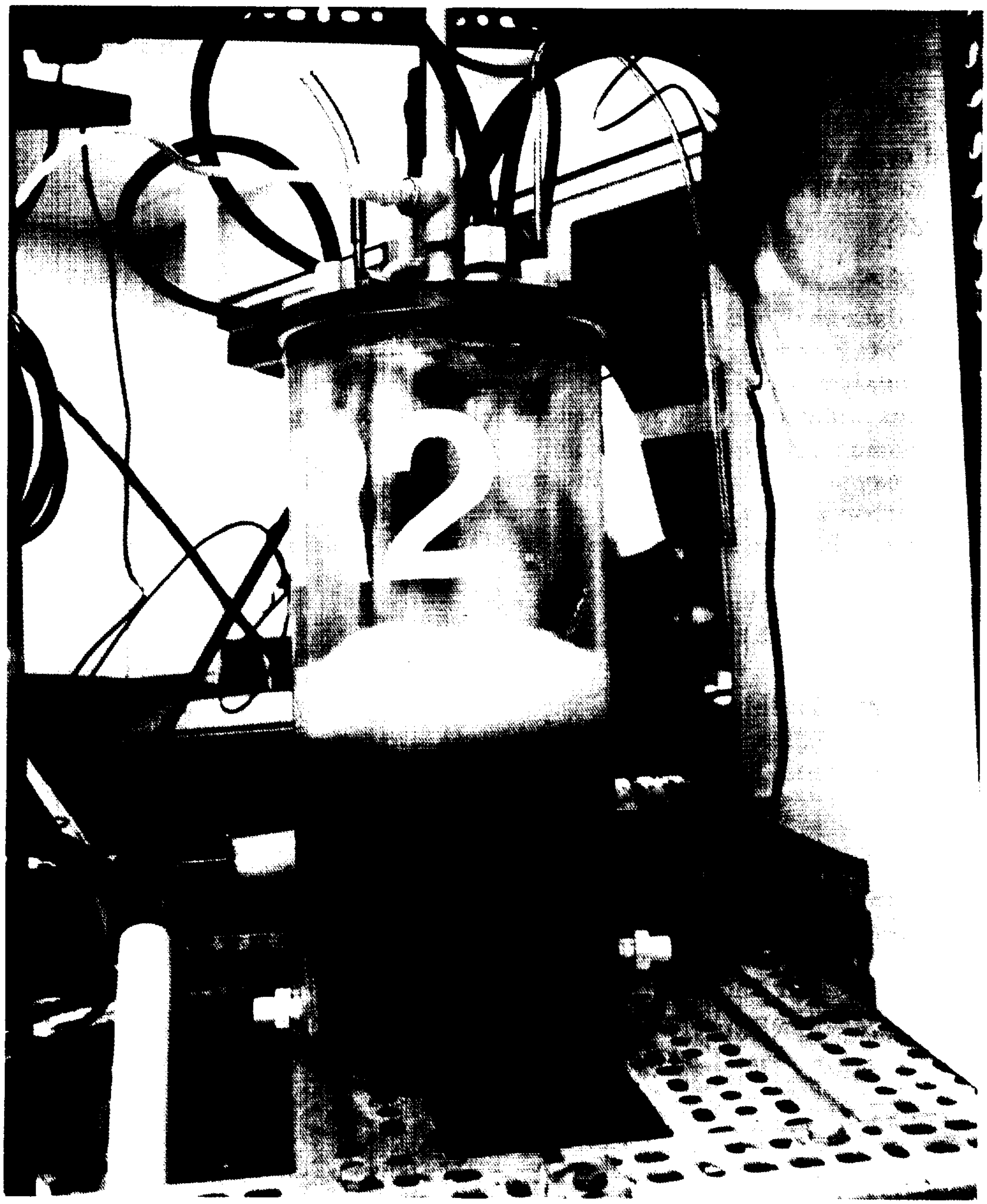
Key milestones:

- 1994: Integration and first operation of the breadboard-scale aerobic bioreactor, recycling nutrients to the BPC. Process optimization.
- 1995: Integration with other crops, mixed crops, and continuous crop production. Process improvement.
- 1996: Integration with aquaculture.

Contact: J.C. Sager, Ph.D., MD-RES, (407) 853-5142

Participating Organization: The Bionetics Corporation (R.F. Strayer, Ph.D)

NASA Headquarters Sponsor: Office of Life and Microgravity Science and Applications



Aerobic Digestion Bioreactor Used To Convert the Soluble Organic Compounds Contained in Crop Residue Leachates Into Carbon Dioxide and Microbial Biomass

CELSS Data Fusion

A Controlled Ecological Life Support System (CELSS) involves the evaluation of large amounts of data. However, an operational CELSS will require minimizing the manpower spent on performing this monitor and control function and the ability to operate autonomously. Thus, the monitor and control subsystem must perform a large amount of advanced data processing.

The goal of this project is to take a significant part of the monitor and control problem and implement that part for experimental use in the KSC CELSS Breadboard Facility in Hangar L at Cape Canaveral Air Force Station. The approach has been to build this capability, using fast prototyping, to ensure user involvement and evaluate particular technologies. Corporate resources and academic contacts were used to develop methodologies. Advanced automation technologies being investigated include neural nets and fuzzy logic.

To date, the breadboard data and selected analysis of photosynthesis data have been the most crucial part of the CELSS data analysis. The data relevant to photosynthesis were identified, the interrelationships among this data and with the state description needed were defined, and advanced automation approaches to the analysis were investigated. A basic package will be in use in Hangar L for estimating daily photosynthesis and respiration from fusion of carbon dioxide partial pressure and mass flow data and for totaling biomass production for a complete crop growout. In 1994, the project will develop a capability to track oxygen production over the growout and relate it to photosynthesis, develop a short-term monitor of carbon uptake, estimate leakage effects, and evaluate other measurable parameters related to photosynthesis, such as transpiration and nutrient uptake.

Key accomplishments:

- Selection of a domain.
- Analysis of data relationships.
- Evaluation of technologies.
- Development of an initial prototype.

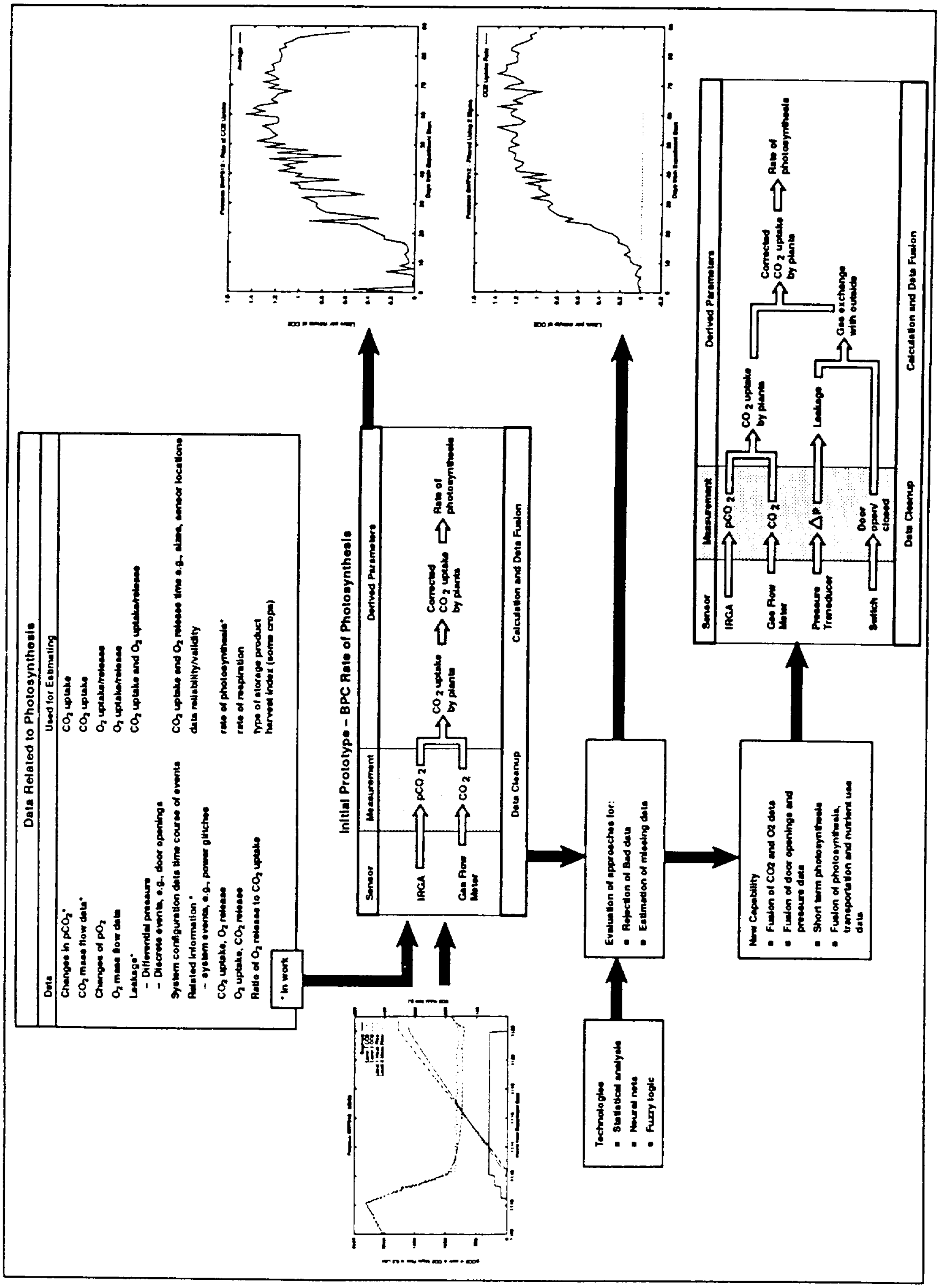
Key milestones:

- Delivery of the enhanced prototype.
- Final package and report.

Contact: J.C. Sager, Ph.D., MD-RES, (407) 853-5142

Participating Organization: McDonnell Douglas Space Systems (Dr. A.E. Drysdale)

NASA Headquarters Sponsor: Office of Life and Microgravity Science and Applications



CELSS Data Fusion

CELSS Organic Analytical Chemistry Research

The chemistry laboratory is developing analytical methods for characterization and monitoring of organic constituents of plant growth chamber atmospheres, nutrient solutions, condensate waters, plant leachate solutions, and plant tissues in KSC's Biomass Production Chamber (BPC). Anthropogenic emissions from manmade materials have been traced with headspace studies of plant growth chamber materials and reagents. The quantification and elucidation of biogenic emissions from plants are significant in understanding the carbon balance within a large, closed plant growth chamber, the BPC. More efficient crops with minimum carbon lost in volatilization will contribute to the optimization of food production. Elevated concentrations of a naturally occurring plant hormone, ethylene, in the BPC may be correlated with physiological effects for both wheat and potatoes. Root exudates, biogenic plant emissions, and leachate materials from the inedible portions of the plants may play a role in phytotoxicity and allelopathy.

Gas chromatograph with photoionization detectors was put on line to the BPC for monitoring ethylene concentrations. Methods of air analyses were investigated including direct sampling and grab samples for trace organic contaminant analysis. Methods of headspace analyses by gas chromatography/mass spectrometry (GC/MS) were developed to separate biogenic and anthropomorphic contaminants in atmospheric samples. Extraction and high-performance liquid chromatograph methods have been investigated for characterization of plant leachate materials, sugars, and plant growth regulators.

Investigations continue to correlate ethylene production with biomass increase and morphological changes in the plant. Characterization and quantification of organic constituents of the plant growth chamber atmospheres, nutrient solutions, condensate waters, plant leachate solutions, and plant tissues continue with various studies of variations of plant growth parameters. Further studies to target source and phytotoxic effects of organic components from plant growth chamber materials and reagents will be implemented.

Key accomplishments:

- 1989: Developed the laboratory.
- 1990: On-line ethylene studies.
- 1991: GC/MS analysis of volatile organics in a BPC condensate water and nutrient solution.
- 1992: Developed methods for biogenic emission measurements. Compared air-sampling techniques for GC/MS studies. Developed methods for the characterization of organic acids in plant leachate materials from bioreactor studies. Developed an analytical method for the characterization of volatile organic contaminants from reagents and BPC construction materials. Developed an analytical method for the characterization of biogenic emissions from plants.
- 1993: Compared air-sampling techniques with an ion trap and quadrapole mass spectrometry for air analysis. Developed an extraction technique for analysis of polyphenols in leachate materials. Completed the characterization of trace organic constituents in potato and wheat crop atmospheric studies. Completed a database for 4 years of ethylene emission profiles with soybean, potato, wheat, and lettuce crops.

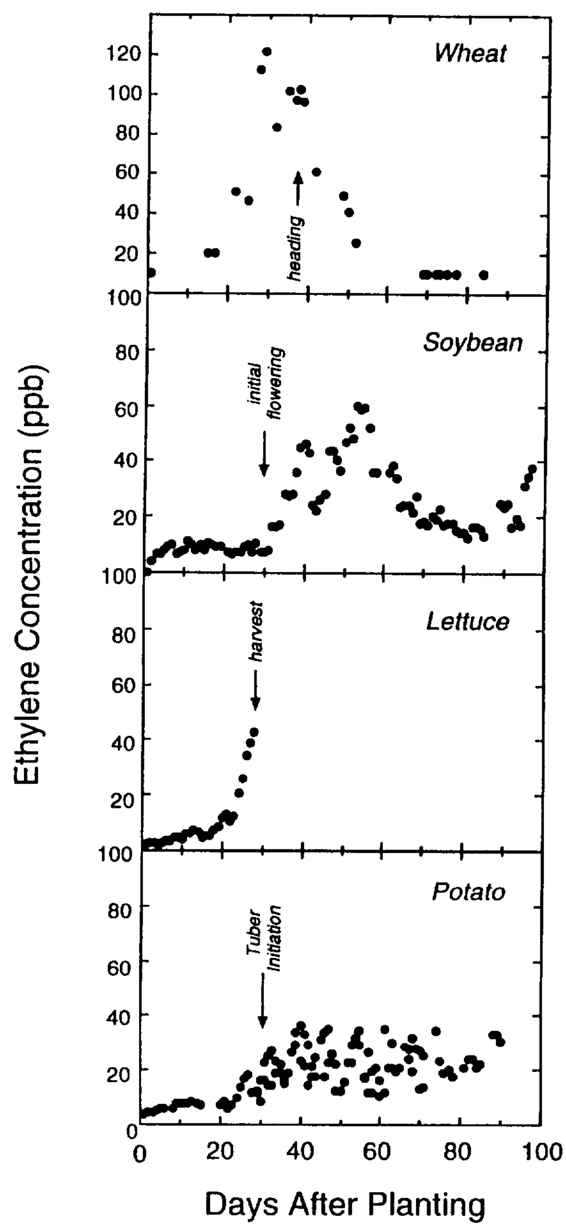
Key milestones:

- 1994: Characterize and monitor the atmosphere from leachate studies. Continue with the characterization and monitoring trace volatile constituents in the BPC atmosphere. Investigate relationships with phytotoxicity and allelopathy to exposure and filtration studies.
- 1995: Continue with the characterization of leachate studies. Automate methods for monitoring organic contaminants.

Contact: J.C. Sager, Ph.D, MD-RES, (407) 853-5142

Participating Organization: The Bionetics Corporation (B.V. Peterson)

NASA Headquarters Sponsor: Office of Life and Microgravity Science and Application



Ethylene Concentration Inside the BPC

Porous Tube Plant Nutrient Delivery System (PTPNDS)

The Microgravity Plant Nutrient Experiment (MPNE) is a Space Shuttle middeck locker hardware test of a concept conceived and developed at KSC. This experiment will verify the PTPNDS in microgravity. Three MPNE test bed units (TBU's) were fabricated and used to test various pore-size porous tubes under varying gravity conditions on the KC-135 aircraft in October 1992. An infrared water availability sensor (WAS) was developed at KSC to control the solution delivery rate on the TBU's. Results of the KC-135 tests indicate the WAS worked as designed and control of nutrient solution delivery to the tube surface in this system had very little dependence on gravity.

Laboratory studies were directed toward developing plant seed holders for microgravity, determining candidate plant species, and measuring plant nutrient uptake. Most recently, clinostat studies were performed to examine plant response to possible plant germination and lighting scenarios for the MPNE.

A preliminary design was developed for the MPNE middeck hardware, and fabrication of prototype components began. The target date for the completion of the flight hardware is September 1995.

Key accomplishments:

- Development and testing of the PTPNDS in a ground-based KSC laboratory with modifications and improvements were incorporated over the past 8 years. System testing with wheat, beans, rice, soybeans, tomatoes, lettuce, radish, white potato, sweet potato, and *Arabidopsis* was performed.
- Miniaturization of the PTPNDS for applying the concept to Space Shuttle middeck hardware has been performed over the past 3 years.
- Construction of the TBU's and physical testing of the PTPNDS on the KC-135 aircraft was accomplished.
- A preliminary middeck hardware design is in the prototype fabrication stage.

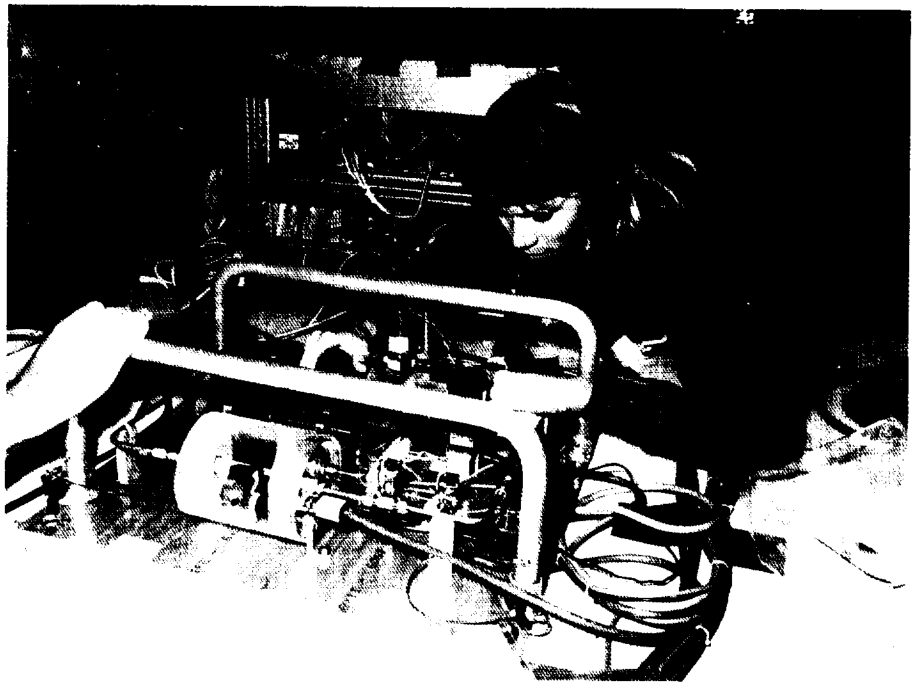
Key milestones:

- 1992: Development and testing of the KC-135 TBU's and initiation of laboratory studies in preparation for space flight.
- 1993: Design of space-flight hardware for the Space Shuttle middeck. Plant selection and germination, nutrient uptake, and plant lighting tests performed.
- 1994: Construction of prototype and space-flight hardware for further testing on the KC-135. Development of an experimental protocol for performing the hardware test on the Space Shuttle.
- 1995: Complete construction and testing of space-flight hardware with the final hardware and protocol ready in September.

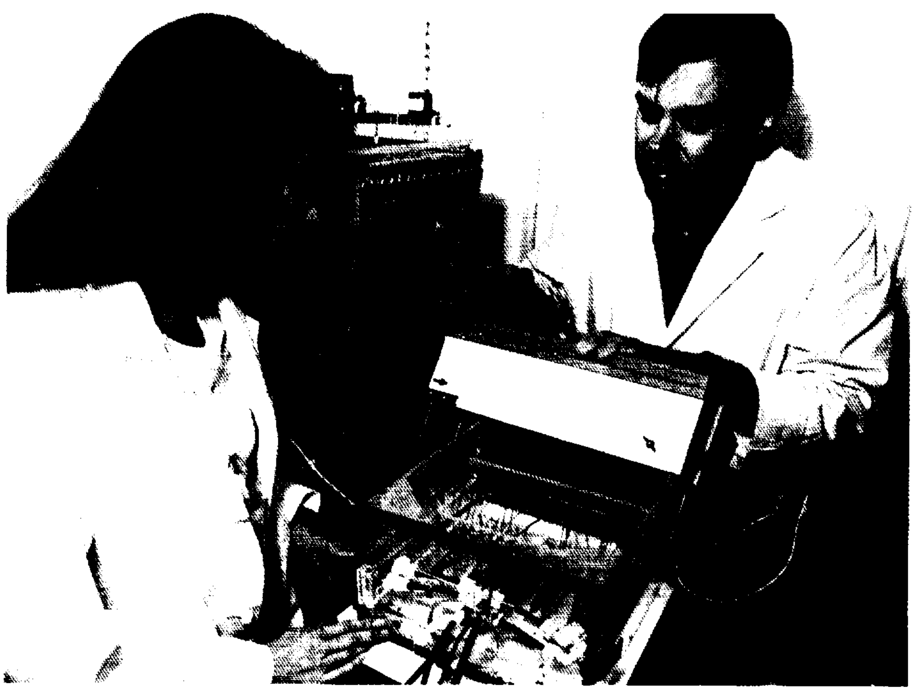
Contacts: W.M. Knott, Ph.D., and J.C. Sager, Ph.D., MD-RES, (407) 853-5142

Participating Organization: The Bionetics Corporation (T.W. Dreschel and C.W. Carlson)

NASA Headquarters Sponsor: Office of Life and Microgravity Science and Applications



Testing of the MPNE Test Bed Units During Parabolic Flight on the NASA KC-135 Aircraft



Wheat Plants Growing on a PTPNDS in a Prototype MPNE Plant Chamber

Advanced Life Support System Evaluations

Advanced life support is a critical technology for long-duration manned spaceflight, whether in low Earth orbit, on the moon, on Mars, or beyond. There are a number of viable options for most of the life support functions. These options must be evaluated and a selection made for a particular mission. In addition, trade studies must be made on where to provide research and development funding based on probable return.

Many factors affect the selection of life support options, including safety, reliability, acceptability, hardware cost, cost of delivery of initial and resupply mass, volume required, provision of electrical power, operational and maintenance manpower, other support requirements, and environmental effects. To eliminate bias so far as possible, an attempt was made to reduce all trade study parameters to a single dimension. The ideal dimension is money, as this is the real selection criterion. However, other dimensions can be effectively used, with fewer complications, such as the cost of money and funding profiles. Consequently, equivalent mass was selected as the dimension.

For the most significant quantifiable parameters, an equivalency can be established, and definitive comparisons can be performed. A list of equivalencies is shown in the table. The parameters that cannot be effectively quantified using an equivalent mass approach are the same ones that cannot effectively be quantified using dollar cost: safety, reliability, and acceptability.

Cost Factor Equivalencies

Pressurized volume	**67 kilogram per cubic meter**
Electrical power	**3900 kilowatthour per kilogram**
Manpower	**1.8 millihenry per kilogram**
Assumptions: Lunar base using Space Station Freedom 28-foot modules with a regolith shielding, a 10-year system life, nuclear power.	

Using the equivalent mass approach, it was shown that a bioregenerative life support system is cost effective and that some complexity of biological recovery of plant waste is also cost effective compared to a plant-only system. The break-even point compared to a physico-chemical system is about 1.5 years, although this is very sensitive to the equivalencies used. For a more realistic near-term system, an option with 85 percent closure for food was evaluated. This is expected to be much more acceptable to a crew, as they would have an adequate supply of highly palatable foods such as steak and a local production of staple foods.

This approach has also been used to compare physico-chemical systems. In looking at water regeneration alone, plants are not competitive due to the high system mass and energy costs. However, the Space Station Freedom baseline also suffers from high resupply mass. Some of the alternatives proposed such as vapor compression distillation suffer from a poor recovery fraction (i.e., below 95 percent). An air evaporation system, a low-technology approach, is attractive in having a low initial mass and a low consumables requirement.

This effort continues to study bioregeneration and physico-chemical regeneration in more detail as more data comes available, as well as additional physico-chemical systems.

Key accomplishments:

- 1991: Developed an equivalent mass approach and a CELSS computer model.
- 1992: Enhanced the CELSS model. Performed trade studies on different CELSS and personal computer (PC) scenarios, including different resource recovery options.

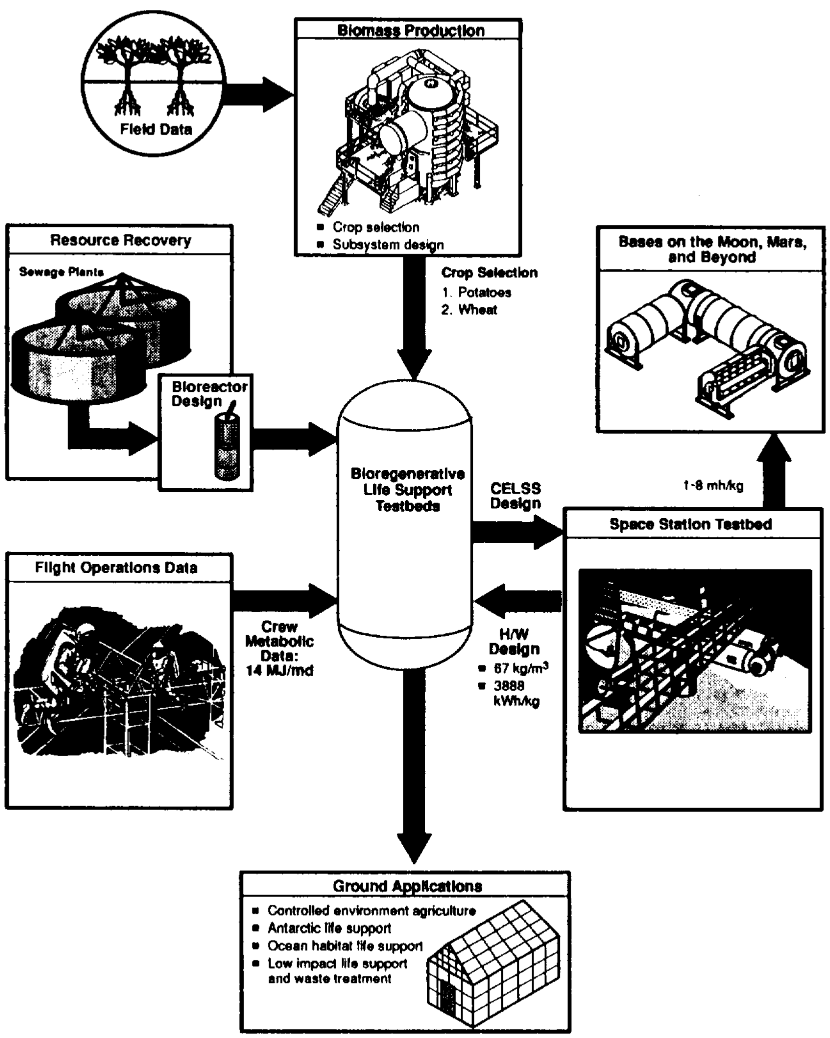
Key milestones:

- 1993: Began to perform PC trade studies. Continued using the equivalent mass approach to evaluate CELSS options and define Phase 2 of the CELSS Breadboard Project. Developed the CELSS Monitor and Control Implementation Plan.
- 1994: Begin sizing of a CELSS based on previous work and identifying resource requirements. Begin execution of the implementation plan. Continue evaluations of PC technology.

Contact: J.C. Sager, Ph.D., MD-RES, (407) 853-5142

Participating Organization: McDonnell Douglas Space Systems (Dr. A.E. Drysdale)

NASA Headquarters Sponsor: Office of Life and Microgravity Science and Applications



Bioregenerative Life Support

Light-Emitting Diodes and Plant Growth

One of the main challenges to growing plants in space is supplying a sufficient quantity and appropriate quality of light. Potential electric light sources must have a high electrical efficiency, small mass and volume, excellent reliability and safety record, and optimal spectral output for photosynthesis and photomorphogenesis. Light-emitting diodes (LED's), particularly in the red region of the spectrum (660 to 690 nanometers), may meet many of the aforementioned criteria. LED technology, as it applies to growing plants, is relatively new, and few studies have been conducted to show its potential usefulness. Further research is necessary prior to the acceptance of LED's for supporting plant growth in space. Toward this end, the Plant Space Biology Laboratory at KSC, in collaboration with Dr. A.C. Schuerger at The Land pavilion of Disney's EPCOT Center, is comparing the growth, structural development, photosynthetic characteristics, and disease resistance of pepper, cucumber, and lettuce plants grown under LED's to plants grown under broad spectrum metal halide (MH) lamps. Research is being conducted at KSC to examine the influence of the monochromatic red LED's on photosynthetic electron transport, chlorophyll biosynthesis, and reproductive development.

Pepper plant growth and response to LED's is shown in the figure "Pepper Plant Growth Under LED's." As is apparent in the photograph and table, the addition of supplemental blue light to the red LED's has a beneficial effect on the growth of pepper plants.

Overall, these studies suggest that LED's may be a viable light source for growing plants in space. Plans include researching a number of different plant species and investigating further the role of blue light in the noted responses.

Key accomplishments and milestones:

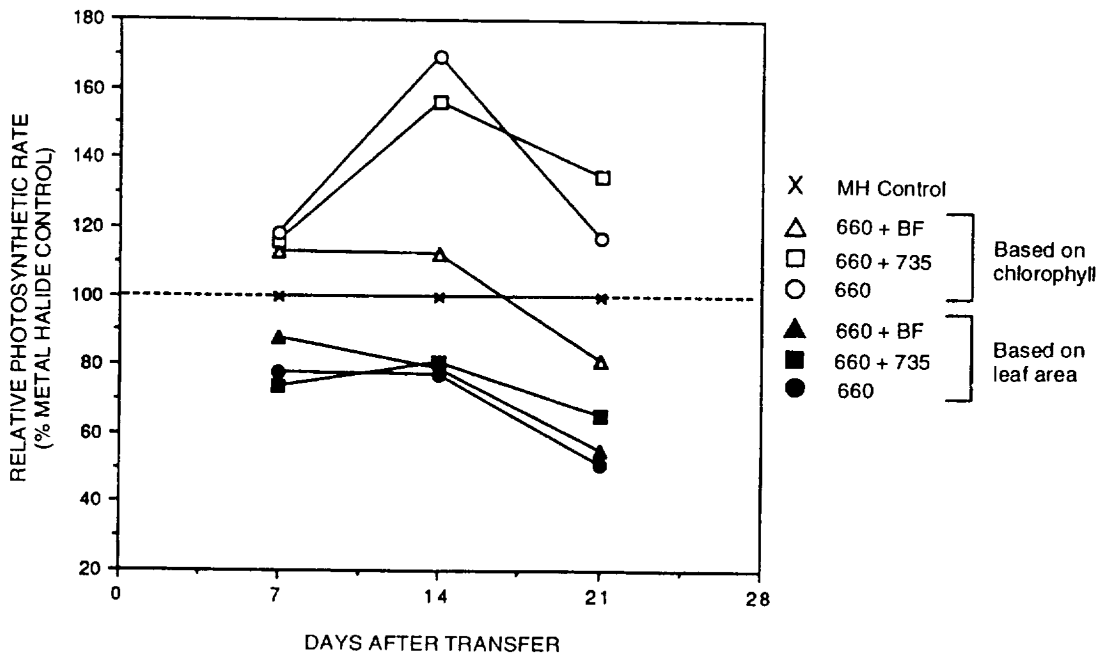
- 1992: Began experiments to assess LED's for plant growth.
- 1993: Continued experimentation with a number of different species under LED's. Began work on photosynthetic electron transport and chlorophyll biosynthesis.
- 1994: Conduct "seed-to-seed" with wheat and *Arabidopsis*.

Contacts: W.M. Knott, Ph.D., and R.M. Wheeler, Ph.D., MD-RES, (407) 853-5142
Participating Organization: The Bionetics Corporation (C.S. Brown, Ph.D.)
NASA Headquarters Sponsor: Office of Life and Microgravity Science and Applications

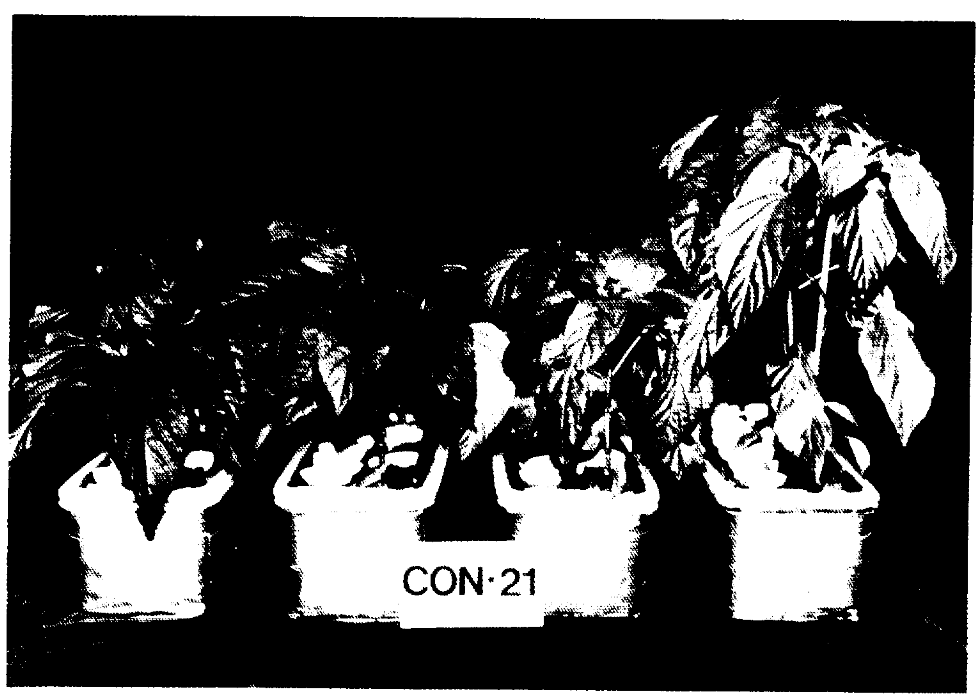
Pepper Plant Growth After 21 Days Under Metal Halide (MH), Red LED's + Blue Fluorescent (660/BF), Red LED's (660), and Red + Far-Red LED's (660/735) (Within a row, values with different letters are significantly different at P=0.05, n=12.)

Growth Parameter	Source			
	MH	660/BF	660	660/735
Plant DW (g)	3.1a	2.6b	1.8c	2.1c
Shoot/root (DW)	3.4b	3.7ab	3.6ab	4.1a
Total leaf area (cm^2)	689ab	778a	573c	532c
No. leaves	19.8a	18.4a	14.7b	13.4b
SLW ($mg\ cm^{-2}$)*	2.0a	1.3b	1.0c	1.1c

*SLW = specific leaf weight of first fully expanded leaf.



Pepper Plant Growth Under LED's



Pepper Plants After 21 Days of Light Treatments

Controlled Ecological Life Support System (CELSS) Engineering

The main purpose of the CELSS Engineering Group is to determine the engineering techniques and hardware required to successfully operate a CELSS. This includes maintaining physical systems for biological research, performing engineering analysis of existing systems, and designing and testing new systems.

Biological components are studied in engineering terms (production rates, consumption rates, and reliability) to determine their effect on the entire CELSS. For crops, food production and gas exchange are controlled by the amount of lighting provided, while water purification is controlled by humidity. Optimal environmental conditions for each crop have been developed, and different automation and control techniques have been tried. Separate computer systems and sensors are used to control and monitor the environment of KSC's Biomass Production Chamber (BPC), and both of these systems have been upgraded with new hardware and software.

Biomass production is only one part of a functioning CELSS. A secondary focus of the breadboard project is resource recovery. This involves recycling inedible biomass back into the system, either as an edible product or as nutrients for the growth of new biomass. Design and operation of these components have been successful. Therefore, future plans are being made to physically integrate resource recovery processes with BPC processes. Installation of a robotic arm for remote BPC operations is also being studied along with automation of other CELSS processes.

Key accomplishments:

- 1988: First closed operation of the BPC.
- 1990: Metal halide lamps tested as a lighting source.
- 1991: Atmospherically separated the two levels of the BPC. Installation of pressure compensation in the upper BPC. Completed the computer database to track reliability of the BPC.
- 1992: New environmental monitoring system computer installed. Completed the condensate recycling and monitoring system. Installed pressure compensation on the lower level of the BPC. Installation of oxygen scrubbers to enable long-term atmospheric closure of the BPC.
- 1993: Redesigned and installed a new environmental control system, computer, and hardware.

Key milestones:

- 1994: Physical integration of the resource recovery subsystem with the BPC system.
- 1995: Installation of the robotic arm for remote BPC operations. Mixed crop growth tests.

Contact: J.C. Sager, Ph.D., MD-RES, (407) 853-5142

Participating Organization: The Bionetics Corporation (R.E. Fortson)

NASA Headquarters Sponsor: Office of Life and Microgravity Science and Applications

Atmospheric Sciences

The Atmospheric Sciences program at the John F. Kennedy Space Center (KSC) addresses the impacts of weather on ground, launch, and landing processing with a view to increasing safety of personnel, protecting resources, and reducing lost work time by improving detection, analysis, and prediction of weather events and protection from weather events. Many of the weather impacts are of a specialized nature, differing from those felt by the public and even aircraft operations, and require studies or development that crosses the lines of conventional scientific disciplines. Weather events focused upon by the program include lightning and cloud electrification, convective cloud growth, atmospheric surface and planetary boundary layer circulations and processes, wind shear effects, severe weather phenomena, rain, wind, and fog. Short-term attention is being directed to:

1. Mesoscale numerical weather prediction models
2. Numerical models for prediction of transport and diffusion of hazardous materials
3. Improvement and development of detection instrumentation and protection methods
4. Use of expert knowledge and artificial neural network techniques
5. Improvement of decisionmaking processes
6. Improvement of the processing and synthesizing of the voluminous data sets needed for accurate description of weather events and processes to effectively display the information and aid in its assimilation by weather forecasters and operations and safety decisionmakers

Long-term attention will be given to encouraging the evolution of more powerful numerical prediction models and computer systems, advanced detection and analysis of weather processes, advanced protection methods, and systems to support the processing and protection of future space vehicles and launch systems.

Thunderstorm Hypothesis Reasoner (THOR)

The Norse god Thor ruled thunderstorms, according to ancient Vikings. A new rule-based expert software system THOR (Thunderstorm Hypothesis Reasoner) is being tested at KSC to help predict the boundaries of storms impacting Space Shuttle ground processing operations.

A substantial number of thundershowers develop over Merritt Island on summer days with light wind conditions. The storms are generally restricted in area, migrate slowly or not at all, and fall in the small thundershower classification. Delineating the boundaries of these storms is a challenge. THOR's job is to apply expert system technology by interpreting data from the mesonetwork of electric field mills at KSC and provide accurate lightning advisories to weather advisors, who in turn alert operators of the various Shuttle work areas.

THOR's rule-based, electric field analysis system is augmented by case-based reasoning techniques gleaned from several domain experts at KSC by a knowledge engineer. Expert answers to questions regarding the use of electric field data, electrification of clouds, and thundershowers were assembled into a set of signatures to identify the occurrence of significant events during the rise and decay of electrification in a cloud. Two modules were developed into a system architecture (see the figure "Architecture of Data Analysis System"), including (1) signature identification and (2) data advisory.

The signature identification module (see the figure "Signature Types") processes electric field mill data, answers questions when they occur, passes that information to the data advisory module, and answers questions from the data advisory module. In turn, the data advisory module applies the rules in its store to provide advisories to operators (such as weather forecasters). The signature identification module runs on MATLAB software. The data advisory module uses the expert system development tool First Class/Fusion.

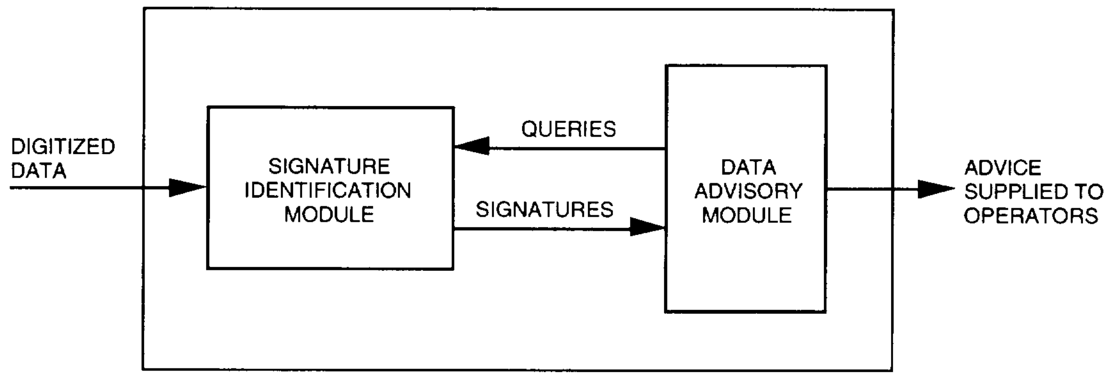
Key accomplishments:

- 1993: Software transitioned to real-time data processing at KSC. Independent data sets being tested.

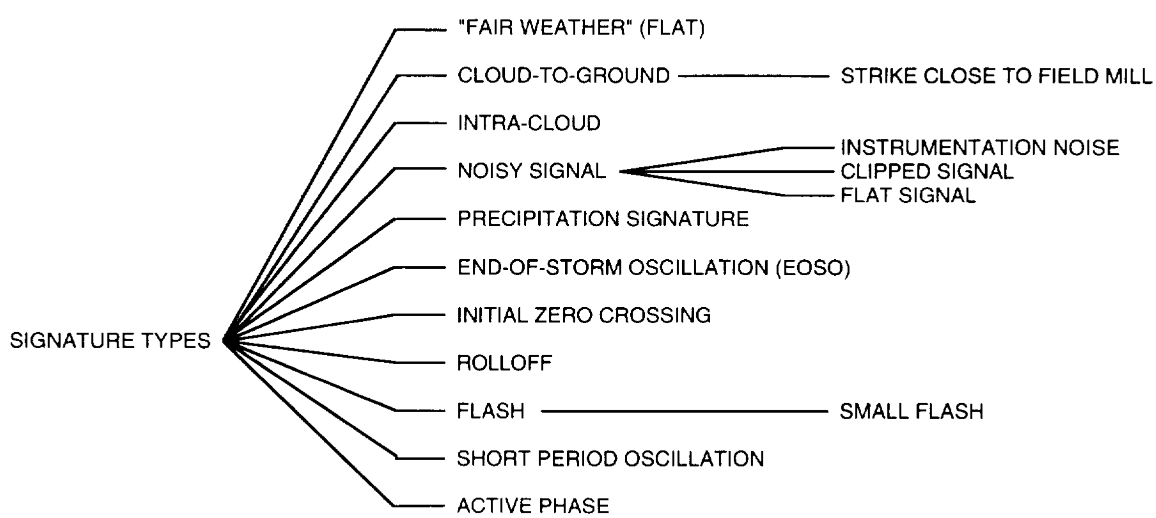
Contacts: L.M. Maier, TE-CID-3, (407) 867-4409; and F.J. Rico-Cusi, DL-DSD-22, (407) 867-3212

Participating Organizations: MITRE Corporation (A. Mulvehill, Ph.D.) and EG&G Florida, Inc. (J.F. Weir)

NASA Headquarters Sponsor: KSC Center Director Discretionary Fund



Architecture of Data Analysis System



Signature Types

Payload Changeout Room (PCR) Lightning Environment Study

This study was undertaken to obtain information for Space Shuttle payload organizations to use in design of payloads. It was funded primarily by Research and Technology Objectives and Plans (RTOP) from NASA Headquarters Safety. Phase I (analysis) was completed in fiscal year 1992.

During fiscal year 1993, experimental measurements were made of lightning-produced magnetic and electric fields outside and inside the PCR. This was done by connecting a lightning simulator to one end of the protective wire system (commonly referred to as the catenary wire system), injecting lightning-like pulses, and measuring the fields at several designated external and internal locations. The PCR was in its parked location, the doors were closed, and the Shuttle vehicle was not present. The test data are currently being evaluated and will be extrapolated to represent the effects of a full-scale lightning stroke.

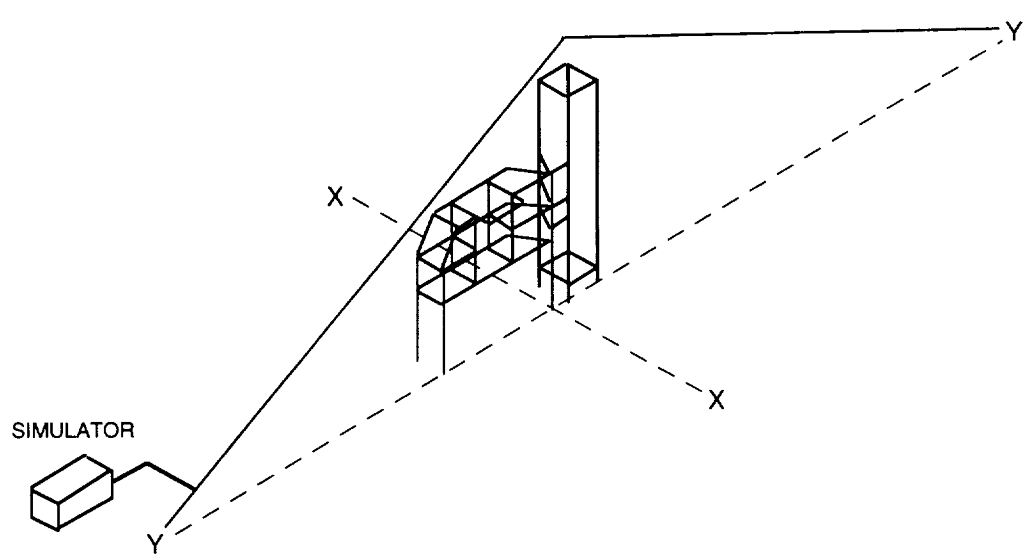
Key accomplishment:

- 1993: Phase II, use of a simulator for testing of analytical results.

Key milestone:

- The next phase of the study will consist of an analysis with the Shuttle vehicle present and the PCR mated to the vehicle with the doors open.

Contact: G.L. Thomas, RT-ENG-1, (407) 867-4493
Participating Organizations: Lightning Technologies, Inc., and Electro Magnetic Applications, Inc.
NASA Headquarters Sponsor: KSC Center Director Discretionary Fund



Simulation Configuration

Coordinated Approach to Mesoscale Numerical Weather Prediction

Sophisticated models, adequate high-resolution data, and affordable computer power are becoming available to attack two difficult weather prediction problems attending operations at KSC: thunderstorms and toxic diffusion. Three separate efforts are being integrated by the Applied Meteorology Unit (AMU). The AMU is a joint venture of NASA, the U.S. Air Force, and the National Weather Service, operated by ENSCO, Inc., in a coherent approach to solve these problems.

The efforts are each derived from Small Business Innovation Research (SBIR) programs. The Mesoscale Atmospheric Simulation System (MASS) model from MESO, Inc., was delivered as the result of a NASA Phase II SBIR. The model is a three-dimensional, hydrostatic nested grid model with cloud physics. The smallest grid is 11 kilometers. It has the ability to continuously "nudge" the model forecasts with real data.

The Emergency Response Dosage Assessment System (ERDAS) model is a three-dimensional, nonhydrostatic nested grid model with toxic diffusion capability but without cloud physics. It was developed under an Air Force Phase II SBIR by ASTeR, Inc., and has a fine grid resolution of 3 kilometers.

The Parallelized Regional Atmospheric Modeling System (RAMS) Operational Weather Simulation System (PROWESS) is a three-dimensional, nonhydrostatic nested grid model based on the same model as ERDAS; but its fine grid resolution is 1.5 kilometers and includes cloud physics without toxic diffusion. It is a follow-on to a NASA Phase I SBIR and is currently under development by ASTeR, Inc., with NASA Advanced Development funding.

The AMU is transitioning MASS to operational forecast use and has been tasked to transition ERDAS for operational support to hazardous operations beginning early in 1994. The AMU also supervises the PROWESS subcontract. Each model has advantages and weaknesses. The unified approach is expected to result in a single-operational, numerical weather prediction system on the 1.5-kilometer scale with both cloud physics and toxic diffusion. It will have all of the advantages of each of the three, and few of their weaknesses.

Key accomplishments:

- 1991 to 1993: MASS and ERDAS models developed under SBIR contracts.
- 1993: MASS model delivered to AMU and configured to accept real-time data from meteorological data systems. PROWESS requirements specified and work begun.

Key milestones:

- 1993 to 1994: MASS and ERDAS models running in real time in operational configuration. PROWESS running at real-time speed with MASS/ERDAS compatible data and display formats.

Contact: F.J. Merceret, Ph.D., TM-LLP-2A, (407) 853-8200

Participating Organizations: ENSCO, Inc., (G. Taylor, Ph.D.); ASTeR, Inc., (W. Lyons, Ph.D.)

NASA Headquarters Sponsor: Office of Space Systems Development and Office of Advanced Concepts and Technology

Environmental Technology

The John F. Kennedy Space Center (KSC) is located on the Merritt Island National Wildlife Refuge. Therefore, KSC has always approached its mission with an awareness of the impact on the environment. As a society, Americans have become increasingly concerned about the effect their actions have on the environment. With this awareness, KSC has increased its efforts to develop technologies that are environmentally oriented.

The projects presented this year cover a wide range of environmental technologies. Engineers are developing effective methods of cleaning without the use of chlorofluorocarbons. Halon, used for fire suppression, is another environmentally damaging compound. The technology has been developed that allows Halon to be recovered after use, limiting the chance that damage will occur. Several development efforts are underway that address the safety and disposal aspects of the hazardous fuels used in launch vehicles and satellites.

Another area of interest is the geographical information required to make environmental decisions. A development is continuing to integrate geographical databases that provide easy access to the data used for planning purposes.

Water Quality Inventory for Mosquito Lagoon

The water quality and ecology of Mosquito Lagoon and the Canaveral National Seashore were the focus of a 3-year interagency study. NASA and the National Park Service use this study to help in developing a long-term monitoring program to ensure protection of this unique natural resource for future generations.

A comprehensive computerized literature and information database was developed of organizations and agencies conducting sampling in the area. Information gaps were identified, and a collection of 2 years of site-specific data was completed. These data are being summarized into a technical report, and a long-term monitoring program for implementation by Canaveral National Seashore personnel is being developed.

The 2-year baseline database includes information on water and sediment chemistry, seagrass distribution and abundance, demersal fish population characteristics, and light attenuation. The extensive underwater light field data set focuses on photosynthetically active radiation and factors that influence backscattering absorption and attenuation. Light fields control the distribution and magnitude of primary production and are known to be influenced by man's activities such as watershed development, stormwater runoff, and sewage disposal through the addition of nutrients and particulates.

Key accomplishments:

- 1990: Interagency Agreement initiated. Literature survey and computerized database developed.
- 1991: Progress report and Phase II sampling plan completed and approved. Field data collection initiated.
- 1992: Mosquito Lagoon Environmental Resource document published. Fish community sampling completed.
- 1993: Water quality inventory, underwater light attenuation, and seagrass bed mapping completed. Final analyses begun.

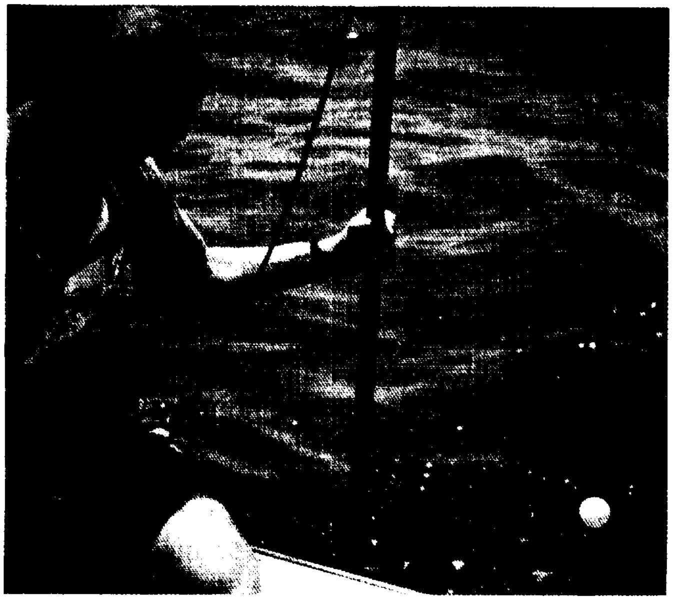
Key milestones:

- Monitor program development. Submit final reports and recommendations.

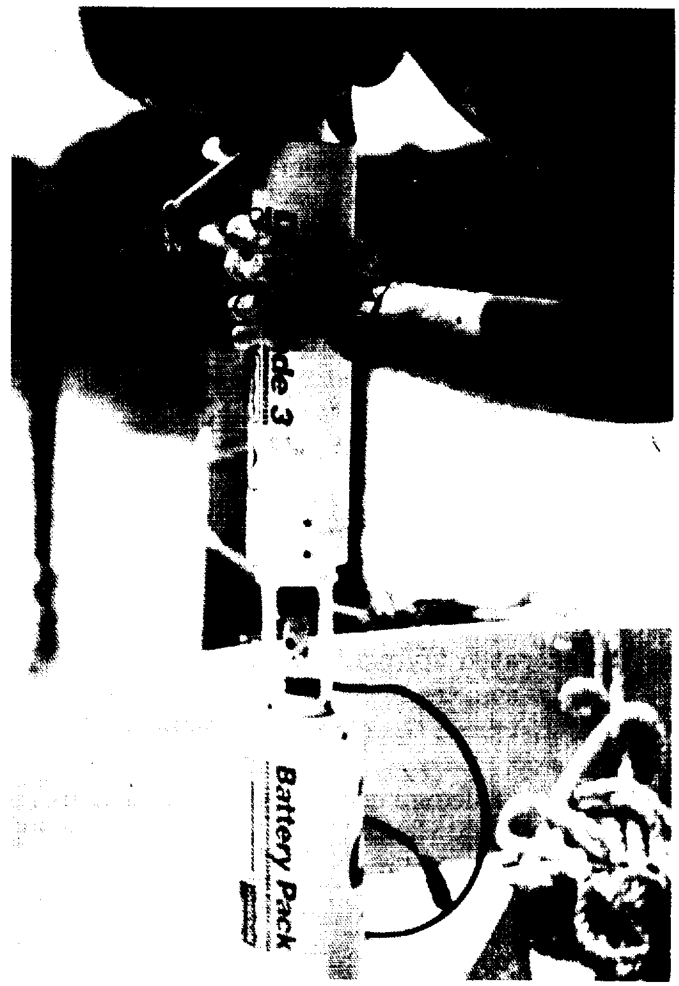
Contact: W.M. Knott, Ph.D., MD-RES, (407) 853-5142

Participating Organization: The Bionetics Corporation (J.A. Provancha and R.H. Lowers)

NASA Headquarters Sponsor: Office of Life and Microgravity Science and Applications



Spherical Quantum Sensor for Measuring Light Attenuation in Mosquito Lagoon



Field Positioning of a Programmed Water Quality Data Collector

Fish Samples Collected in Mosquito Lagoon

Application of Ultraviolet Oxidization Technology for the Destruction of Hydrazine Wastewater at KSC

In the context of today's environmental regulatory climate, the quest for effective wastewater treatment has received special emphasis throughout industry. The annual generation of high volumes of hazardous waste carries the attendant costs and liabilities associated with the handling and final disposition (such as subcontract disposal). An effective treatment technology, recognized as unique and challenging, would benefit the management of environmentally regulated waste generated in the support of space launch operations.

Personnel at KSC have pursued the development of a viable technology for hazardous waste management as effective treatment of propellant-derived wastewaters generated during launch support activity. The technology provided by the ultraviolet (UV) enhanced oxidation process (EOP) was recognized as a successful treatment method that is also in concert with Environmental Protection Agency treatment standards for hydrazine wastewater. The process utilizes UV radiation and a photolytically activated catalyst to detoxify hydrazine-contaminated wastewater and undesired intermediate products.

A process utilizing UV/oxidation technology that provided design aspects for a full-scale process was investigated and demonstrated. It was determined to be an environmentally acceptable treatment regime with the capability to manage hazardous wastewater at KSC. These efforts led to further development in the design and procurement of a second-generation photochemical treatment system, furnished specifically for the KSC application. Future plans include process implementation, testing, and refinement of operations for cost-effectiveness and capability to treat other waste streams.

Key accomplishments:

- Investigated UV oxidation technology at White Sands Test Facility (Air Force prototype) and commercial sources.
- Demonstrated the technology by onsite pilot plant testing and conducted site visits to field installations.
- Developed design criteria and a performance specification for KSC chemistry and treatment regime.
- Designed, fabricated, and received a second-generation commercial UV/oxidation unit known as RAYOX.
- Activation and validation of the RAYOX process unit.

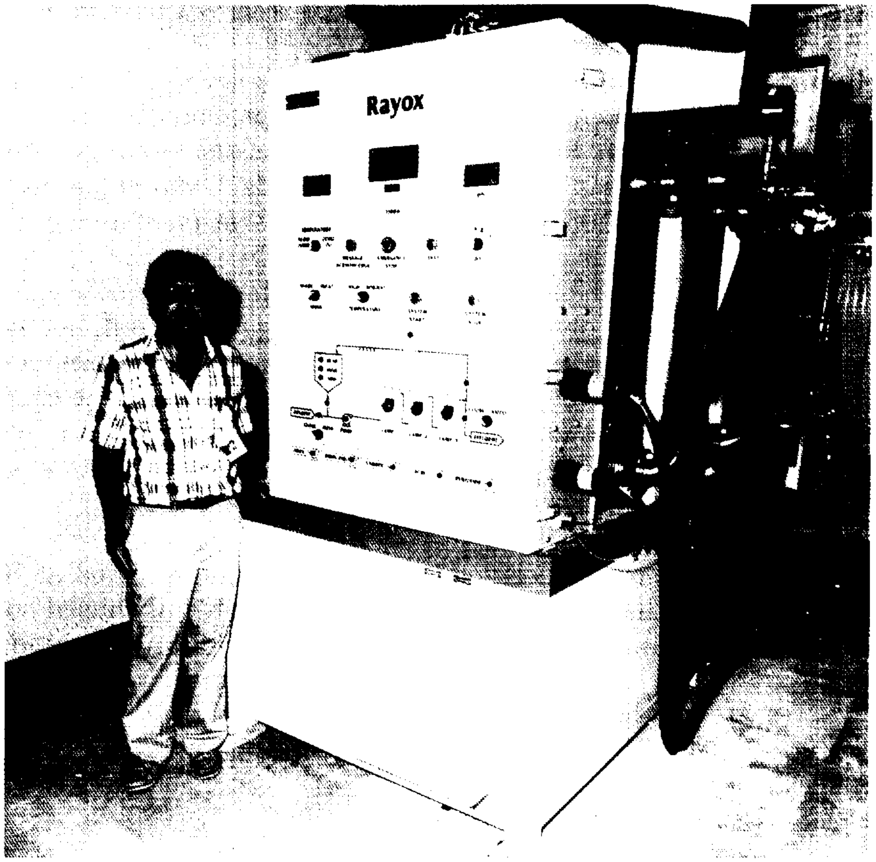
Key milestones:

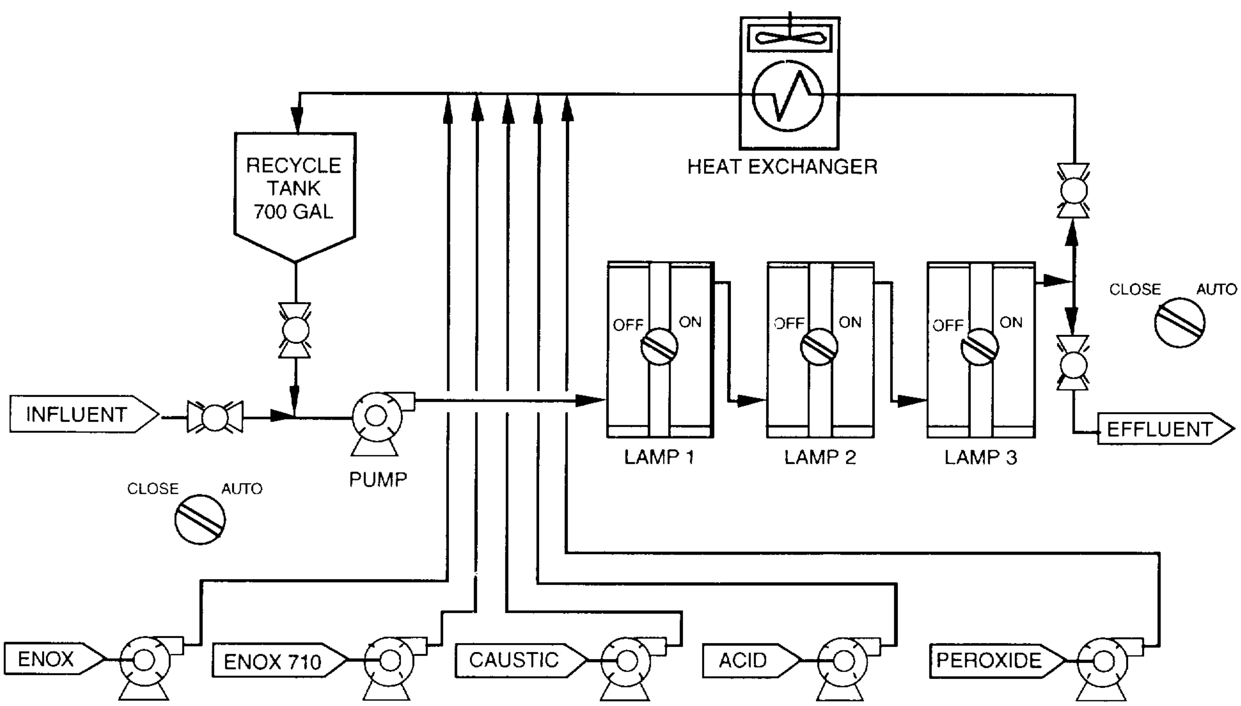
- Implement the RAYOX process, integrate the treatment, and continue the testing for process refinement.
- Apply the treatment to alternate waste types (e.g., solvents).
- Develop an additional unit dedicated to groundwater remediation.

Contacts: J.E. Thompson and G.S. Kosar, SI-PEC-3, (407) 867-8295

Participating Organization: EG&G Florida, Inc., (D.J. Tierney and E.W. Fickey)

NASA Headquarters Sponsor: Office of Space Flight





RAYOX Process

Recovery of Halon 1301 Superpressurized With Nitrogen

In order to comply with current Environmental Protection Agency regulations on chlorofluorocarbon (CFC) Halon emissions, an effective means of recovering superpressurized Halon 1301 from inservice fire extinguishers must be employed at KSC. To realize an efficient recovery rate (amount recovered expressed as a percentage over the original amount in the cylinder), two major obstacles must be overcome: (1) the high vapor pressure of Halon 1301 and (2) the separation of nitrogen from Halon 1301.

Personnel at KSC pursued the design of a Halon recovery system that would safely handle the extensive varieties of cylinders and the large quantities of Halon being phased out, not only at KSC but at all NASA centers. The process of expanding superpressurized Halon into a low-temperature (-150 degrees Fahrenheit) condenser/separator while venting the nitrogen and pumping the condensed Halon into a storage vessel was found to be the most feasible for the KSC environment. In addition to recovering Halon, the system is capable of automatically filling cylinders with Halon to a specified weight and superpressurizing the cylinders with nitrogen.

The Halon 1301 recovery system was designed, fabricated, and activated at KSC. The system is currently used to empty cylinders that require maintenance or are being phased out of service. Future plans include enhancing the condenser/separator to decrease cool-down time and improve the Halon phase changes process.

Key accomplishments:

- Halon 1301 recovery system installed and activated at KSC.
- System currently used to recover Halon from in-service cylinders.

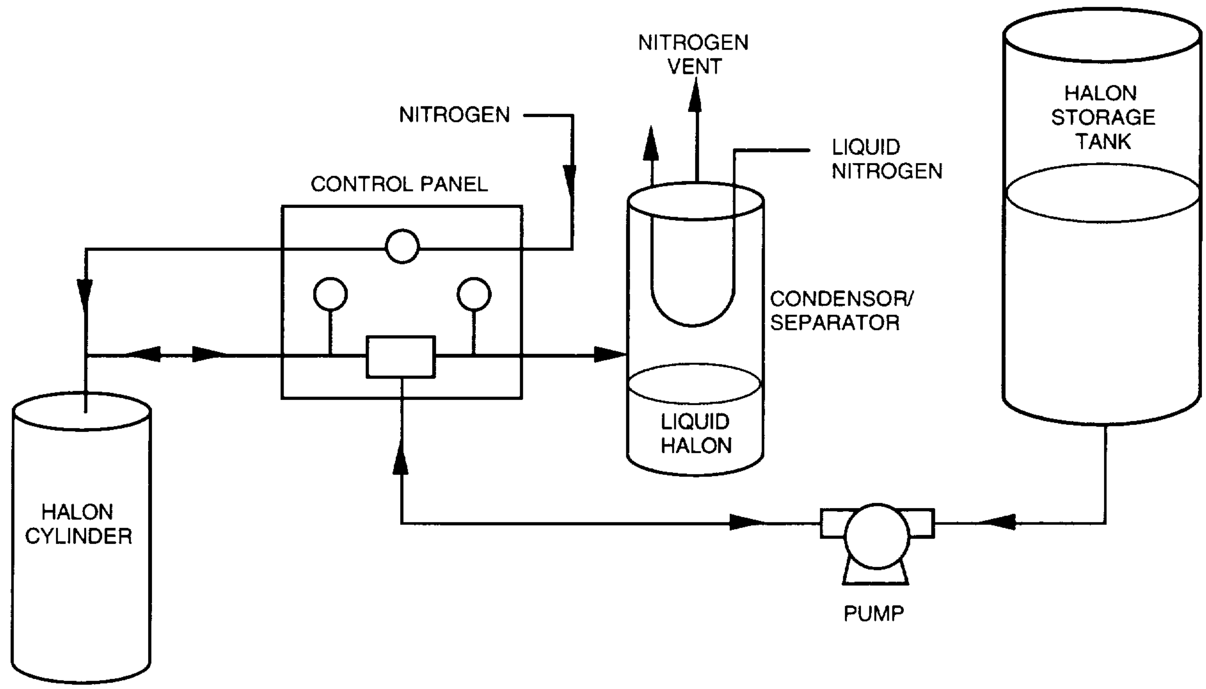
Key milestone:

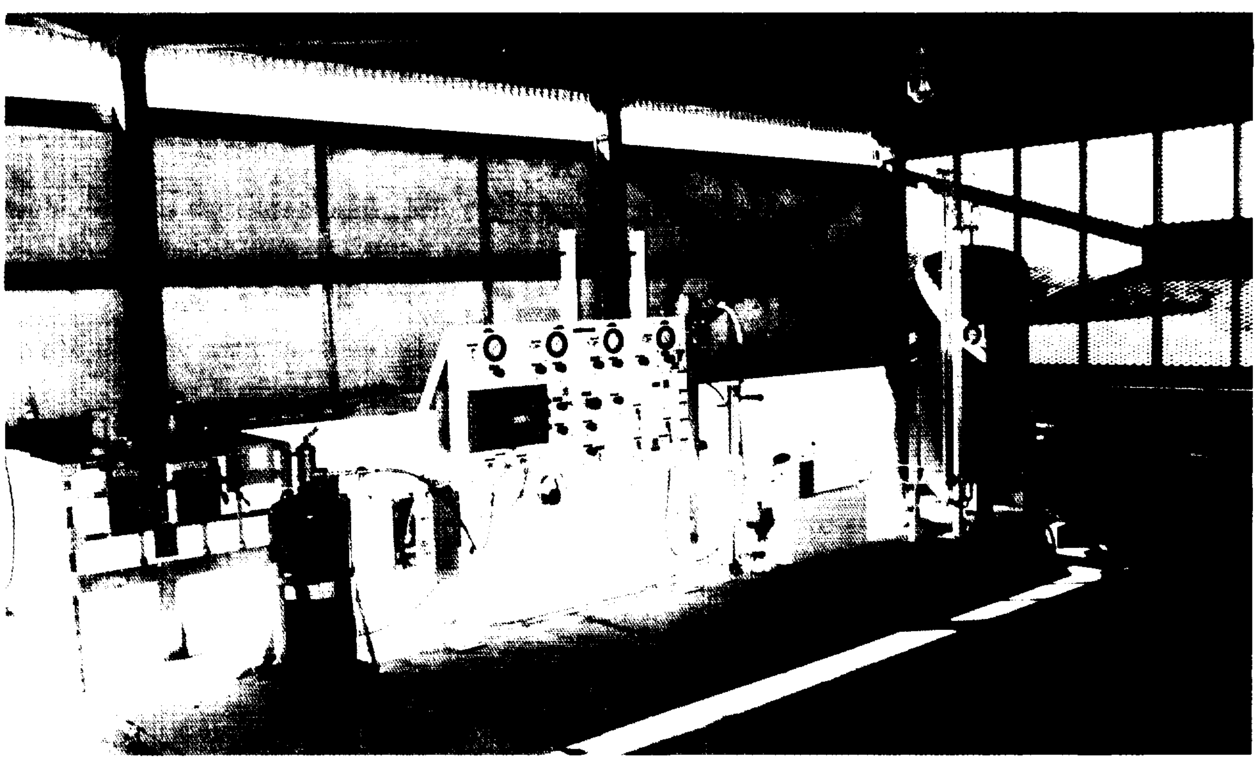
- Enhance the condenser/separator for an improved Halon phase change process.

Contact: T.C. Lippitt, SI-PEC-2, (407) 867-7186

Participating Organization: EG&G Florida, Inc. (N.J. Kamphaus and S. Song)

NASA Headquarters Sponsor: Office of Space Flight





Halon 1301 Recovery System

Mapping Analysis and Planning Systems (MAPS)

At KSC (as at other large Federal facilities), the management, analysis, and interpretation of extensive and diverse volumes of environmental data are required to operate the facility in compliance with local, state, and Federal laws and regulations. Users of the data include the Environmental Management Office, Master Planning Office, Pollution Control Office, U.S. Fish and Wildlife Service, National Park Service, U.S. Air Force, and various other KSC, state, and local organizations.

An increasing demand exists for local maps and charts of geographic-type environmental data (e.g., vegetation types, location of habitat for threatened and endangered species, and location of wetlands) to support environmental decisionmaking in the operation of KSC. The objective of the Mapping Analysis and Planning Systems (MAPS) project is to develop a network of integrated workstation-type computer systems that link a knowledge-based computer shell to centralized Geographic Information System (GIS) databases, environmental models, and other environmental data to enhance and streamline the environmental management decisionmaking process.

The initial workstation establishment has increased the output of useful information to various users; concomitantly, the information requests have increased. Further development of the system, including expanded networks, knowledge-base integration, neural networks, and more powerful hardware, will ensure the capability to support the data users.

Key accomplishments:

- 1990: Initial system setup was accomplished and a pilot study was completed.
- 1991: Hardware and software were obtained and configured and existing data were placed into the system.
- 1992: A Local Area Network (LAN) was established for user access and a global positioning system was acquired to streamline input of geographic data.
- 1993: The Global Positioning System was incorporated into daily field activities such as identification of permanent sampling locations. A knowledge-based system was compiled that incorporated assorted environmental data to assist in environmental impact documentation. Three-dimensional modeling of ground water contamination sites utilizing masterplanning files, SPOT data, and tabular data was accomplished. A Visiting Investigator Program (VIP) was initiated with Stennis Space Flight Center and the University of South Carolina.

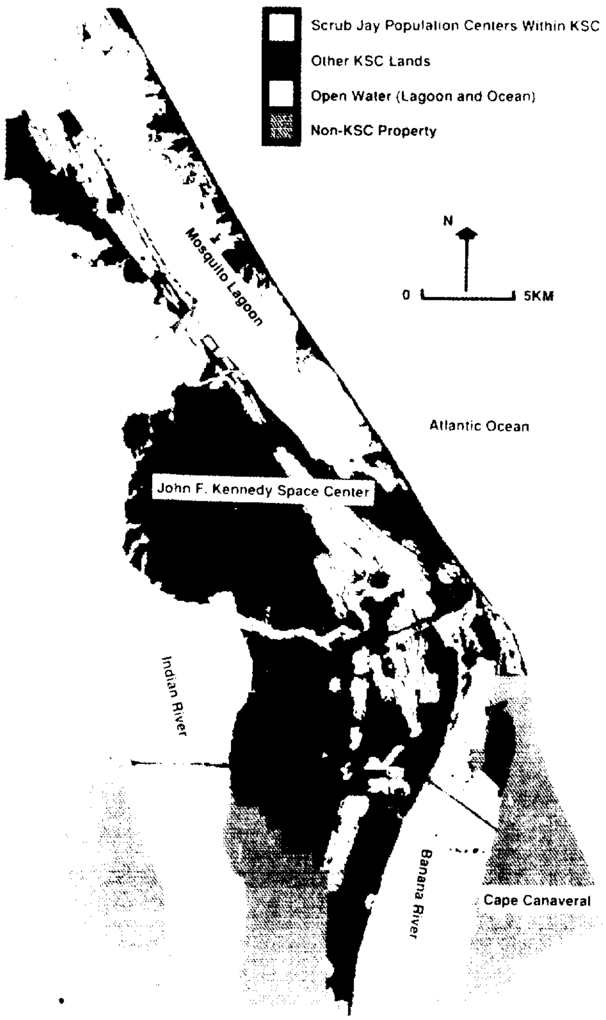
Key milestones:

- 1994: Establish fiber-optic lines to allow for rapid data transmission. Complete the distributed GIS to identified site, the incorporation of a major relational database management system, the distributed databasing, the VIP with Stennis Space Flight Center, and the neural network and image processing.

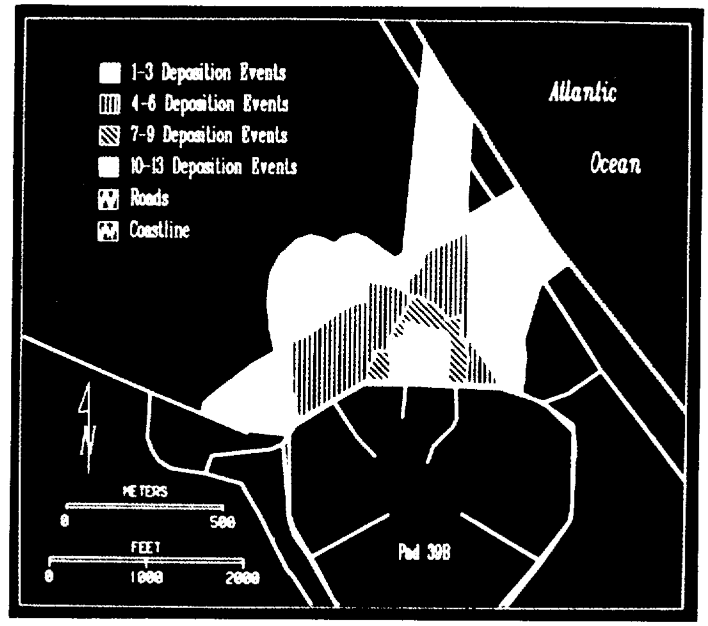
Contact: W.M. Knott, Ph.D., MD-RES, (407) 853-5142

Participating Organization: The Bionetics Corporation (M.J. Provancha)

NASA Headquarters Sponsor: Office of Life and Microgravity Science and Applications

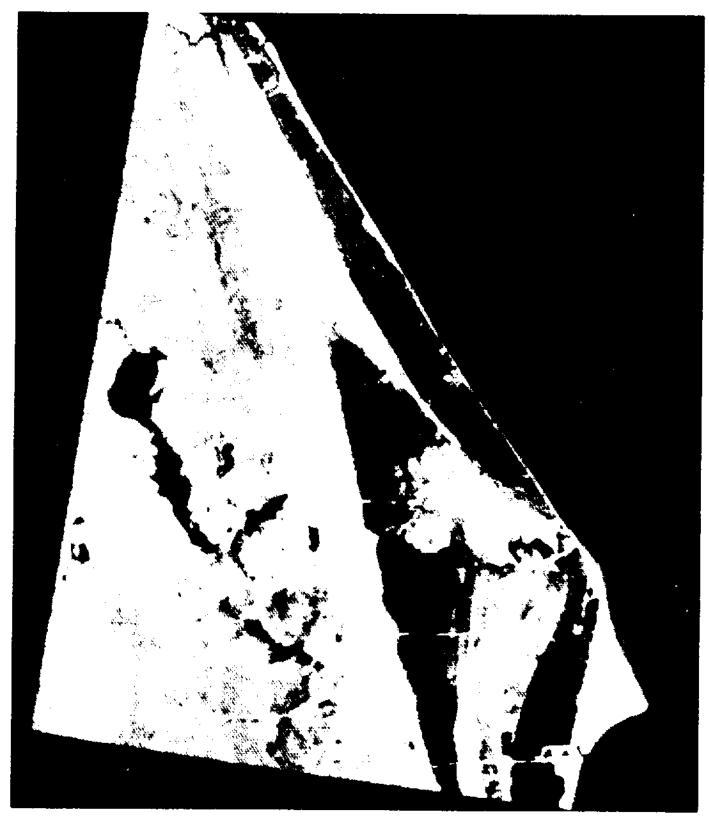


Geographic Information System Map of Potential Scrub Jay Habitat at KSC



Documentation of Near-Field Launch Effects Using GIS Technology

Geographic Information System Workstation



LANDSAT Image of KSC for Use in Resource Management

Threatened and Endangered Species Monitoring

The 57,000 hectares of KSC represent an area of biological diversity unsurpassed among other Federal facilities within the continental U.S. Approximately 100 wildlife species on the Merritt Island National Wildlife Refuge are in danger of declining population and/or extinction. Under the requirements of the Endangered Species Act and the National Environmental Policy Act, each new construction project and ongoing operations at KSC must be evaluated to ensure impacts to these species and their habitat are minimized.

To address this growing concern, a ranking system was developed, based on: (1) a specie's vulnerability in the U.S., in Florida, and at KSC and (2) the relevancy of KSC for maintaining U.S. and Florida populations. Studies are conducted on priority species to develop predictive and interpretive abilities regarding the ecology of their populations. Currently, program activities focus on listed species, including marine turtles, manatees, scrub jays, wading birds, shore birds, indigo snakes, gopher tortoises, and southeastern beach mice.

During 1993, a wetlands restoration program was developed to mitigate for impacts produced by KSC construction activities. The focus of this program will be to restore many of the 9308 hectares of impounded salt marsh to more natural conditions by increasing the exchange of water with the Indian River Lagoon. This program is being conducted in conjunction with the U.S. Fish and Wildlife Service, the Environmental Protection Agency National Estuaries Program, the St. Johns River Water Management District, and the Brevard Mosquito Control District.

Key accomplishments:

- 1991: Developed habitat maps of the most important areas on KSC for manatees, scrub jays, wading birds, and other species.
- 1992: Developed a scrub restoration and monitoring program.
- 1993: Developed a wetlands restoration program.

Key milestones:

- 1994: Complete the study on threats to biological diversity. Implement the wetlands mitigation and restoration program.
- 1995: Complete analyses of several priority species studies.

Contact: W.M. Knott, Ph.D., MD-RES, (407) 853-5142

Participating Organization: The Bionetics Corporation (D.R. Breininger)

NASA Headquarters Sponsor: Office of Life and Microgravity Science and Applications

Releasing an Indigo Snake With Radio Transmitter

Federally Protected Wood Storks Feeding Near Launch Pad 39A

Scrub Jay, a Federally Listed Species, on KSC

Air Quality Monitoring

For pollutants assigned priority by the Environmental Protection Agency (EPA) and the Florida Department of Environmental Regulation (DER), long-term ambient monitoring is conducted to fulfill requirements of the National Environmental Policy Act commitments made in the KSC Environmental Impact Statement and to provide data for use in permitting, compliance, and impact analysis.

The monitoring of priority pollutants, including ozone, sulfur dioxide, carbon monoxide, nitrogen dioxides, and particulates, as well as local meteorological conditions continued at the permanent air monitoring station (PAMS) site. Instrumentation used for sampling employs different analytical techniques including ozone (ultraviolet absorption), sulfur dioxide (pulsed ultraviolet fluorescence), carbon monoxide (gas filter correlation infrared absorption), and nitrogen oxides (gas chemiluminescence). The data are collected once per minute by a Hewlett Packard 9000 series mainframe computer and validated using the EPA and DER quality assurance guidelines. There were no exceedances of the Federal or state air quality standards during the year for the KSC area.

Accomplishments during the year included installation of new samplers to monitor inhalable particulates (PM-10), acquisition from the U.S. Air Force of a spatial database on historic rainfall volumes for KSC, initial screening of light hydrocarbons in the ambient air environment, and collection of samples of Shuttle exhaust particulates for determination of trace metal constituents. Sampling of ambient volatile organic carbon (VOC) compounds with a portable gas chromatograph will allow for a more complete assessment of fates of VOC's released into the atmosphere from permitted facility operations. Identification of VOC's released by plants will allow for development of models of carbon cycling in the ecosystem and possible identification of ecosystem responses to man-made disturbances.

Key accomplishments:

- 1991: Acquisition and installation of the new replacement trailer and new monitors for ozone and nitrogen dioxides.
- 1992: Acquisition of new PM-10 monitors and a portable gas chromatograph.
- 1993: Deployment and use of the PM-10 monitors and the portable gas chromatograph. Began looking at the spatial distribution of rainfall data for KSC.

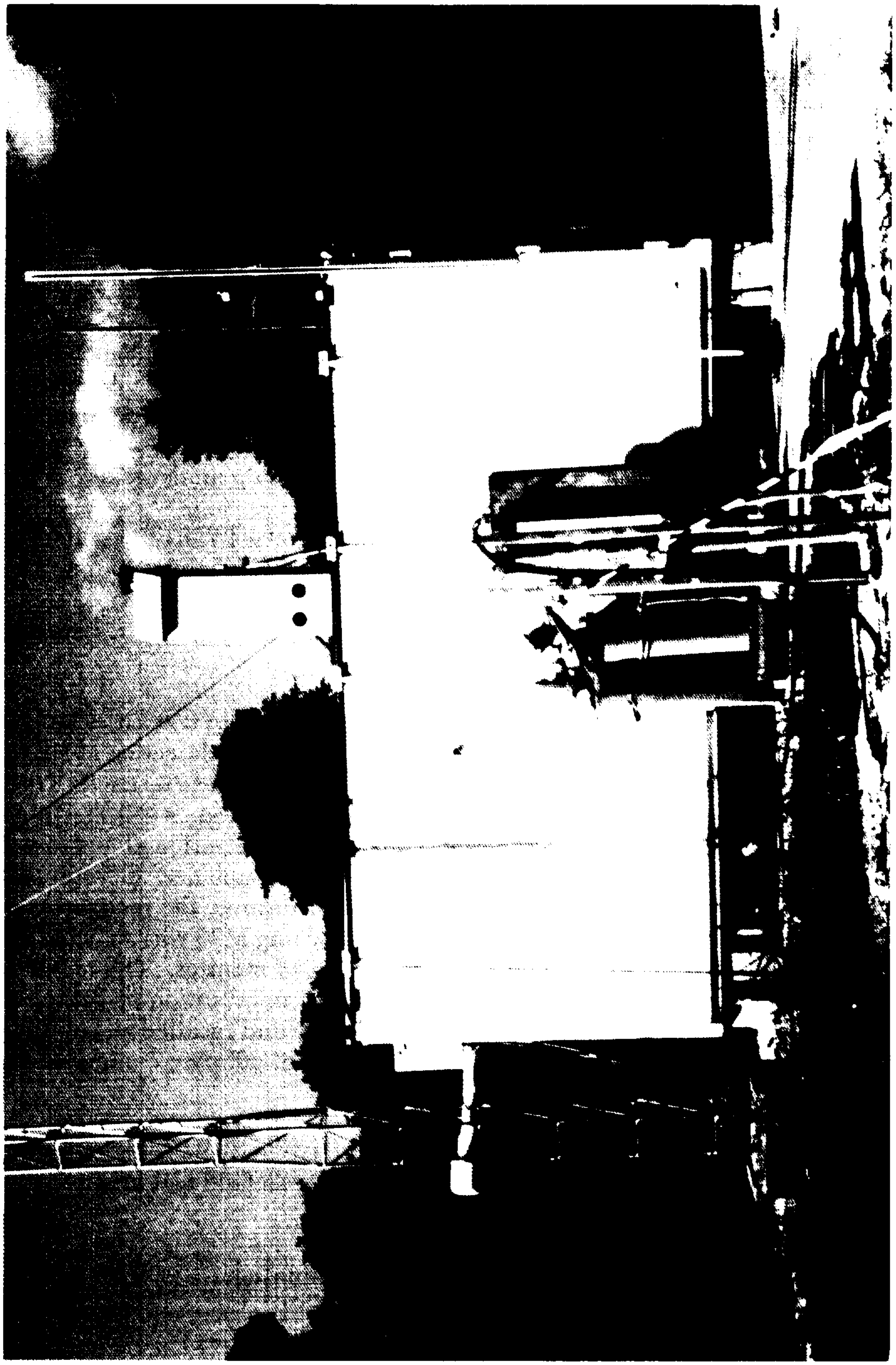
Key milestones:

- 1994: Continue monitoring of the ambient criteria pollutants and begin KSC-wide monitoring of light hydrocarbons and other VOC's. Also, begin monitoring inhalable particulates at three sites on KSC. Complete the summary document of the long-term air monitoring data.
- 1995: Continue monitoring of the above pollutants and begin analysis of the VOC data.

Contact: W.M. Knott, Ph.D., MD-RES, (407) 853-5142

Participating Organization: The Bionetics Corporation (J.H. Drese)

NASA Headquarters Sponsor: Office of Life and Microgravity Science and Applications



Permanent Air Monitoring Station

Analysis and Measurement of pH and Hydrazine Content in Rainwater Containment Troughs at KSC

As part of vehicle processing performed on Space Shuttle orbiters at KSC, hypergols are frequently required to be vented from the facility in which work is being conducted. These vapors are vented through large scrubbers, which remove the hypergols and vent the remaining sample to the atmosphere. It is known that these scrubbers do not remove 100 percent of the hydrazine (HZ), and some is released from the vent stack. During rainstorms, hydrazine vapors emitted by the vent stack may be washed into catch basins surrounding the scrubber pad. The rainwater from these scrubber pad areas must be collected and stored and not discarded until it can be analyzed and found to contain acceptable levels of hypergols. This analysis can take several days to perform and report the results back to operations. In the meantime, the water must be removed from the trough and stored in a tanker trailer until its pH and HZ content is known. If the reported value is over 200 parts per billion (ppb) or the pH is less than 4 or greater than 9, the water must be handled as hazardous waste. NASA's Toxic Vapor Detection Laboratory (TVDL) was asked to identify commercially available instrumentation able to adequately quantify samples with 200 ppb of HZ or monomethylhydrazine (MMH) and effectively determine the pH of the rainwater while it is still in the trough. This allows operations to dispose of water under the 200-ppb limit without storing it or performing other costly and time-consuming analyses.

Several commercially available instruments were evaluated by the TVDL. Instruments were used to measure laboratory samples of water and HZ or MMH from 50 to 400 ppb in 50-ppb increments. The data obtained from testing was used to determine the linearity and repeatability of each of the instruments. In order to ensure the instrument selected was as practical to use as it was accurate, all the instruments were compared.

Two instruments were selected to be incorporated into a portable field test kit. The Hach Model DR/700 colorimeter, a lightweight, portable photometer, was selected for the detection of HZ in water. Hach was the only instrument tested that allows user-programmed calibration to be used. The HZ content of the majority of rainwater samples analyzed at KSC is currently reported as MMH. In order to satisfy the requirement that a field analyzer be able to report the HZ concentration of a rainwater sample as MMH, a separate user-generated calibration was developed using 0-ppb and 200-ppb MMH standards as inputs for the Hach DR/700 calibration program. If the user desires, the measurement can still be displayed as HZ using the factory calibration program. The Corning M90 was selected for pH determination. This pH meter is a small handheld, microprocessor-based monitor. The meter has automatic temperature compensation and the ability to perform and store information on either a 1- or 2-point calibration. The last five measurements can be stored in memory and recalled at any time for comparison purposes. The output to the LCD display is automatically shut off after 7 minutes of inactivity.

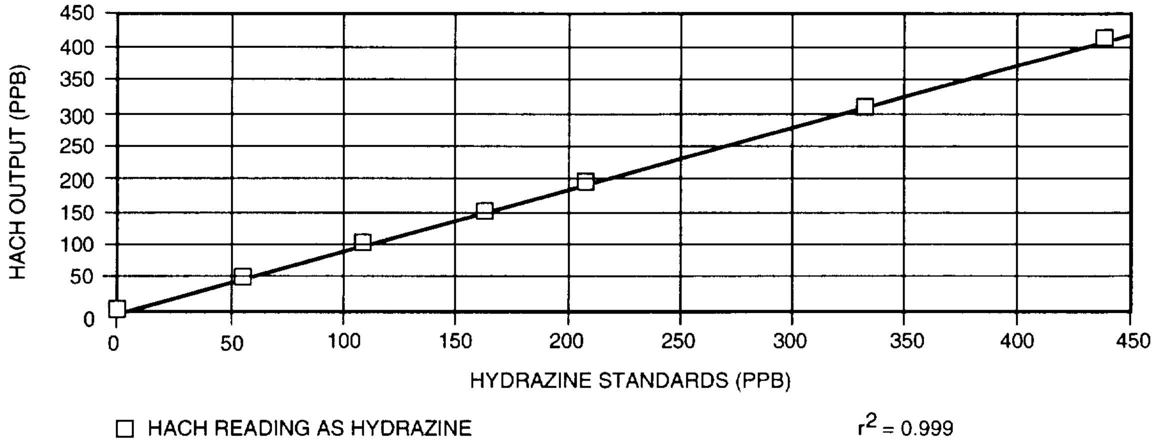
Key accomplishments:

- Evaluated several instruments for use in the rainwater analysis field test kits.
- Developed calibration methods for HZ, MMH, and pH.
- Fabricated five field test kits.
- Delivered a field test kit and procedure to operations for evaluation.

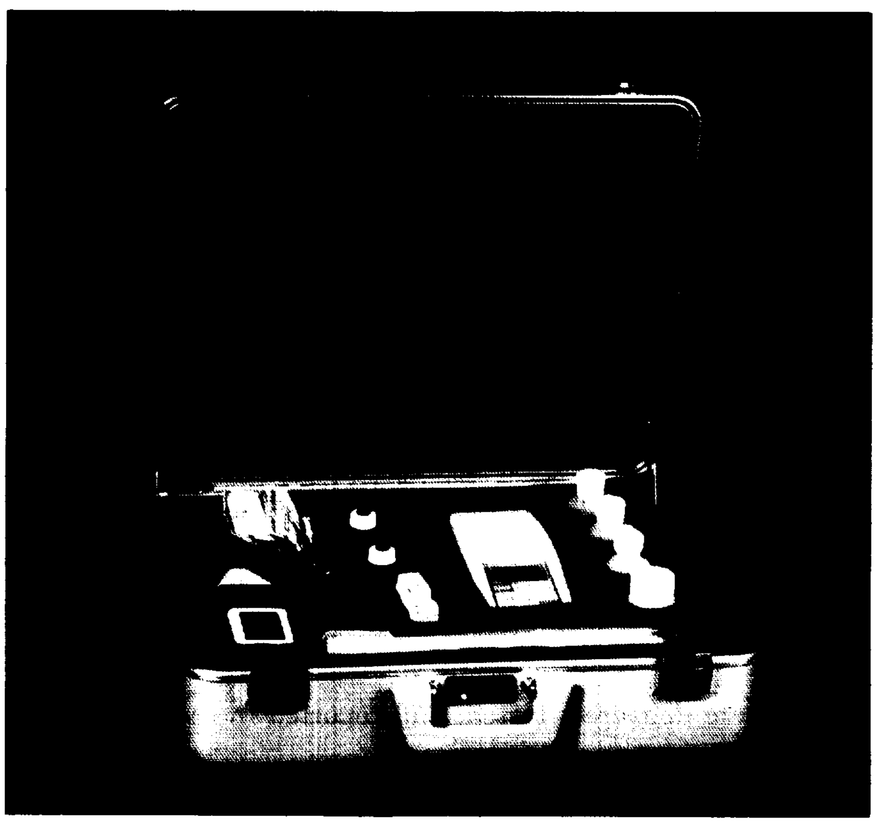
Contact: D.E. Lueck, DL-ESS-24, (407) 867-4439

Participating Organization: I-NET, Inc., (M. D. Springer and B. J. Meneghelli)

NASA Headquarters Sponsor: Office of Space Flight



Hach Model DR / 700 Linearity Data



Rainwater Analysis Field Kit

Development of a Portable Vapor Detector for N_2H_4, MMH, and UDMH

Recently the American Conference of Governmental Industrial Hygienists (ACGIH) proposed to reduce threshold limit values (TLV's) for hydrazine (N_2H_4), monomethylhydrazine (MMH), and unsymmetrical dimethyl hydrazine (UDMH) to 10 parts per billion (ppb). To meet the new proposed monitoring requirement, NASA at KSC contracted with three instrument manufacturers to supply prototype instruments capable of detecting fuel vapor concentrations of 10 ppb. Of the three different technologies that were evaluated as part of Phase I, Interscan Corporation's electrochemical cell instrument was capable of meeting most of the contract criteria (reported in KSC's Research and Technology 1992 Annual Report). In Phase II of the contract (NAS10-11791), four production prototype instruments were furnished by Interscan Corporation for evaluation and qualification at the KSC Toxic Vapor Detection Laboratory (TVDL). To test these prototype units, the TVDL used a vapor generation system that is capable of reliably providing concentrations of 10 to 1000 ppb of N_2H_4, MMH, and UDMH vapors at a wide range of temperatures and relative humidities.

The production prototype Interscan-4000 unit is an electrochemical hydrazine gas detector. The production prototype incorporated design changes that were a result of the Phase I evaluation. These modifications included a heavier gauge housing with a digital rather than analog display. The sensor electrolyte was replaced with cesium hydroxide, which had an extended sensor lifetime in the TVDL tests. A replaceable lithium battery powers the electronics section. An internal switch provides the ability to change to an onboard backup lithium cell in the field, if required. An intrinsically safe sample pump capable of a 2.5-liter-per-minute continuous pump rate for 12 hours on a single charge replaced the old pump system. A visible rotometer verifies the proper pump rate. The span adjustment potentiometer was relocated to a position inside the unit to avoid inadvertent calibration changes.

The results of the evaluation of the Interscan Phase II production prototype are shown in the table "Performance Summary of Four Production Prototype Instruments." Interscan electrochemical cells are capable of reliably detecting a 10-ppb MMH, N_2H_4, or UDMH sample. The precision of the instruments met the criteria for all hydrazines. When sampling zero air, the instruments showed a drift that was within specification. The 4-hour span drift (observed at 10 ppb) for all hydrazines was outside the ±2-ppb specification. There was some variation between units while testing accuracy, linearity, response times, and recovery times. When testing the linearity of the instrument, MMH produced a linear response over a range of 0 to 1000 ppb. N_2H_4 vapor produced a linear response over a range of approximately 0 to 200 ppb before the response moved slightly outside the 15-percent criteria. For UDMH, the linear range was about 0 to 700 ppb. On the average, the response times to 10-ppb MMH, N_2H_4, and UDMH were 5.5, 5.2, and 3.2 minutes, respectively. Recovery times also varied from unit to unit with the 10-ppb recovery time for MMH, N_2H_4, and UDMH being 2.5, 3.8, and 4.8 minutes, respectively.

Key accomplishments:

- Proof-of-concept units were delivered, tested, and reported in the Research and Technology 1992 Annual Report.
- Sensor life was extended as a result of electrolyte replacement with cesium hydroxide.
- Testing was completed on four production prototype instruments for MMH, N_2H_4, and UDMH.

Key milestones:

- Future testing will be done to determine the effects of relative humidities from 25 to 85 percent.
- A final report will be written summarizing the evaluation of the various technologies and the results of the extensive testing done in Phases I and II of the Interscan units.

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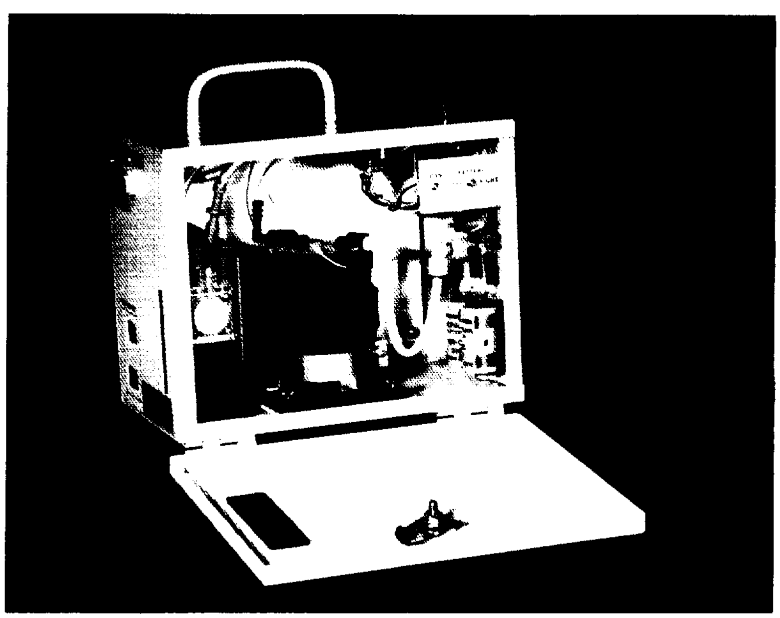
Participating Organization: I-NET, Inc. (D.J. Curran)

NASA Headquarters Sponsor: Office of Space Flight

Performance Summary of Four Production Prototype Instruments

Test	Criteria	Instrument 1	Instrument 2	Instrument 3	Instrument 4
Precision	10% maximum deviation	Notes 1, 2, and 3	Notes 1, 2, and 3	Notes 1, 2, and 3	Notes 1, 2, and 3
Linearity/Accuracy	15% of actual	Note 1; not tested on N_2H_4 or UDMH	Note 1	Note 1	Note 1
Zero Drift	2 ppb for 4 hours	Note 1; not tested on N_2H_4 or UDMH	Notes 1, 2, and 3	Notes 1, 2, and 3	Notes 1, 2, and 3
Span Drift	2 ppb for 4 hours at 10 ppb	Note 1; not tested on N_2H_4 or UDMH	Note 3	Note 3	Note 3
Response	90% of 10 ppb in 4 minutes	Not tested on N_2H_4 or UDMH	Note 3	Note 3	Note 3
Recovery	10% of 10 ppb in 4 minutes	Note 1; not tested on N_2H_4 or UDMH	Notes 1 and 2	Notes 1 and 2	Notes 1 and 2

Notes:
1. Within specification for N_2H_4
2. Within specification for MMH
3. Within specification for UDMH



Interscan Hydrazine Detector

Turbine-Powered Brush Pipe Recycling Non-CFC Cleaner System

The Earth's ozone layer, protecting the Earth from ultraviolet radiation, is under attack from manmade chemicals — chlorofluorocarbons (CFC's). In an effort to limit damage, the Montreal Protocol (1987 and 1990) established a worldwide phaseout of CFC production of the most hazardous compounds by 1996. Additionally, DuPont has announced that its production of R-11, R-12, and R-113 will cease by 1995. KSC, in response to the phaseout of R-113, is taking action to develop replacements. R-113 is used extensively at KSC to clean piping and components to high levels as required by KSC specifications.

The turbine brush cleaner (patent applied for — reference KSC 11669) provides an improved method of cleaning the inside of piping and tubing. The mechanical action of the brush aids the cleaning action of the cleaners, which is more environmentally acceptable than CFC's (Freon). It offers advantages over existing rotating brush systems that require flexible drive shafts and a facility air source for power. The elimination of the drive shaft allows a much more compact design, which can traverse smaller diameters and up to 90-degree bends over longer distances. Another advantage is reduced contamination of the cleaned sections without a trailing drive shaft. The cleaning system consists of an electrical motor and pump that provide liquid flow to spin the turbine and deliver the cleaning solution. The outflow of the pipe section being cleaned is recycled back to the pump inlet after filtration. Venturi injection of a concentrate is provided upstream of the turbine if required. The system is transportable by pickup truck: the only facility requirement is 220 volts alternating current for the pump motor. The prototype system is designed for cleaning pipes up to 2 inches in diameter and tubing up to 100 feet long.

Key accomplishments:

- April to June 1993: Design and fabrication of a 2-inch turbine/brush.
- June 1993: Demonstration of the turbine/brush cleaner in a clear pipe and 90-degree bend.
- July 1993: Technology reported and patent applied for (DE-PAT).
- September 1993: Design recirculation/filter pumping system (powers turbine).

Key milestones:

- November 1993: Design/fabrication of a 1-inch turbine and pump demonstration system.
- January 1994: Fabrication of a recirculation/filter pumping system.
- February to March 1994: Qualification of a turbine brush and pumping system.

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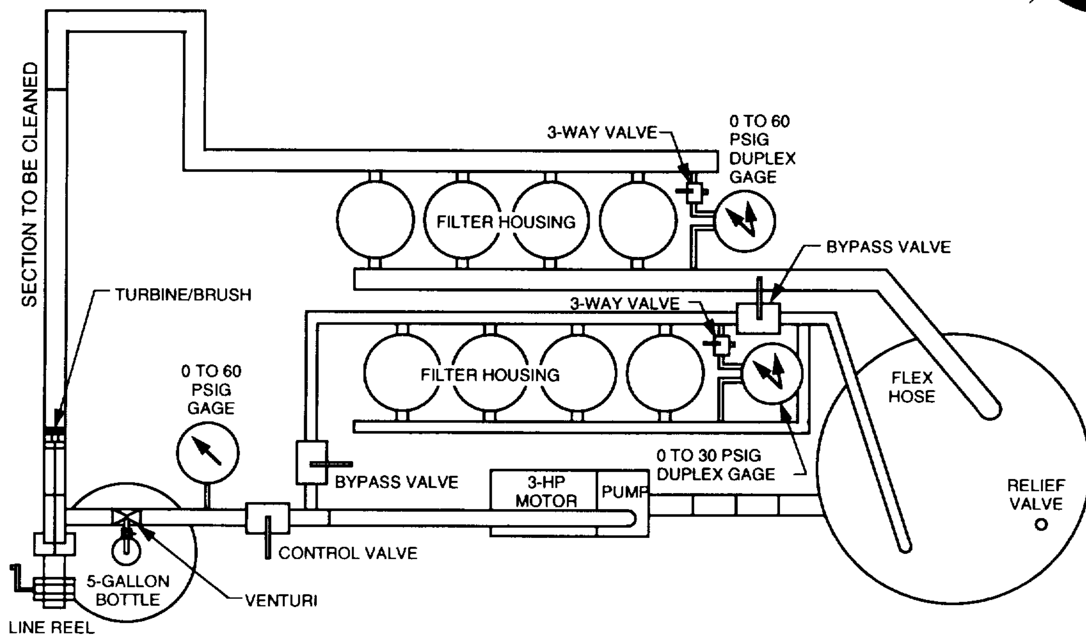
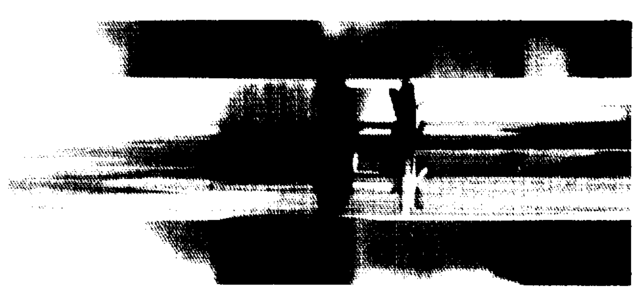
NASA Headquarters Sponsor: Office of Space Flight



Recirculation System

Turbine Brush Cleaner Assembly

2-Inch Turbine Preliminary Test



Turbine Brush Cleaner Operation

Development of the MDA/Polymetron Hydrazine Analyzer as an Area Monitor

The current threshold limit value (TLV) for hydrazine is 100 parts per billion (ppb) as established by the American Conference of Governmental Industrial Hygienists (ACGIH). A proposal has been made to lower the limit to 10 ppb. An area monitor analyzer system incorporating the MDA/Polymetron hydrazine analyzer has been developed, which will meet the proposed TLV and ensure worker safety in areas where hydrazine is handled.

The MDA/Polymetron hydrazine analyzer is a three-electrode liquid analyzer, typically used in boiler feed water applications. In order to quantify the concentration of hydrazine in a vapor sample, a method has been developed that simultaneously pulls hydrazine vapors and a very dilute (0.0001 molar) sulfuric acid solution down a 40-foot length of 1/4-inch outside diameter tubing from a remote site to the MDA analyzer. The hydrazine-laden dilute acid stream is separated from the majority of the air and adjusted to a pH level between 10.2 and 11.0 with sodium hydroxide (NaOH) prior to analysis. Samples with vapor concentrations ranging from the 10-ppb level to low parts-per-million (ppm) values can be analyzed by diluting the sulfuric acid/hydrazine mix with pure water. A two-position multiport rotary valve was incorporated into the liquid system as a way of selecting one of two dilution waterflow rates (TLV/LEAK). The resulting two ranges can differ by a ratio of 10:1 or more by simply varying the waterflow rates. The pumping of all liquid streams is accomplished using a multiple-cartridge peristaltic pump head. A liquid dilution system was developed for the analyzer that dynamically generates acid/base solutions on an as-needed basis by mixing a metered amount of concentrated acid/base solution with clean water. Liquid-level sensors trigger the generation of acid/base solutions. All waste water generated by the analyzer is purified for reuse by ion exchange and carbon bed filters to minimize the generation of waste materials. The area monitor analyzer system was developed for unattended, 24-hour-per-day operation and a 3-month service interval.

The system has response times on the order of 10 to 12 minutes at low flow (TLV mode) and approximately 2 minutes at high flow (LEAK mode). The analyzer output is linear over the range of 10 ppb to approximately 10 ppm. The analyzer did not show a response greater than 2 ppb when exposed to a series of potential interferant vapors at twice the allowable TLV value.

Key accomplishments:

- Development of a vapor/liquid sample delivery system.
- Development of a sample dilution system to quantify both ppb and ppm hydrazine vapor samples.
- Buildup of the laboratory prototype hydrazine analyzer system.

Key milestones:

- Buildup of the field prototype hydrazine analyzer system.
- Qualification of the field prototype hydrazine analyzer system.
- Ninety-day testing of the field prototype hydrazine analyzer system.

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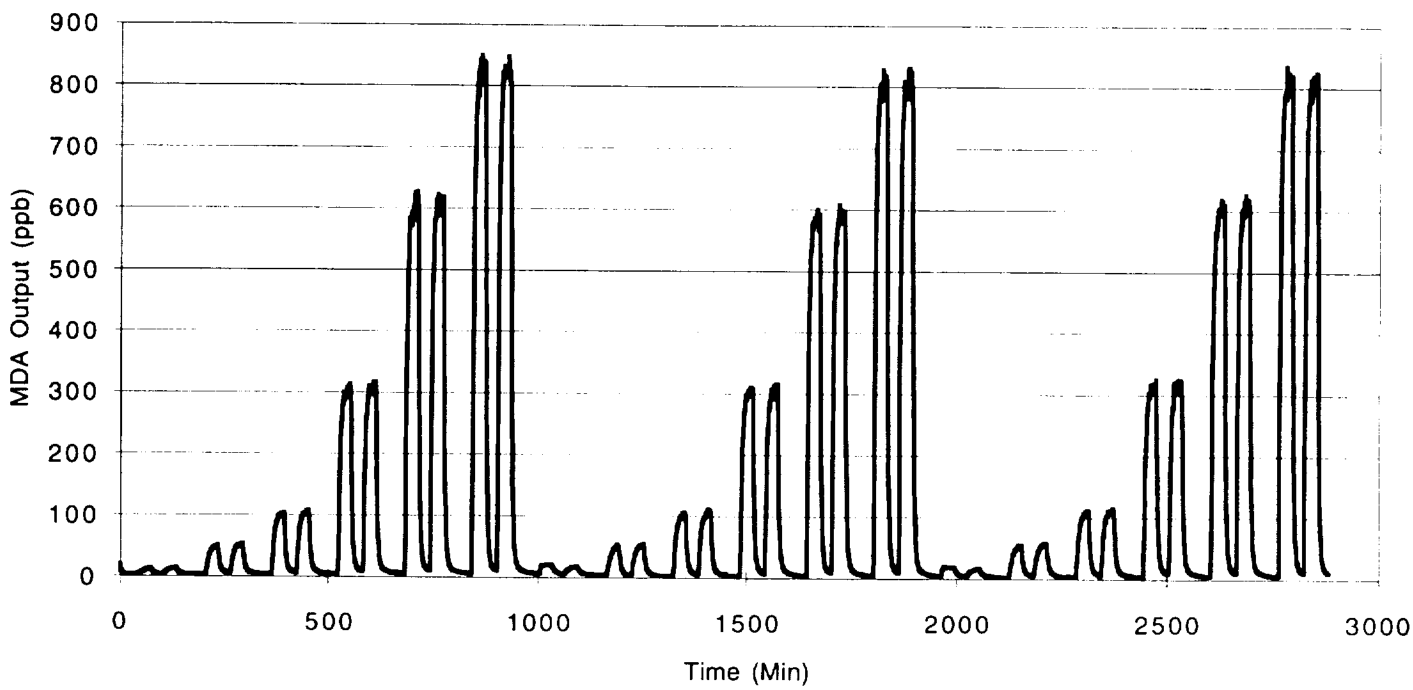
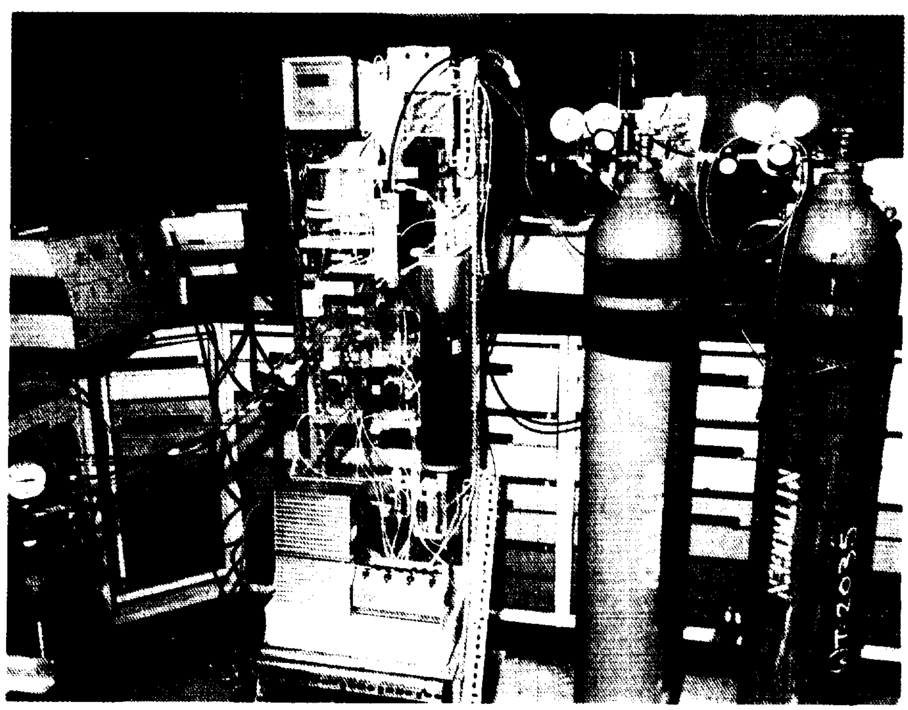
Participating Organization: I-NET, Inc. (B.J. Meneghelli)

NASA Headquarters Sponsor: Office of Space Flight



MDA Hydrazine Analyzer Data (Input: 13, 50, 100, 277, 603, and 848 ppb)



Prototype Hydrazine Analyzer System

Chlorofluorocarbon (CFC) Replacement Cleaning System Using Supersonic Nozzles

The purpose of the CFC Replacement Cleaning System is to provide cleaning and cleanliness verification of mechanical and fluid components. It is intended to replace solvent cleaning and verification methods using CFC-113 (commonly called Freon). CFC-113 is being phased out due to ozone depletion problems associated with the CFC family of solvents and refrigerants. Traditional cleaning and verification methods use large quantities of CFC-113, which then becomes an environmental problem. The components to be cleaned and verified include valves, pipes, and compressed gas cylinders (K-bottles).

The system operates by flowing high-pressure air or nitrogen through a throttling valve to the nozzle. Water is injected into the gas flow stream through an orifice upstream of the converging/diverging section of the nozzle. The mixed gas-liquid flow then enters the converging/diverging nozzle where it is accelerated to supersonic speeds. The supersonic gas-liquid stream is directed onto components that require cleaning or cleanliness verification. The velocity imparted to the water by the gas flow gives it sufficient momentum at impact to remove contaminants on the surface of the component being cleaned or verified while simultaneously dissolving the contaminant into the water, which can be captured for cleanliness verification. The flow parameters for the gas-liquid nozzle can be set so virtually any gas and liquid can be used for a desired flow and mixing ratio. In addition, the size and number of nozzles are adjustable. This adjustability makes it possible to create sizes ranging from small handheld cleaning nozzles to very large multiple-nozzle configurations.

The supersonic cleaning system has been assembled and tested, and data has been collected for the cleaning rate and the system's ability to verify the cleanliness of components. The data collected suggest that the system cleans the components more completely then the previous method using CFC-113. The K-bottle nozzle has been built and has undergone preliminary testing. A mechanism to clean the K-bottles automatically is currently being designed. A nozzle configuration to clean and verify large pipes (over 6 inches) has been designed and is being fabricated.

Key accomplishments:

- Handheld system for large components was built and tested.
- K-bottle cleaning nozzle was fabricated.
- Large pipe nozzle was designed.
- Patent applications for the nozzle and K-bottle cleaner were submitted.

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Participating Organization: I-NET, Inc. (C.H. Fogarty and C.K. Cantrell)

NASA Headquarters Sponsor: Office of Space Flight

Robotics

The Advanced Technology Robotics effort at the John F. Kennedy Space Center (KSC) is focused on solving existing launch vehicle and payload ground processing operational problems. In addition, the program also provides a forum for NASA research centers to demonstrate advanced technology for complex robotic problems that must be addressed for future space missions. Automating ground operations in areas such as payload inspection, Shuttle tile rewaterproofing, removing and replacing flight items, and facility maintenance enables KSC to develop procedures, processes, and methods that can be translated into solving on-orbit requirements as well as solving ground processing problems. KSC will work with NASA research centers to develop the technology for increased automation of ground processing by investigating advanced collision-avoidance systems, multidegree-of-freedom robotic systems, intelligent control systems, sensors for inspection, and integration of robotics with real-time processing data information systems.

Robotic Tile Processing System (RTPS) Development

The objective of this project is to design and develop a prototype system to robotically process lower surface orbiter tiles. The project is approximately 85 percent complete. The robotic system will perform preflight and postflight inspections and rewaterproofing of 85 percent of the lower surface tiles. This is a 3-1/2-year development effort that will conclude with a demonstration of the prototype mobile robotic system in the first quarter of 1994. Certification of this system for use on orbiters will be initiated in the second quarter of 1994.

Maintenance and repair of the orbiter Thermal Protection System (TPS) tiles involve many labor-intensive tasks. As a result of a detailed orbiter TPS automation study, orbiter lower surface tile rewaterproofing and visual inspection were selected for initial robotic automation. Both of these tasks are performed on more than 20,000 tiles for each orbiter refurbishment flow. Automation of these processes is expected to save 2 to 3 weeks of TPS flow time and more than 630 direct labor man-hours per flow. Paperwork reductions will reduce indirect labor costs (i.e., documentation processing) for each of the tasks automated because the robot information system will be integrated with existing data management and information processing systems. The benefits of the paperwork reductions have been estimated to be as high as $200,000 per orbiter flow. This estimate is based on the average number of problem and discrepancy reports generated per orbiter flow. Quality and reliability will be improved by providing accurate first-pass inspections and rewaterproofing injections. Increased personnel safety will result because human exposure to the rewaterproofing chemical will be virtually eliminated for the bottomside tile rewaterproofing process. Long term, the RTPS is being designed to support automation of other labor-intensive TPS processes that will result in more than 2,500 direct man-hour savings per orbiter flow.

The robotic system will integrate state-of-the-art systems in navigation, control, mobility, manipulation, information management, and sensor technologies to inspect and rewaterproof the bottomside orbiter tiles in the Orbiter Processing Facility (OPF) at KSC.

Key design features of the robot include: (1) a fully self-contained operation (i.e., no tether), (2) redundant sensors used in critical applications to ensure safe operation, (3) a 7-degree-of-freedom robot manipulator with a 3-degree-of-freedom mobile base, (4) an intuitive graphical user interface for ease of operation, and (5) interfaces to existing NASA databases.

The accomplishments for fiscal year 1993 include final design of all subsystems. Fabrication is 90 percent complete for all subsystems and integration has been initiated. Technology demonstrations of the vision system and rewaterproofing system were given. These demonstrations were conducted with the hardware that will be integrated into the prototype system. Additionally, baseline versions of manipulator motion control and robot system high-level controller software have been established and integration and tests of this software have been initiated. The approach to certify the system was drafted and reviewed by appropriate KSC and Johnson Space Center personnel.

The effort for fiscal year 1994 will focus on completing the integration of all subsystems into a functional robotic system. A system demonstration will occur in the second quarter of fiscal year 1994. It is expected that the certification process will begin after the system demonstration and will require approximately 18 months to complete.

Key accomplishments and milestones:

- 1991: Project initiated and subsystem designs 30 to 40 percent completed.
- 1992: Technology demonstration of mobile base, vision, and rewaterproofing subsystems.
- 1993: Subsystem design completed and system integration initiated.
- 1994: Complete system integration. System demonstration of the fully functioning prototype. Certification and implementation of the system into orbiter processing.

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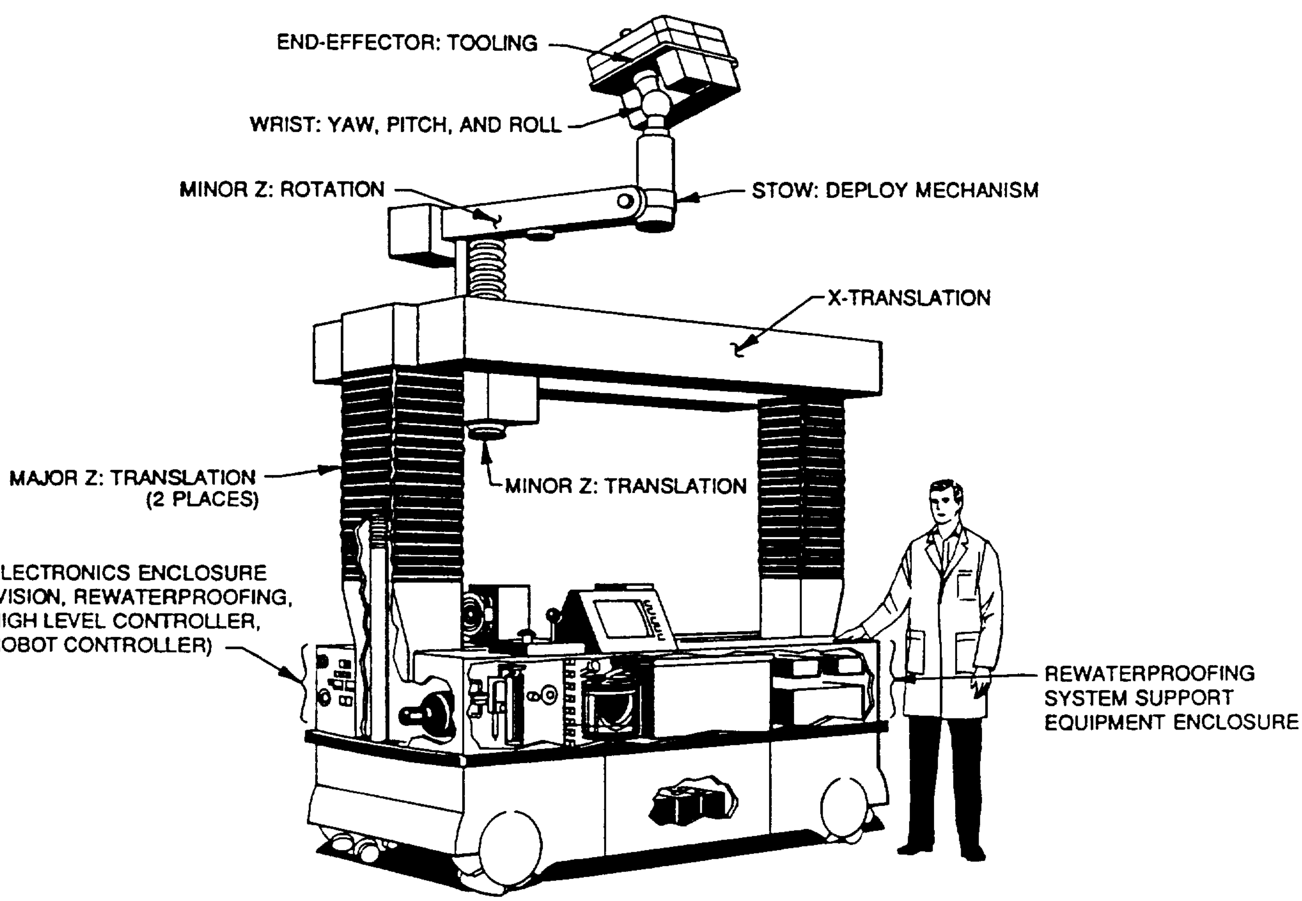
Participating Organizations: I-NET, Inc. (R.R. Bennett); Carnegie Mellon University (K. Dowling); NASA Langley Research Center (E. Cooper); SRI International (C. Cowan); and Rockwell International Corporation (D. Manouchehri)

NASA Headquarters Sponsor: Office of Advanced Concepts and Technology



KSC Tile Robot Configuration

PCR Inspection and Processing Robot

Several efforts are being made to investigate the use of a robot system in the launch pad Payload Changeout Room (PCR) for Space Shuttle payload bay and payload processing operations. A study was performed to identify and evaluate processing tasks that would benefit from the use of a robot system. The study was conducted to determine the applications of a robot system that would reduce costs, enhance reliability and safety, increase payload access, provide capability for contingency operations, and reduce processing turnaround time. Operations at the PCR were the prime focus of the effort; however, other facilities such as the Orbiter Processing Facility (OPF) were also considered.

The study focused on two major areas. One area was an evaluation of payload and orbiter processing tasks to determine the requirements and potential benefits of a robotic system. The second area was the conceptual design and feasibility analysis of a robotic system. The payload tasks were evaluated with assistance from payload customers and KSC processing personnel. A set of near-term payload missions that reflect typical orbiter and payload tasks was selected as the basis for a realistic, detailed evaluation. The robotic system conceptual design and feasibility analysis were performed based on the results of the payload task evaluation and the development of a prototype serpentine robot manipulator recently completed under an SBIR contract. A complete computer-aided design model and graphic simulation of the PCR handling equipment, orbiter payload bay, representative payloads, and the SBIR-developed serpentine manipulator arm were used to verify and model the initial concept.

The prototype serpentine manipulator arm developed under the NASA SBIR program was delivered to the KSC Robotics Application Development Laboratory and will be used to demonstrate the performance of typical PCR robot tasks. Activities to test, control, and demonstrate the serpentine arm, as well as demonstrate the proximity sensing capability, will continue through the middle of fiscal year 1994.

A proximity sensor system currently being developed under the NASA SBIR program will be delivered to KSC in 1994. This sensor will provide another necessary capability to the PCR inspection and processing robot — obstacle detection and avoidance.

Key accomplishments:

- Identified processing tasks suitable for robotic processing.
- Performed a survey of payload customers.
- Completed the initial design and computer graphic model of the conceptual robot system.
- Received the prototype serpentine arm from the NASA SBIR program.

Key milestones:

- Perform an extended study and design the robot system.
- Receive the proximity sensor skin from the SBIR contract.
- Demonstrate the serpentine manipulator arm.

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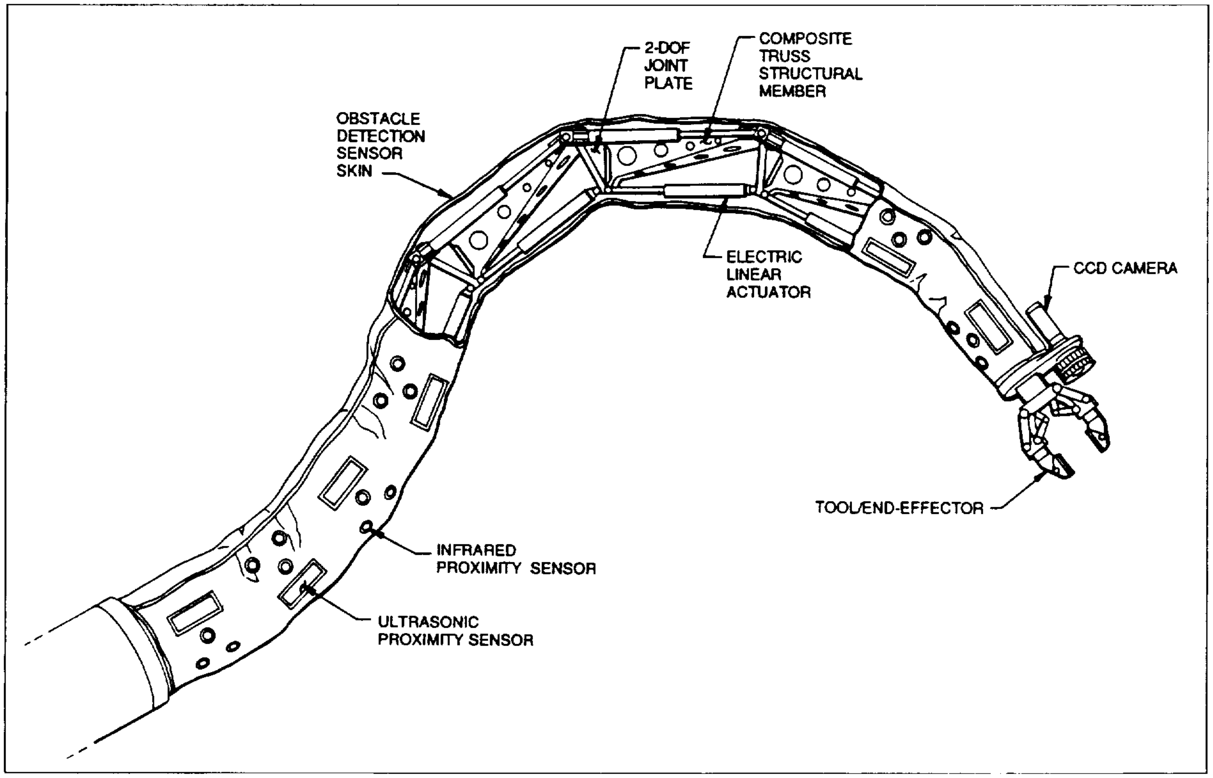
Participating Organizations: McDonnell Douglas Space Systems (M.E. Sklar and B. Richards) and I-NET, Inc. (J.E. Spencer)

NASA Headquarters Sponsor: Office of Space Flight and Office of Advanced Concepts and Technology



Payload Inspection and Processing Robot

Automated Inspection of Orbiter Radiators

In 1989, the Engineering Development Directorate at KSC began a search for ways to improve the orbiter radiator inspection process. An accurate positioning tool, an inspection tool, and a database were needed to keep track of inspection results. A concept using a robot arm, a vision system, and a computer database emerged.

A postflight inspection of the orbiter radiators takes place immediately after the cargo bay doors are opened following a Shuttle orbiter landing. Additionally, a preflight inspection occurs just before the doors are closed after concluding flow operations in the Orbiter Processing Facility (OPF). The current method uses four bridge buckets, four bucket drivers, eight quality inspectors, and two safety monitoring personnel. Nominally, the process may take 8 hours. More commonly, two buckets attached to one bridge crane are utilized to free the other bridge for technicians requiring overhead access to the payload bay for other tasks. In this case, inspection time may take from 16 to 24 hours. Current methods do not guarantee consistency in the quality of the inspection process. Improper inspections may result in launch delays if defects that require repairs are overlooked during the postflight inspection and found during the preflight inspection.

The task was divided into two systems: the Automated Radiator Inspection Device (ARID) arm and the Vision Inspection System (VIS). The ARID arm has evolved into a 4-degree-of-freedom robot that will be used to position the VIS over the Orbiter radiators for inspection and defect detection. The ARID provides highly accurate positioning of the vision system and provides the timing signal to the vision system to take its pictures. NASA and its Engineering Support Contractor (I-NET) are responsible for the design, fabrication, assembly, integration, testing, and certification of this robot arm. The vision system has been under development by Lockheed's Optical Laboratory in Palo Alto, California.

The ARID robot has a unique fail-safe design incorporating redundant drive and control features. Each joint in the ARID arm consists of a dual-drive unit with two brushless servomotors, two harmonic drives for power transmission, and two brakes. Two personal computers are used to control arm motion and position. In the event there is a malfunction or failure that would cause loss of control of the robot arm, the system is designed to shut down safely and notify the operator. A user-friendly, graphical interface is provided for technicians to operate the ARID. Software limits, emergency stop switches, hard stops, and a wire rope are in place to keep the mechanism from hitting flight hardware, which results in a high degree of safety and reliability.

The VIS will identify, measure, and catalog radiator damages. Microdamage identification will include punctures, scratches, and gouges. Macrodamage identification will include dents and tape delaminations. The VIS hardware consists of a high-resolution charge-coupled device array camera, a strobe fringe line projector, a diffusely reflecting illuminator, a SUN Sparcstation, a real-time image processing board, and a real-time processor for communication.

The ARID/VIS is expected to occupy two operators (one per door), two safety monitoring personnel, and one quality inspector to check the system during startup. It does not require the use of the OPF bridge buckets, which then become fully available to crews working in the payload bay. The inspection data is transferred electronically to the automated data entry system and the automated scheduling system to generate problem reports. Engineers expect the inspection sequence to take less than 5 hours.

Key accomplishments and milestones:

- 1989: ARID/VIS system concept and design.
- 1990: ARID/VIS revisions and procurement activities.
- 1991: ARID/VIS fabrication, installation, troubleshooting, and testing.
- 1992: ARID/VIS integration testing.
- 1993: Design and procurement of the ARID cable management system. Completion of the ARID robotic positioning system.
- 1994: Completion of the vision system and final integration and test with the ARID robotic arm.

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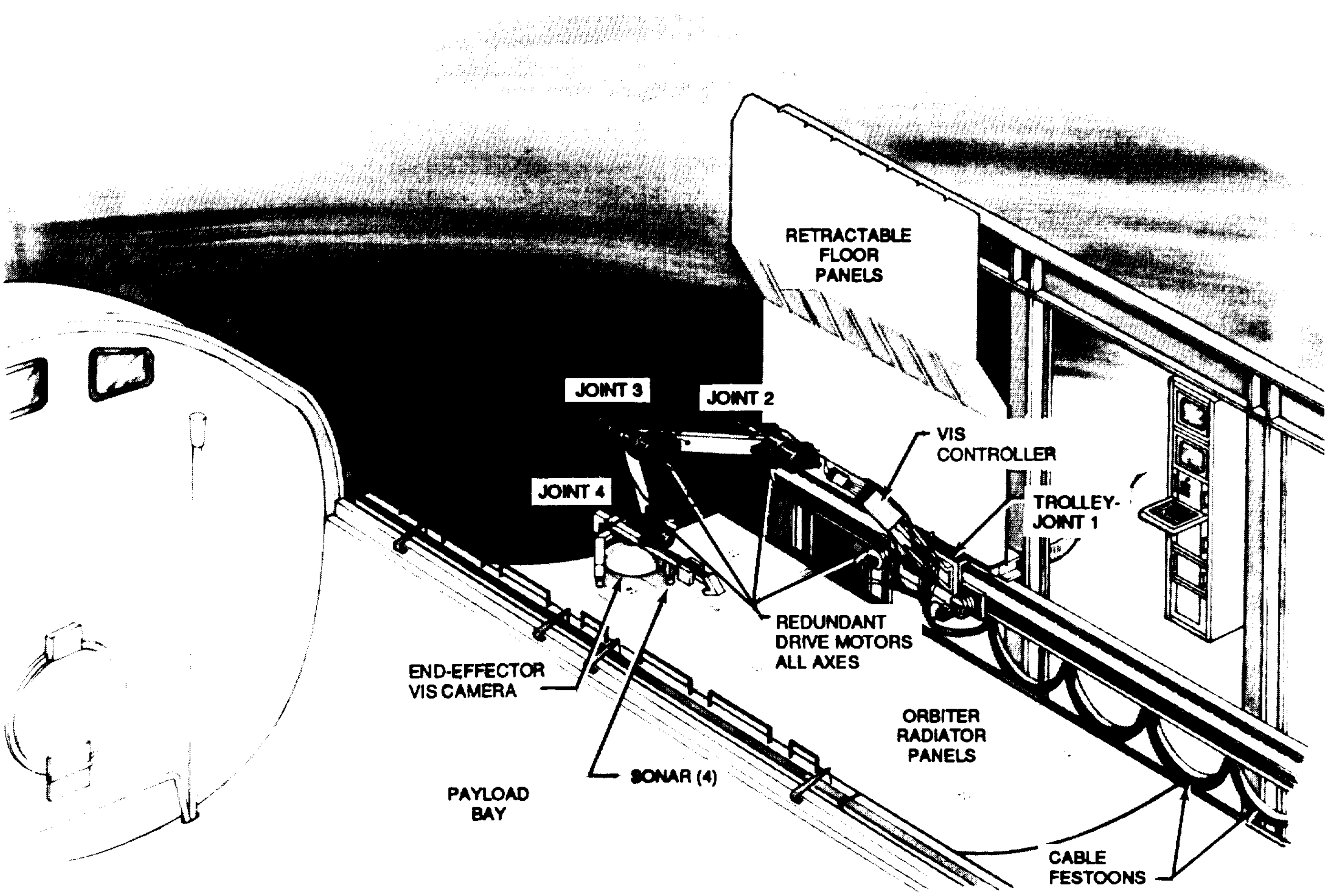
Participating Organization: I-NET, Inc. (R.L. Remus, J.R. Lago, K. Wolcott, and K.W. Heckle, Jr.)

NASA Headquarters Sponsor: Office of Advanced Concepts and Technology



Automated Radiator Inspection Device (ARID)

Launch Complex 39 Payload Changeout Room HEPA Filter Inspection Robot (HFIR)

An application for a robotic system has been developed at KSC as an effective means to aid NASA engineers to further improve ground-based, launch-related processing of the Space Shuttle and its associated facilities. This unique, custom-designed robotic system has been developed by engineers in the Robotics Applications Development Laboratory to automate a dangerous and critical time-consuming task of High-Efficiency Particulate Accumulator (HEPA) filter inspection in the launch pad Payload Changeout Room (PCR).

Previously, filter inspection was performed manually and took about 120 man-hours to complete. This inspection task required technicians to utilize ladders and special access platforms deployed on top of a six-story, movable structure inside the PCR. This massive structure, known as the Payload Ground-Handling Mechanism (PGHM), is used to move satellites and other payloads in and out of the Shuttle orbiter's cargo bay.

The HFIR is a 4-degree-of-freedom (DOF) robot that utilizes the existing 5-ton bridge crane rails in the PCR ceiling to implement its fourth degree of freedom (gross positioning). The HFIR mechanism has an integrated end-effector consisting of the following: a particulate counter, an air velocity sensor, a laser distance sensor, and a CCD video camera. The HFIR is controlled through a user-friendly graphical interface via a supervisory computer system consisting of an input/output processor, motion controller, and host computer. System users can manually or automatically perform HEPA filter inspection with the device, with real-time filter test status provided to the operator by the graphical user interface and test data recorded on a tape drive for later analysis and reporting.

In October 1993, the HFIR project team successfully started integration of the HFIR system in the PCR at Launch Complex 39, Pad B. The purpose of this exercise was to perform a system fit-check for all components to verify facility constraints and the current operational scenario. In addition to gathering critical information about the system configuration in its real operational environment, the HFIR team successfully demonstrated inspection pattern profiling and gathered filter inspection data with the integrated sensor suite. After configuration programming and verification testing at both Launch Pads A and B, the HFIR will be transferred over to Shuttle Operations for filter inspection.

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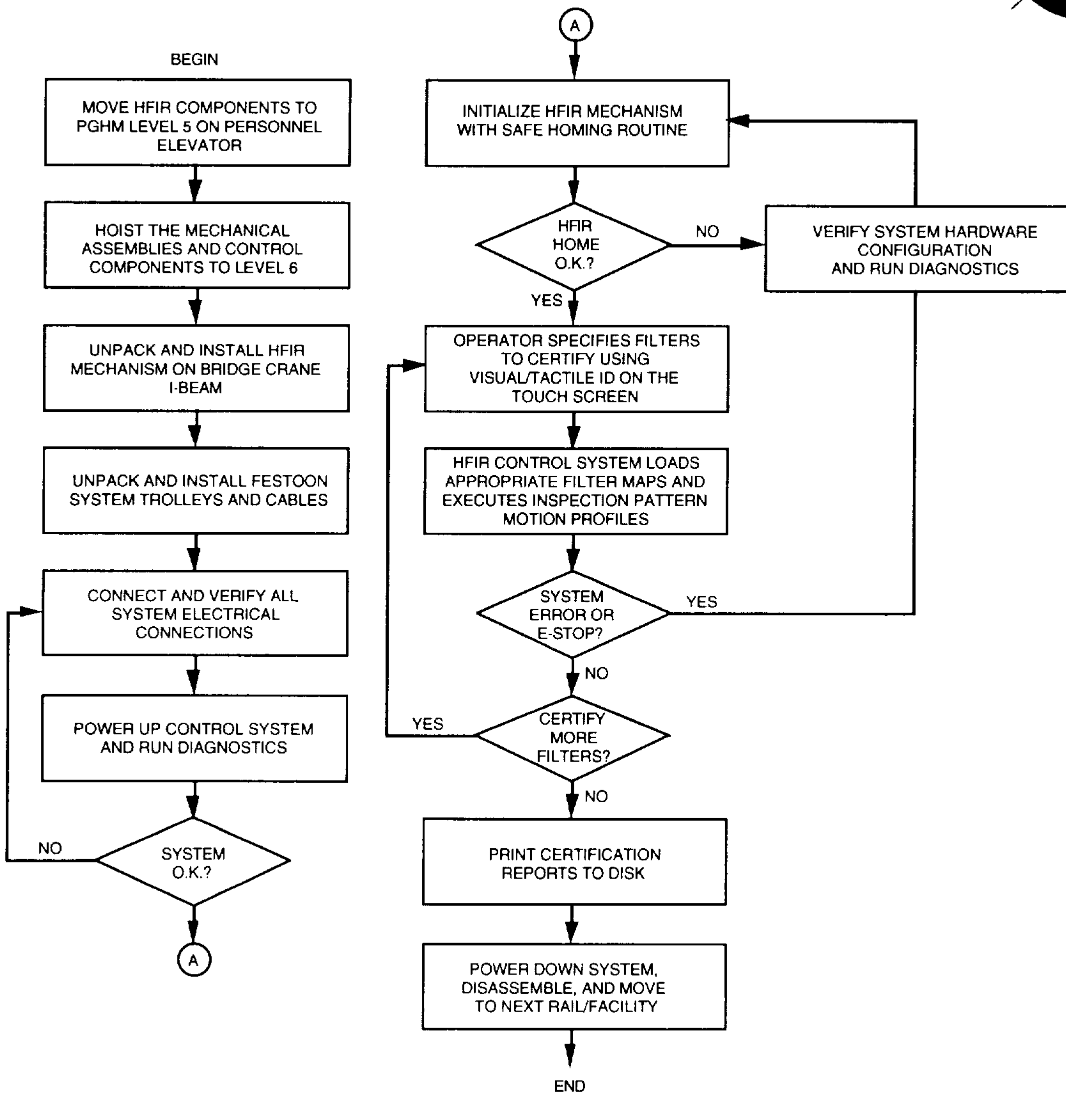
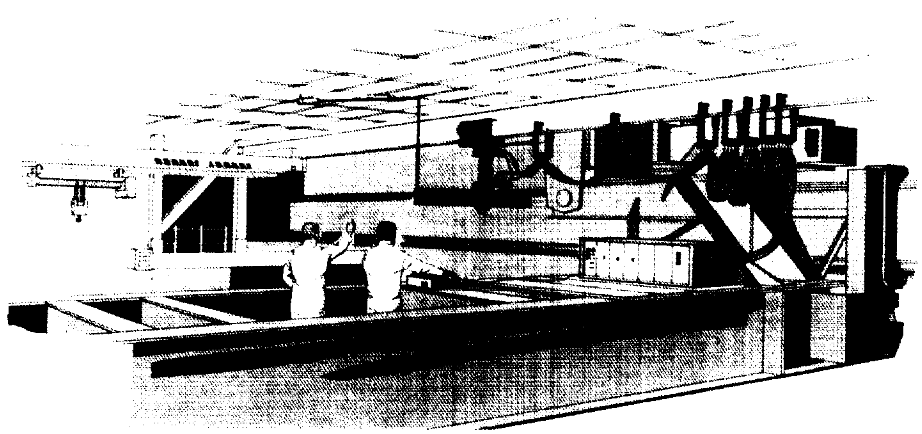
Participating Organization: I-NET, Inc., (J.E. Spencer and C.J. Looney)

NASA Headquarters Sponsor: Office of Advanced Concepts and Technology



Portable and Deployable HFIR Operational Flow Diagram



HEPA Filter Inspection Robot System

Innovative Mechanism for Measuring the Mass Properties of an Object

In order to properly control the Space Shuttle in orbit and in landing situations, the mass properties of its payloads must be measured with accuracy. The mass and center of mass location of a Spacelab and other similar sized payloads (i.e., Spacelab rack) is currently obtained through the use of a table that is equipped with load cells. Although this method is accurate, it is a time-consuming process that requires multiple overhead crane operations. The Engineering Development Directorate's Robotics Applications Development Laboratory recently completed development, analytical studies, and testing on a novel approach to measure the mass properties of an object. This approach would reduce the time required per measurement and potentially eliminate all crane operations. The unique design has the capability of measuring the payload's weight, mass center location, and moments of inertia about three orthogonal axes. Furthermore, these measurements can be made with a single torque sensor and a single angular position sensor.

Basic feasibility of the mechanism was verified through testing of a prototype mechanism. This testing addressed accuracy, repeatability, and scalability aspects of the mechanism. Future plans are to develop fiscal year 1995 proposals to construct a full-scale version that will measure the mass properties of racks for the Spacelab modules and the Space Station logistics support modules.

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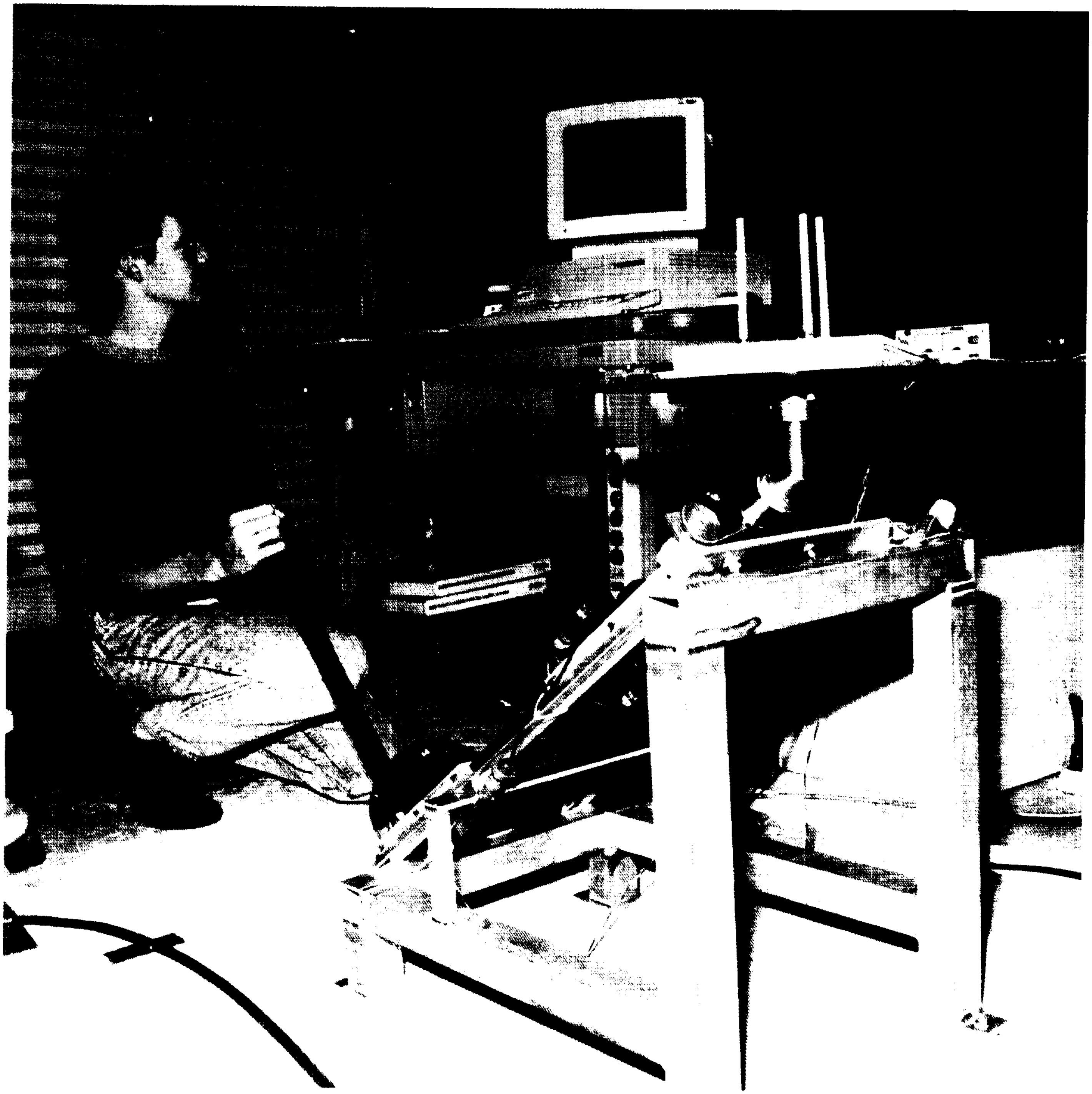
Participating Organization: I-NET, Inc. (K. Wolcott)

NASA Headquarters Sponsor: Office of Space Flight



Mass Properties Measurement System

Electronics and Instrumentation

The Electronics and Instrumentation Technology program at the John F. Kennedy Space Center (KSC) supports the development of advanced electronic engineering technologies that decrease vehicle and payload ground processing time and cost, improve process automation, and enhance quality and safety. The program includes the application of electrical and electronic engineering disciplines, particularly in the areas of data acquisition and transmission, advanced audio systems, digital computer-controlled video, environmental monitoring instruments, and circuit monitoring instrumentation. The near-term program focuses on Shuttle ground processing enhancement by developing instruments that improve ground support equipment used in monitoring and testing. The long-term program will develop technology for support of future space vehicles, payloads, and launch systems by investigating instruments that can provide "component intelligence" and contribute to vehicle health management data for synergy with the Advanced Software systems under development.

Development of an Aerosol Generation System for Calibration of Particle Counters

Optical particle counters (OPC's) are used in cleanrooms throughout aerospace and semiconductor industries to monitor air cleanliness. Freedom from airborne particulate contaminants becomes especially critical for the processing of optical payloads (e.g., the Hubble Space Telescope). Currently available systems that generate the test aerosols used in OPC calibration do not reliably generate aerosols over the entire size range required by calibration laboratories at KSC. No method currently exists for field verification of the functionality of an OPC.

An aerosol generation system was developed and field tested at KSC. It makes use of a medical respiratory nebulizer to generate an aerosol stream. Calibration microspheres are dispersed in high-purity water and nebulized. Dilution air then dries the stream to produce a uniform stream of particles. Sizes from 0.5 to 7.0 microns have been successfully produced. The aerosol generator has also been repackaged so as to be portable.

Performance parameters that must be considered in evaluation of these units include background contamination, ease of operation and maintenance, and uniformity of particle samples produced. These configurations have been thoroughly evaluated in each of these areas.

The accompanying diagram shows a miniaturized version of the test aerosol generation system. This system uses technology proven in earlier designs and takes advantage of the fact that the original sampling plenum was larger then required. The current design uses a plenum of plexiglass. At this time, the plexiglass material appears to be compatible with this application. The plexiglass allows easy determination of any possible buildup of contamination or water in the plenum. This has never been observed.

In addition to the above research, the field verification issue has been addressed. Calibration micropheres have been packaged into an aerosol spray can arrangement such that a convenient source of calibration particles can be produced on demand for field functional verification.

Key accomplishments:

- Repackaging of the test aerosol generator.
- Design and fabrication of a portable aerosol generator.
- Development of an aerosol spray for field verification of OPC's.

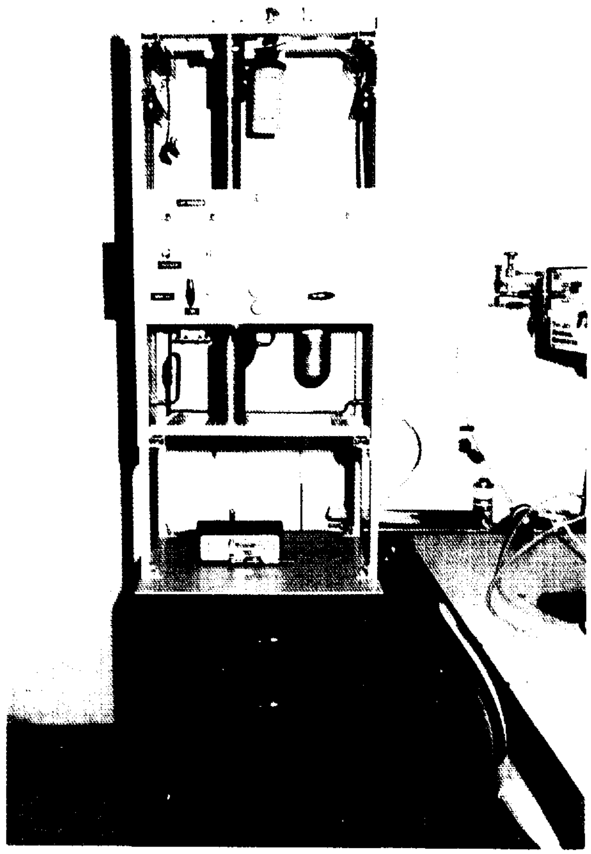
Key milestones:

- Qualification of the portable calibration unit.
- Field testing of the portable calibration unit.
- Refinement of the aerosol spray for field validation of OPC's.

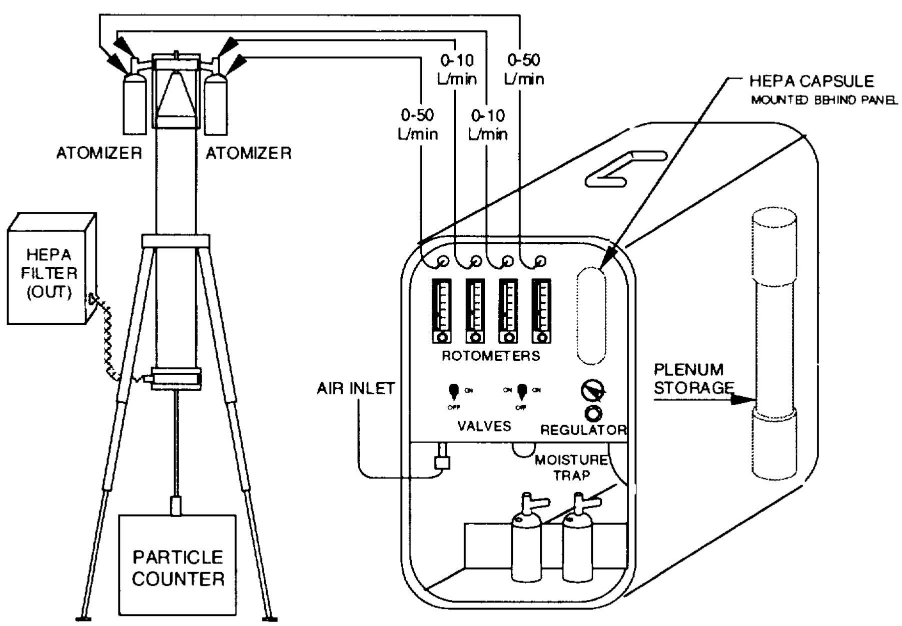
Contact: P.A. Mogan, DL-ESS-24, (407) 867-9167

Participating Organizations: I-NET, Inc. (C.J. Schwindt) and McDonnell Douglas Space Systems (V.V. Bukauskas)

NASA Headquarters Sponsor: Office of Space Systems Development



Test Aerosol Generator in Place at the Calibration Laboratory



Portable TAG

Development of a Real-Time Nonvolatile Residue Monitor for Use in Cleanrooms

Deposition of layers of molecular contaminants (nonvolatile residues), such as hydrocarbons and various lubricants, can degrade the performance of flight hardware optics and thermal radiator surfaces. Measurements of nonvolatile residues are currently made by placing a witness plate in the payload environment for 2 weeks and then measuring the amount of accumulated residue on the witness plate. This method cannot provide any information about contamination until well after a particular event has taken place. A real-time indication of the accumulation of nonvolatile residues is needed so measures can be taken to protect sensitive payloads.

Under a Small Business Innovation Research (SBIR) contract with Femtometrics, Inc., of Costa Mesa, California, an instrument has been developed and field tested at KSC that will measure nonvolatile residue contamination in real time. This device is based on a surface acoustic wave (SAW) microbalance, which operates similarly to a piezoelectric crystal microbalance but has much greater sensitivity. The crystal is held at a constant temperature just below room temperature and thus accurately reflects conditions on the payload.

Laboratory testing shows that, when a source of contamination is brought into a chamber where the instrument is located, the beat frequency between the measurement and reference crystal increases. When the contamination source is removed, the beat frequency decreases, indicating offgassing from the surface. These tests always leave a residue that is truly nonvolatile. This phenomenon was also observed during testing conducted at KSC. Increases and decreases in measured levels corresponded directly with activity logs kept for the area.

This device demonstrates that it is possible to quantitatively measure nonvolatile residues in real time. Future research will involve calibration methods and repackaging the instrument.

Key accomplishments:

- Field test completed at KSC. Theoretical sensitivity of the SAW device is much greater than current analytical methods.
- Prototype instrument was used to monitor the Hubble Space Telescope refurbishment payload.
- Prototype sold to SEMITECH as a contaminant monitor in the wafer fabrication process.

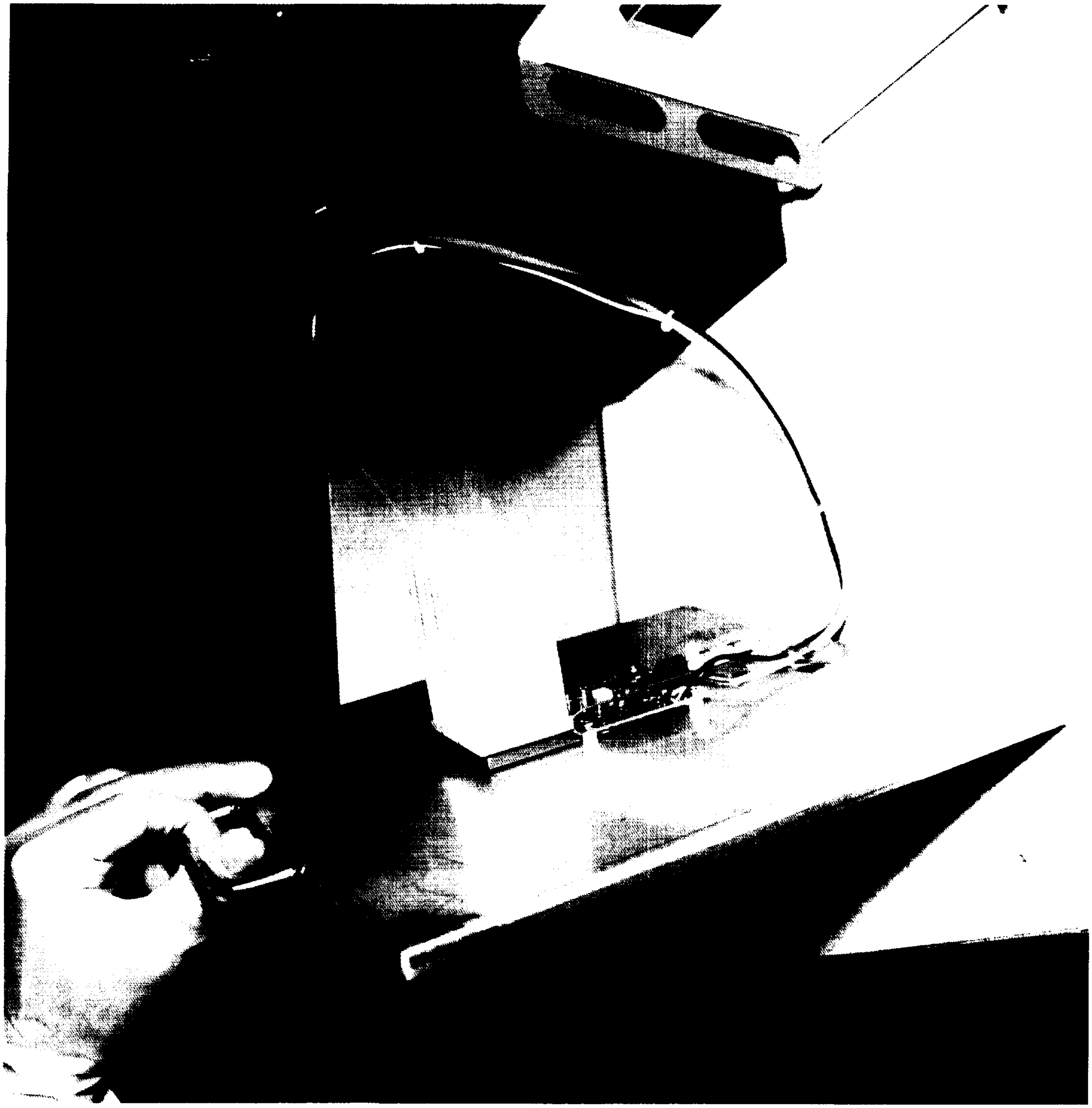
Key milestones:

- 1994: A subcontractor will develop calibration methods. A relative humidity sensor will be incorporated into the instrument to compensate for humidity effects. The instrumentation control software and packaging will be modified.

Contact: P.A. Mogan, DL-ESS-24, (407) 867-9167

Participating Organization: Femtometrics, Inc. (Dr. W.D. Bowers)

NASA Headquarters Sponsor: Office of Advanced Concepts and Technology



Real-Time Nonvolatile Residue Detector Field Test

Fourier Transform Infrared (FTIR) Spectrometer Based Ammonia Detection System for Space Station Processing

Processing of elements of the Space Station will be performed at the Space Station Processing Facility (SSPF) at KSC. The current design of the Space Station will use ammonia as a refrigerant. Monitoring of ammonia vapor concentrations during loading and storage is required because of its toxic and flammable properties. This monitoring is difficult since there are a number of other vapors that may be present because of testing or cleaning performed in the area.

Due to the requirement for detection of ammonia over a wide concentration range (parts per million to percent levels) and the need for discrimination of ammonia from a wide variety of other compounds, FTIR was the technology selected. A commercially available industrial FTIR with 0.5-wave-number resolution was chosen. A compact 80486 DX computer was used as a controller, performing the data acquisition from the FTIR instrumentation and all the computations that yield vapor concentrations. Custom calibration software was developed for discrimination and quantification of compounds from their absorbance spectra. All of this will be integrated into a cart for use in the SSPF.

Testing performed at the NASA Toxic Vapor Detection Laboratory involving three different FTIR's and use of a sample cell with a variable path length allowed the appropriate physical configuration to be determined. It was found that one sample cell could be used with a path length of 1.5 meters to monitor vapor concentrations over the entire range of interest. This was accomplished by using a major peak for part-per-million concentrations and one of the minor peaks for percent levels.

Various methods of spectral analysis were investigated, and one that yielded the best results was selected. Custom software was developed for FTIR control, and various algorithms for performing the required fast Fourier transforms (FFT's) were evaluated. The software was developed in Pascal.

A sampling system was also designed and prototyped in the laboratory. This sampling system uses venturi pumps that produce no heat load within the FTIR instrumentation cabinet. It has appropriate flow alarms needed by the system.

Key accomplishments:

- Selection of the FTIR technology and determination of the required cell path length.
- Development of an algorithm for baseline correction.
- Development of FTIR instrumentation software for control and FFT's.
- Training of the FTIR instrumentation to recognize spectra of interfering compounds.

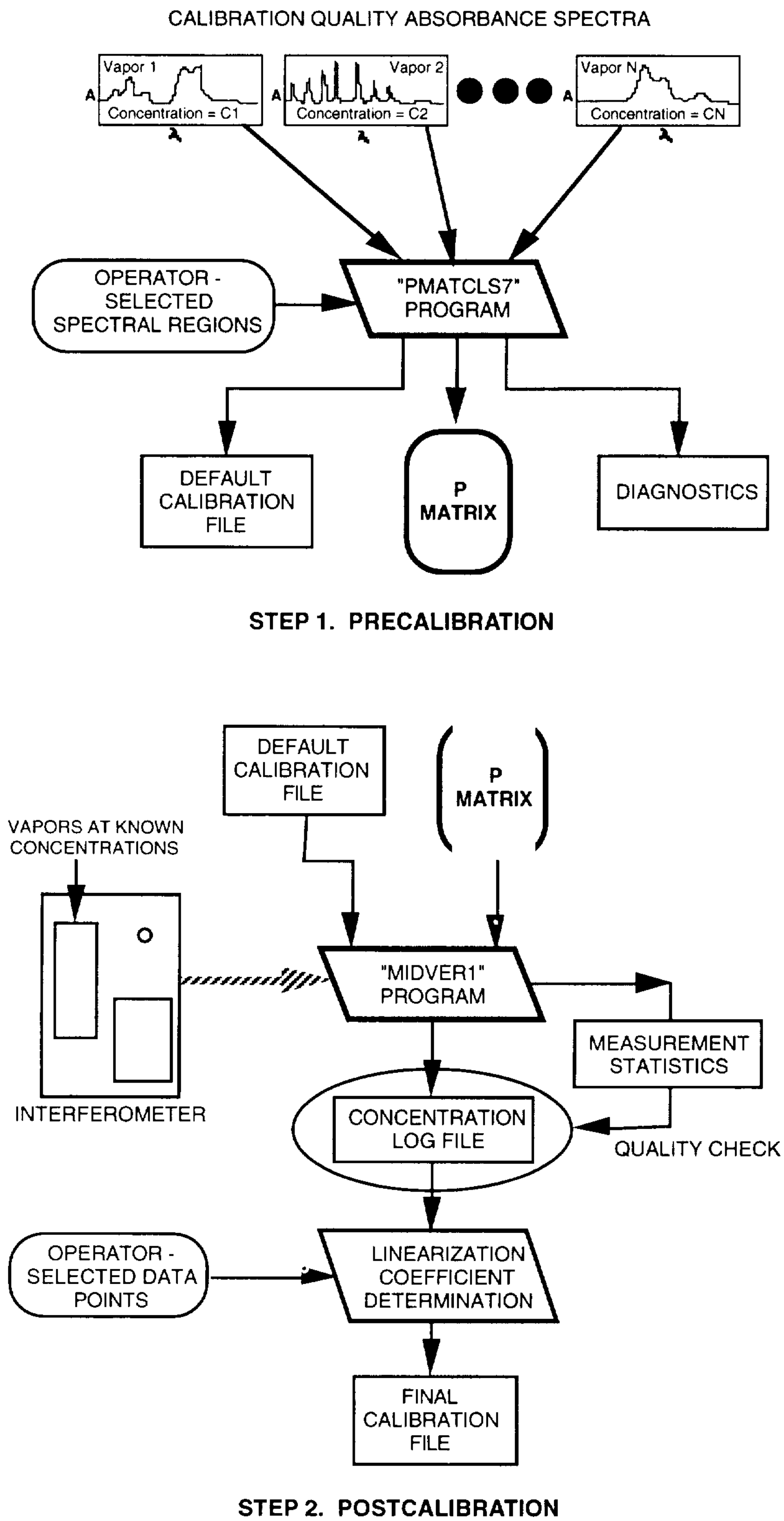
Key milestones:

- Receipt and checkout of the final instrumentation.
- Completion of the system controller software.
- Concept design for final integration of system components.

Contact: P.A. Mogan, DL-ESS-24, (407) 867-9167

Participating Organization: I-NET, Inc. (C.J. Schwindt and C.B. Mattson)

NASA Headquarters Sponsor: Office of Space Flight



FTIR-Based Vapor Monitoring System: Calibration Process Flow Chart

Quantitative Calibration of Aerosol Particle Counters

Current methods used for the calibration of aerosol particle counters involve setting a count or don't-count threshold voltage within the instrument's detector circuitry. Although this is a necessary step, it is not sufficient to guarantee the particle count reported by the instrument is accurate. Significant efforts are now being focused on establishing a particle counter's counting accuracy. The latest effort by the Institute of Environmental Sciences in this area has produced a recommended practice (RP-014) in which a particle counter's count is compared with a condensation particle counter (CPC) or condensation nucleation counter (CNC). This is still not entirely satisfactory, since the CPC and the particle counters being calibrated are based on the same technology and are subject to similar systematic errors.

In order to perform quantitative calibration of aerosol particle counters, the particle counter must be challenged with a stream of particles of a known size and number. An instrument for generating a stream of particles of a known size was developed at the University of Arkansas, Little Rock, and refined at the Contamination Monitoring Laboratory at KSC. This instrument generates a stream of particles that is quite stable over time. All that remains is to verify the particle concentrations with an independent technology. Additionally, it is required that the particle concentration verification process be a first-principle method.

The available independent first-principle technologies for accomplishing this task fall into two categories: gravimetric and visual. Because of the large numbers of particles involved, any visual method must be augmented by a computerized image analysis system. Such a system was installed at the Contamination Monitoring Laboratory. The image analysis system actually counts each particle, making it truly first-principle. In actual practice, a statistically significant number of representative samples are counted, although a 100-percent count is theoretically possible, if not tedious. Tests done with the image analysis system have shown it to be very effective. However, a satisfactory method for capturing 100 percent of the particulate stream for counting has not yet been found. A wet capture system that passes the aerosol stream through a liquid was tested. Capture ratios were found to be unacceptably low. Future testing with this technology will focus on a dry filtering system. The gravimetric approach has focused on the development of a surface acoustic wave (SAW) microbalance capable of measurements in the picogram range. A carefully designed, single-stage impactor captures the particles on a crystal surface where they are weighed. Since the particles are of a precisely known size and density, their count may be ascertained from the total mass. The SAW device is being calibrated and will be tested at KSC in 1994.

Key accomplishments:

- The aerosol generation system was finalized.
- Alternative particle collection and counting methods were investigated.
- A wet filtration system was evaluated using several different collection liquids.

Key milestones:

- Dry filtration system enhancements are under way.
- SAW device testing is scheduled for testing in 1994.
- Video digitizer and automatic image processing provisions will be evaluated.

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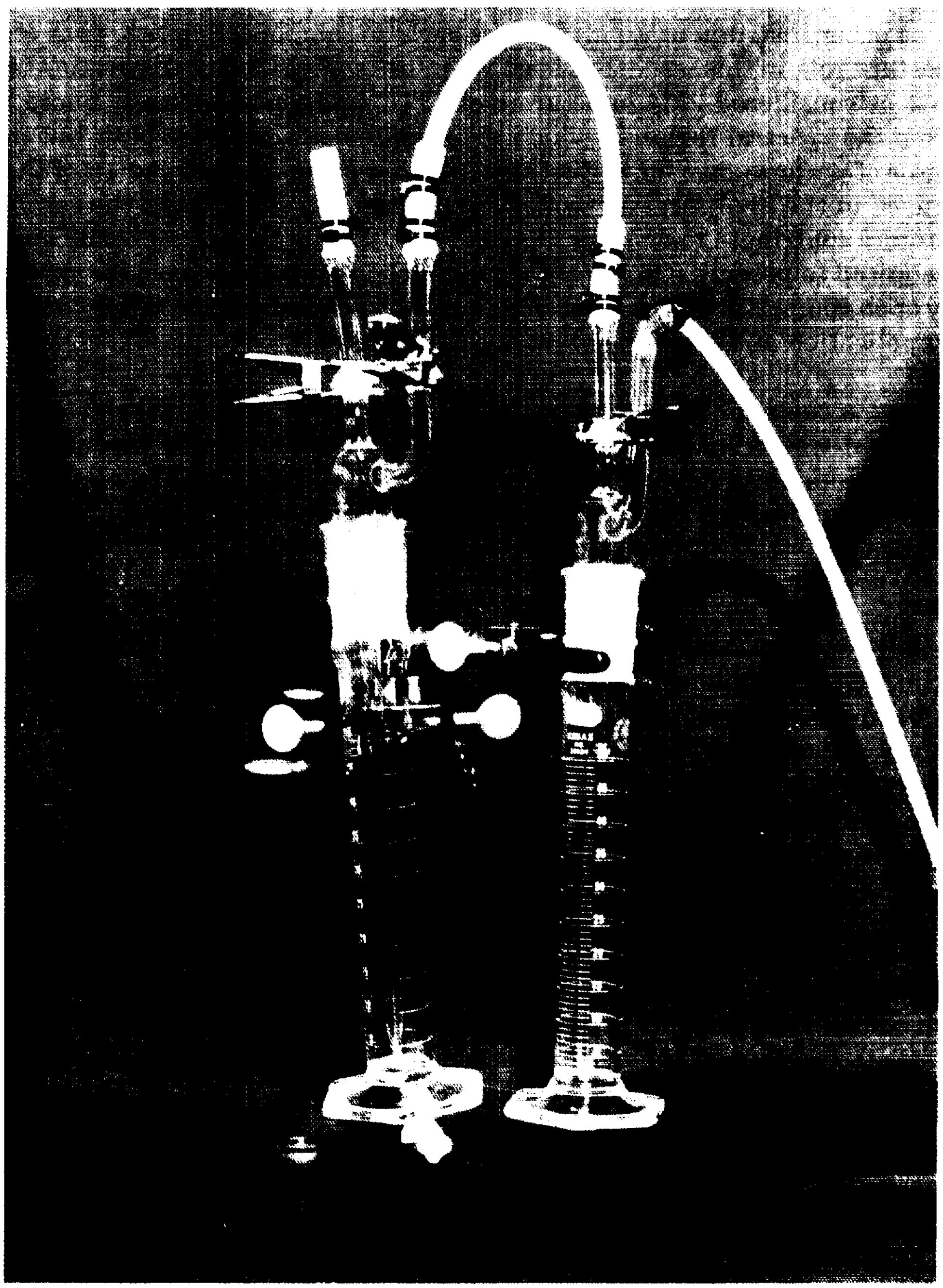
Participating Organizations: McDonnell Douglas Space Systems (V.V. Bukauskas) and I-NET, Inc. (C.J. Schwindt)
NASA Headquarters Sponsor: Office of Space Systems Development



Surface Acoustic Wave Single-Stage Aerosol Impactor

Measurement of Noise Characteristics of Fourier Transform Infrared (FTIR) Instrumentation

NASA at KSC is developing FTIR-based instrumentation for several vapor monitoring requirements related to Space Shuttle and payload processing. The quantitative performance of the FTIR spectroscopic analysis is critical to meet the required sensitivity for the monitoring task and is a function of the noise characteristics of an FTIR instrument. The noise characteristics of an FTIR instrument are not as easily expressed as other instrumentation. Factors such as sample cell optics, path length, and geometry play an important role in this issue; but even when the sample cell configuration is specified, many other factors must be considered. Manufacturers of FTIR equipment typically quote a signal-to-noise ratio obtained from the spectral region in which their equipment performs best; but in general, this is not a good predictor of performance for a spectrum analysis using another region of the spectrum. The spectral regions used in the analytical method, spectral baseline effects, and the resolution of the data acquisition electronics contribute to noise in the analytical results that is not easily specified. Since the Government is required to procure instruments (even instruments to be used for specific measurement requirements) by open competition, it is necessary to specify performance in a way that can be quantified for the required application and is independent of the FTIR itself.

To meet this need, a customized noise measurement procedure was developed to produce a procurement specification that would ensure the Government could competitively procure FTIR instruments having the analytical capability needed. This procedure is dependent on the spectral regions used for the required analysis and does not require generation of test streams of specialty gases. The procedure measures noise characteristics over the spectral regions specified for the required analysis and ensures the instrument will provide the required analytical performance.

The noise measurement procedure for a specific instrument and for a particular vapor analysis method calculates the standard deviation of 100 transmittance spectra at each wave number, which is referenced in a given vapor analysis method. This gives an estimate of the variability to be expected from that instrument when used as a monitor employing that analysis method. Once the transmittance spectra standard deviation function is defined for all wave numbers within the FTIR instrument's range, noise estimates may be made for any given method by considering only those wave numbers referenced in the method of interest.

Once the standard deviation function has been defined for a particular instrument, it then serves as a baseline from which instrument degradation can be tracked, independent from that instrument's application. This is particularly useful in maintaining the instrument in the field, since this noise measurement process can be performed with the instrument in place and, in many cases, while the instrument is performing its function. The noise measurement curve on a floppy disk is all that needs to be transported to the calibration facility to determine if calibration is necessary.

Key accomplishments:

- Determination of critical parameters in a noise measurement.
- Development of a written procedure for noise measurement.
- Demonstration of the correlation between noise measurement and analytical performance.
- Review by spectroscopists at FTIR manufacturing companies.

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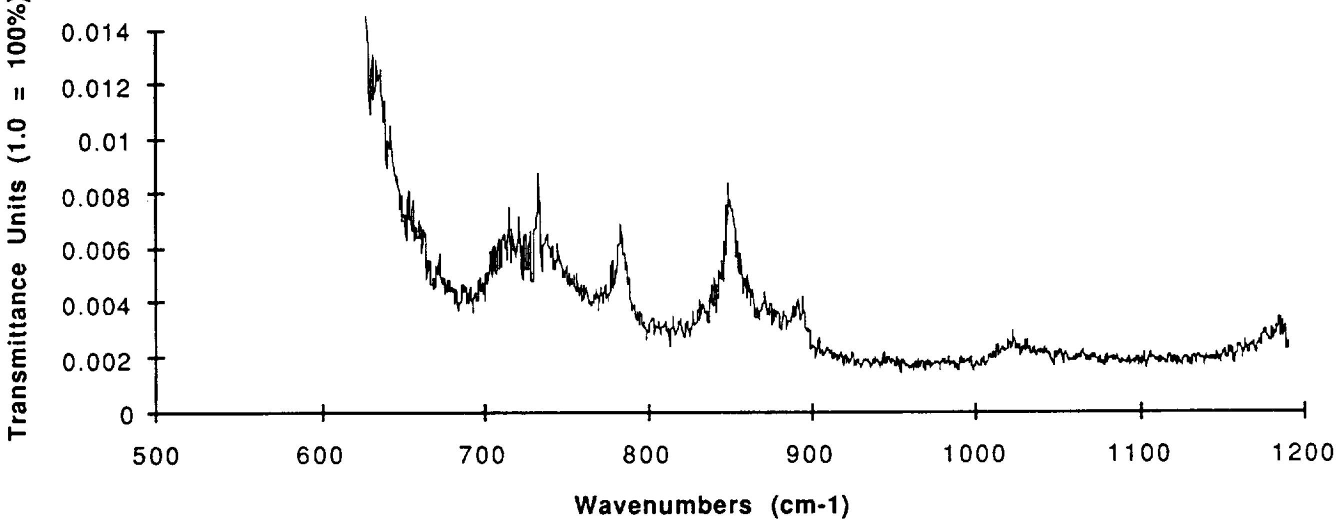
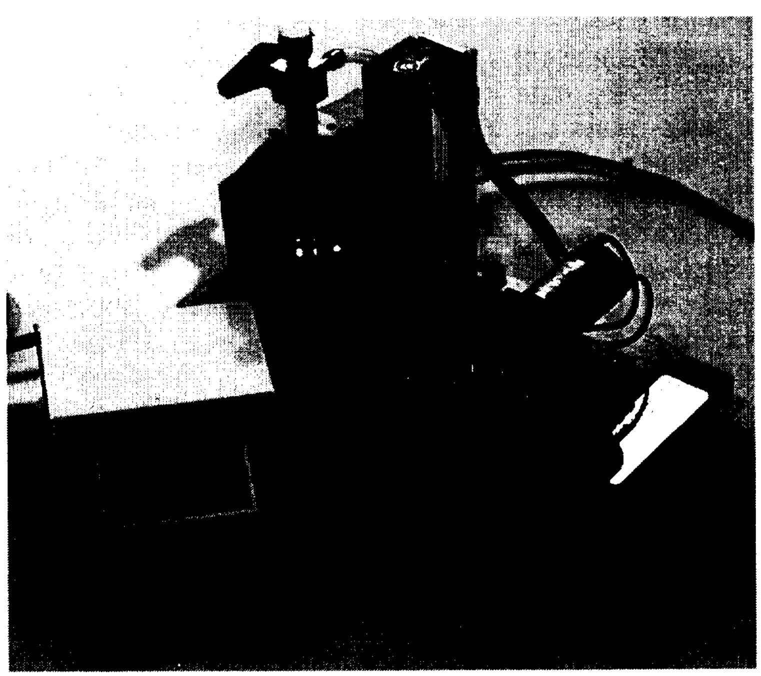
Participating Organizations: McDonnell Douglas Space Systems (L.H. Allen) and I-NET, Inc. (C.J. Schwindt and C.B. Mattson)

NASA Headquarters Sponsor: Office of Space Flight



Standard Deviation From Nominal FTIR Transmittance Spectrum as a Function of Wavenumber



Surface Acoustic Wave Single-Stage Aerosol Impactor

Hydrogen Flame Simulator

Fire detectors used to support launch operations at KSC are designed to detect hydrogen fires. Hydrogen fires emit large amounts of ultraviolet (UV) radiation and almost no visible light radiation. The fire detectors used on the cross-country fuel lines, launch pad service structures, and Mobile Launcher Platforms detect such UV radiation. To calibrate these detectors, a standard UV source must be used. The standard source must emit UV radiation at the same wavelengths as that of a hydrogen fire and at some specific and repeatable intensity. This calibration is performed currently at KSC and/or by the vendor by a "standard" flame. This standard flame is produced by burning a hydrogen gas flowing at 5 standard liters per minute through a 1/16-inch orifice. This calibration method has several drawbacks. Due to fire safety concerns, these calibrations must be performed in isolated areas (usually outside) in conditions other than favorable and at hours that are usually inconvenient. Also, the method of burning a flame as a calibration device is questionable, flame intensity is distorted by air currents, and the contaminants and other such unknowns are unpredictable. There is no control over the environment from extraneous UV sources if the device is calibrated outdoors. Finally, the detectors cannot be calibrated or verified in place at the launch pads due to safety concerns of having open flames around hydrogen fuel sources.

To solve these problems, a more repeatable, dependable, and practical calibration source was developed. To accomplish this, a UV emission source that is controllable and of known intensity was used. To aid in finding the proper source, a determination of the spectra of a "typical" hydrogen flame was made. A photo spectrometer was calibrated using known sources and then used to measure the hydrogen flame. The KSC-defined "standard" flame, 5 standard liters per minute of hydrogen through a 1/16-inch orifice, burned under laboratory conditions. The hydrogen flame has specific peaks at specific wave lengths. These locations were measured and quantified. The sensitivity of the Hamamatsu UV-sensitive bulb (used in the hydrogen flame sensors) was measured. The bulb sensitivity was compared to the hydrogen flame peaks to find the best calibration UV source. Once the calibration source was determined, a control circuit was developed to stabilize and control the intensity of the UV source. Surrounding hardware, such as filters, was used to ensure the UV source system transmitted a spectra representative of a hydrogen flame. This device is also able to test the UV sensors for solar sensitivity (that is, the UV radiation emitted by the sun). Most UV detectors are made immune to solar sensitivity by using a sensing device only sensitive to the UV radiation below the 360-nanometer (nm) range, most likely around 180 to 300 nm where hydrogen fires emit some limited amounts of UV radiation. The final devices developed were a laboratory-type calibration device and a handheld unit for field calibrations or verifications. The laboratory device has the ability to vary its intensity to simulate changes in the distance of the detector from the source. It has been verified that the intensity of a hydrogen flame falls off as $1/(\text{distance})^2$. The handheld units have preselected intensity settings to allow the field technician to stand in predesignated locations and field test a detector in place. All of this gives greater reliability and confidence in the hydrogen fire detectors used at the launch pads.

The accomplishments over the past 2 years have been tremendous. The photo spectrometer was calibrated and used to characterize the standard hydrogen flame both qualitatively and quantitatively. A suitable UV source bulb was identified and checked for its spectral qualities as well as for its intensity. The Hamamatsu UV sensor, used in KSC flame detectors, was tested and found to be most sensitive to UV in the 195- to 205-nm range. Filters that allow the UV source to simulate the standard hydrogen flame have been selected and tested. These characterizations and identifications have allowed KSC to design and build the laboratory-type calibration device and the handheld unit. The laboratory-type calibration device is currently undergoing software modifications to extend its test capabilities. The handheld unit is currently being field tested.

Key accomplishments:

- 1992: Characterized the standard hydrogen flame.
- 1993: Built a laboratory calibration device prototype and final device. Built a handheld prototype and final device.

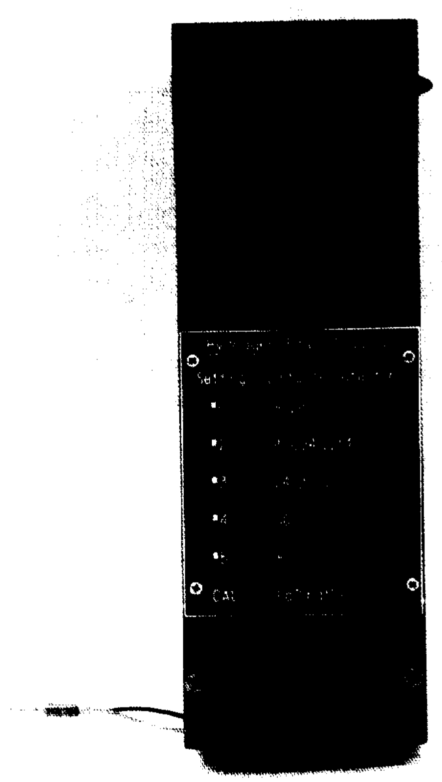
Key milestones:

- 1994: Test the laboratory calibration device for its ability to reliably and repeatedly calibrate UV flame detectors. Also, define a simplistic calibration method to calibrate the laboratory transfer standard calibrator. Field test handheld devices.

Contact: G.A. Hall, DL-ESS-23, (407) 867-3185

Participating Organization: I-NET, Inc. (S.J. Stout, Dr. R.C. Youngquist, R.B. Cox, W.D. Haskell, and J.S. Moerk)

NASA Headquarters Sponsor: Office of Space Systems Developmen



Handheld Hydrogen Fire Simulator

Automated Leak Rate Calibration System

Leak rate artifacts are widely used in manned space flight and research programs to set up leak detectors, residual gas analyzers, and mass spectrometers. Since no inhouse capability existed, NASA used a variety of commercial sources for the calibration of these leak rate standards. Calibration errors and inconsistencies of test results provided by such services were shown by National Institute of Standards and Technology (NIST) studies to be as large as 50 percent. NIST undertook the development of a leak rate calibration service to provide lower-echelon calibration laboratories with a consistent basis for the calibration of leak rate artifacts. This provided the opportunity for NASA to resolve inconsistencies noted in leak rate calibrations.

A project to develop an automated leak rate calibration system for NASA capable of calibrating leak artifacts traceable to NIST was initiated. The technical requirement was for a completely automated, stand-alone system capable of performing leak-rate-versus-temperature and leak-rate-versus-back-pressure calibrations primarily for helium, with the capability for argon, neon, nitrogen, and Freon as well. The project was sponsored by the NASA Metrology and Calibration Working Group and funded by Code Q.

In June 1992, NIST designed, built, tested, and delivered to KSC an automated leak rate system capable of intercomparing three standards and three unknowns over the range of 1×10^{-08} to 1×10^{-15} moles per second at controlled temperatures between 0 and 100 degrees Celsius and back pressures from 10 to 1000 pounds per square inch. Temperature control allows the system to generate a flow-rate-versus-temperature table for temperature-dependent capillary leaks, a capability not currently available from commercial sources. The system also provides for automated control of leak selection, flow rate, back pressure, and temperature. Test sequencing and data analysis are controlled by system software. System tests confirm the system performance objectives have been achieved.

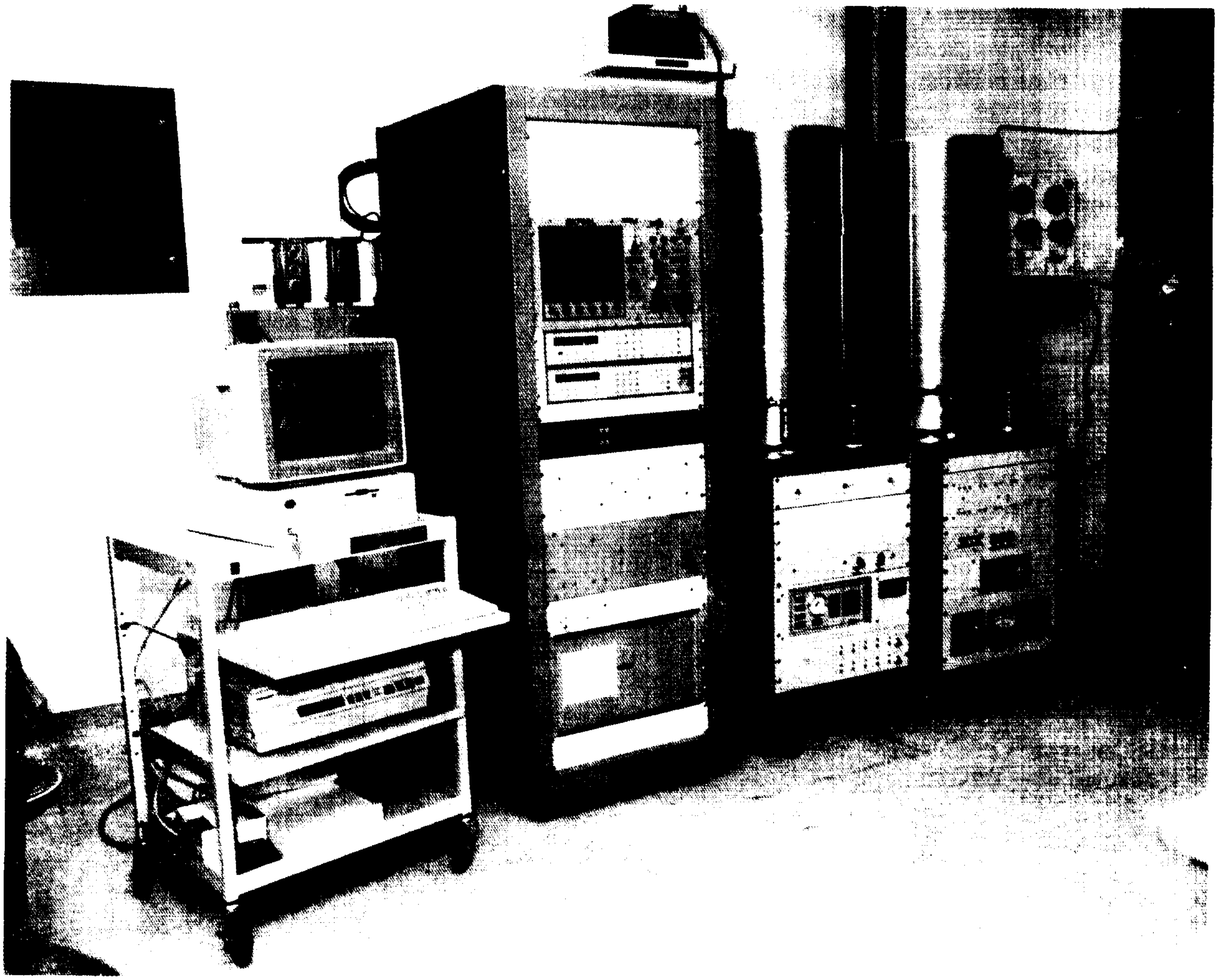
Key accomplishments:

- 1990: Developed system requirements (KSC).
- 1991: Designed and constructed the system (NIST).
- 1992: Completed the hardware and software test, documentation, and delivery (NIST).
- 1993: Put the system online and commenced calibration of leak rate artifacts (KSC).

Contact: J.P. Riley, SI-PEI-1B, (407) 867-4737

Participating Organization: EG&G Florida, Inc. (J.H. Tidwell)

NASA Headquarters Sponsor: Office of Safety and Mission Assurance



Automated Leak Rate Calibration Instruments

Universal Signal Conditioning Amplifier

The goal of this project is to develop and commercialize a state-of-the-art Universal Signal Conditioning Amplifier (USCA) that can be used with most types of transducers and data acquisition systems. The USCA will significantly decrease operation and maintenance costs by eliminating costly measurement setup time between the signal conditioner/amplifier and the transducer and will increase reliability and measurement accuracies. The USCA, when combined with the Self-Aware Measurement System (SAMS), will provide enhanced system configurability, control, and measurement visibility. In addition, USCA will eliminate the need to store large inventories of customized spare signal conditioners, resulting in a substantial logistics savings.

When a measurement is set up and calibrated utilizing USCA, a transducer is equipped with a nonvolatile memory chip (Tag RAM), which stores data pertinent to the transducer. This data includes required excitation levels, linearization coefficients, required output signal levels, and other parameters. When connected to the transducer, the USCA then automatically adjusts the excitation levels and signal output levels and configures itself for maximum accuracy and resolution, using the information stored in the nonvolatile memory. Once the transducer and USCA are installed in the field, the SAMS polls the newly added USCA to update the new system configuration. Additional features of USCA include built-in power on self-tests, dynamic temperature compensation over an operating range of -20 to 70 degrees Celsius, real-time fourth-order signal linearization, 16-bit analog-to-digital conversion at 10 kilohertz (oversampled at 24 kilohertz), minimum 12-bit measurement accuracy, user-definable digital filtering, digital or analog output, built-in lightning protection, and an explosionproof housing. The figure shows the USCA/SAMS system and how it interfaces to both unconditioned and Launch Processing System type transducers. A detailed block level diagram of USCA's primary functions is also shown.

Efforts are underway to transfer the USCA/SAMS technology to the commercial arena. Its 12-bit accuracy is better than many commercially available amplifiers. The state-of-the-art technology utilized in USCA, which enables the dynamic compensation of temperature changes so the accuracy can be maintained over the temperature range, can also be used in other applications.

Key accomplishments:

- 1991: Tag RAM concept fabricated and tested.
- 1992 through spring 1993: USCA prototype fabricated, tested, and demonstrated to Shuttle Operations.
- 1993: First miniaturization, characterization, and environmental testing.

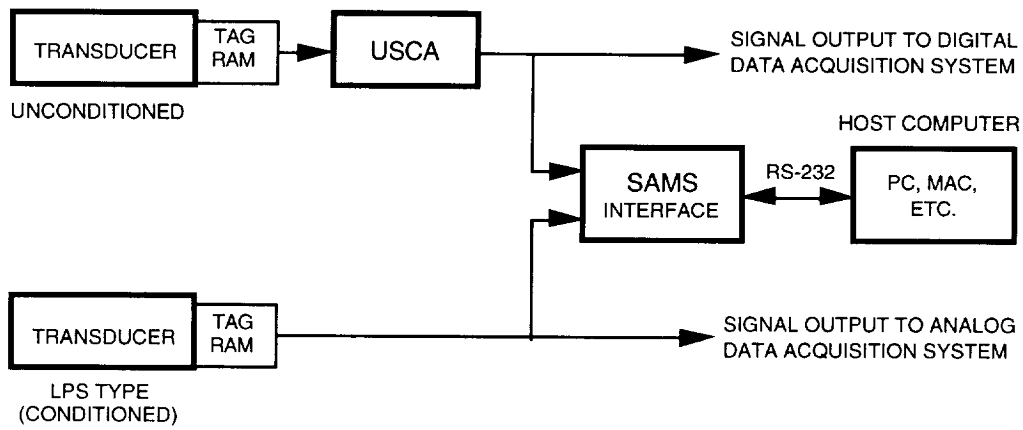
Key milestones:

- 1994: Final miniaturization, characterization, and environmental testing; USCA commercialization and refinement of SAMS.
- 1996: Begin commercial procurement of USCA devices for use in a permanent measurement system upgrade.

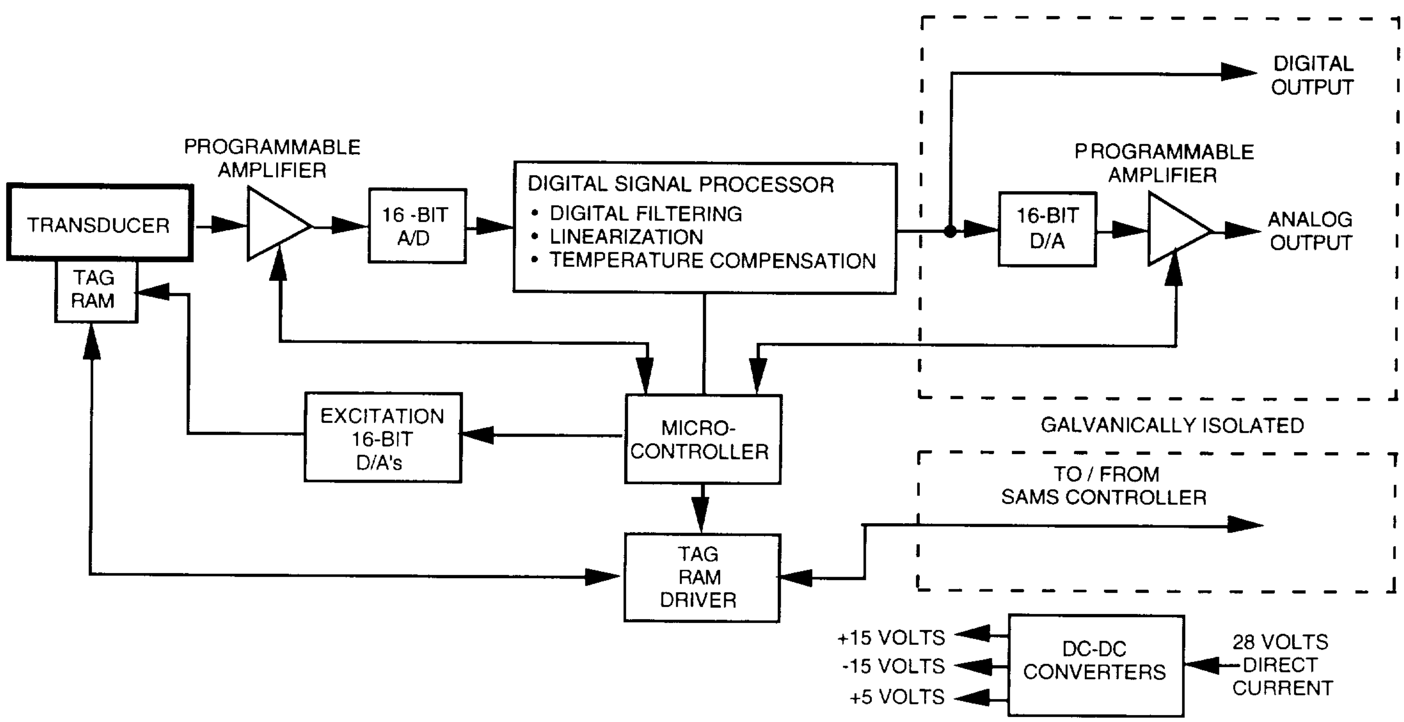
Contact: J.D. Cecil, DL-ESS-23, (407) 867-8094

Participating Organization: I-NET, Inc. (P.J. Medelius)

NASA Headquarters Sponsor: Office of Space Systems Development



System Configuration Showing USCA, SAMS, and Tag RAM



USCA Block Diagram

Development of a Real-Time Particulate Fallout Monitor for Use in Cleanrooms

Measurement of contamination deposition levels on surfaces such as payload optics is critical to ensuring the payload's functionality is not impaired. Currently, these measurements are performed by placing a 37-millimeter-diameter gridded filter near a payload for 2 weeks and then optically counting and sizing the contamination in a laboratory. This method is manpower intensive and subject to human error.

A real-time particle fallout monitor was developed in the NASA Contamination Monitoring Laboratory for use in operational clean work areas at KSC. This device qualitatively measures the total amount of contamination by monitoring the amount of light scattered by particles deposited on a mirror surface in the instrument.

The monitor was field tested in the Operations and Checkout building at KSC. It was found to correlate well with scheduled activities in the test area and will be turned over to payload operations personnel for evaluation and subsequently to Shuttle operations.

Work will also be done on this project to produce a quantitative device that counts and sizes fallout contamination. This device will be developed during fiscal year 1994.

Key accomplishments:

- Fabrication of the initial prototype and repackaging.
- Laboratory and field testing of the fallout detection instrument.
- Investigation into the production of a quantitative instrument.

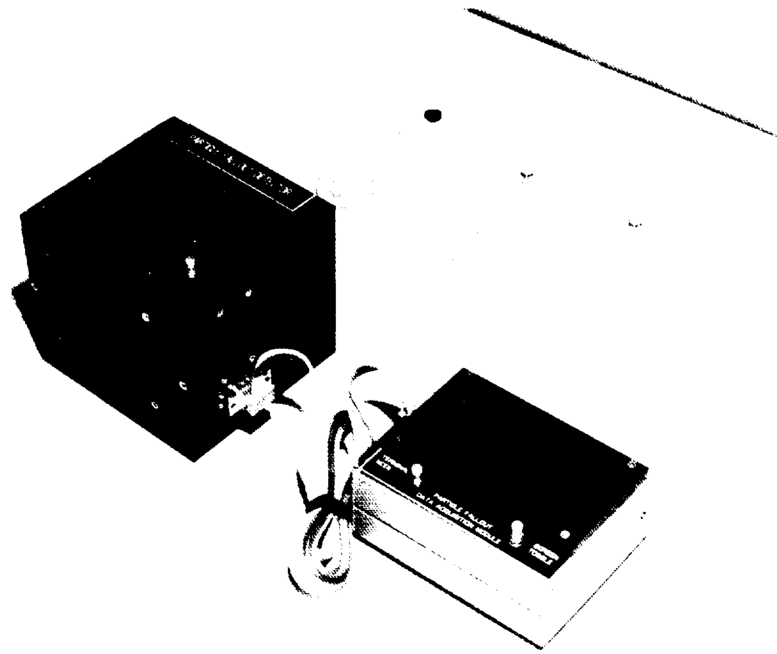
Key milestones:

- Turnover of the qualitative instrument for operational evaluation.
- Final packaging of the qualitative instrument.
- Development of a quantitative instrument.

Contact: P.A. Mogan, DL-ESS-24, (407) 867-9167

Participating Organizations: McDonnell Douglas Space Systems (V.V. Bukauskas) and I-NET, Inc. (C.J. Schwindt and R.C. Youngquist)

NASA Headquarters Sponsor: Payloads



Optical Fallout Monitor Prototype in Field for Testing

Optical Fallout Monitor Sensor Head Unit

T-0 Cable Analysis System

Currently, the checkout of the cables at the T-0 cable plant for the Space Shuttle at KSC is done by time-consuming manual methods. A test set must be manually plugged in at either end of a cable. If an anomaly is detected, then one test set is moved along various junctions of the cable until it is located. The ends of the cable are separated by a large distance, thus further slowing testing.

The objective of the T-0 Cable Analysis System (CAS) project is to develop an advanced cable analysis system for the T-0 cable plant from the Pad Terminal Connection Room (PTCR) to the orbiter and from the PTCR to the Payload Changeout Room (PCR). The system will include intelligent remote terminators, historical archiving of test results, fault prediction, and report generation capabilities. The goal of the program is to test cables in place through the use of intelligent remote configurators. These configurators attach to the end of the cable under test, receive the data from a suitcase-based tester through the cable under test, and reconfigure based on that data.

At the time of this report, the project is at the midpoint of Phase II. During Phase I, a prototype breadboard was assembled. The prototype allowed testing and verification for the cable tests listed below (the tests are valid for a cable with 64 conductors and up to 2,000 feet in length):

1. Tests to prove control and measurement can be achieved with access to only one end of the cable for hookup to the main CAS unit
2. Resistance tests (0.2-ohm resolution)
3. Bandwidth tests (direct current to 6.5 megahertz)
4. Low-voltage isolation tests (fail below 1 megohm)
5. High-voltage isolation tests between 500 and 1,500 volts (fail below 1 megohm)

For Phase II, the fabrication of the suitcase that acts as the base for the tester is proceeding on schedule, software for initial testing of the system is being written, and PC boards are being fabricated. Delivery of the prototype test unit will be in late fall of 1993. Future plans include a complete field testing of the unit upon delivery to KSC. On the basis of successful testing and the comments of the field test engineers, production units of the system will be built, along with units customized for other cable assemblies at KSC.

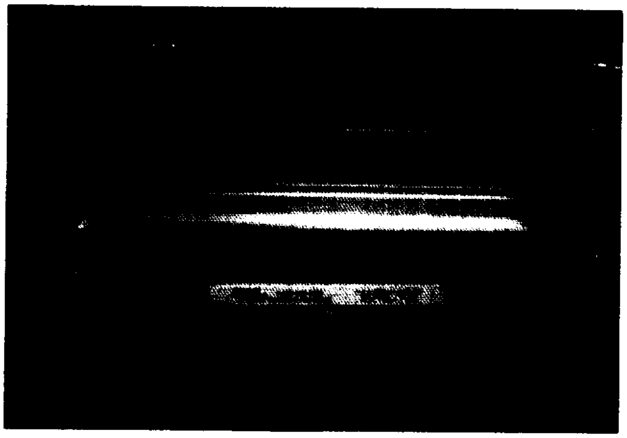
Key accomplishments:

- 1992: Prototype breadboard assembled.
- 1993: Completion of a new high-speed current source. Completion of a track and hold circuit.

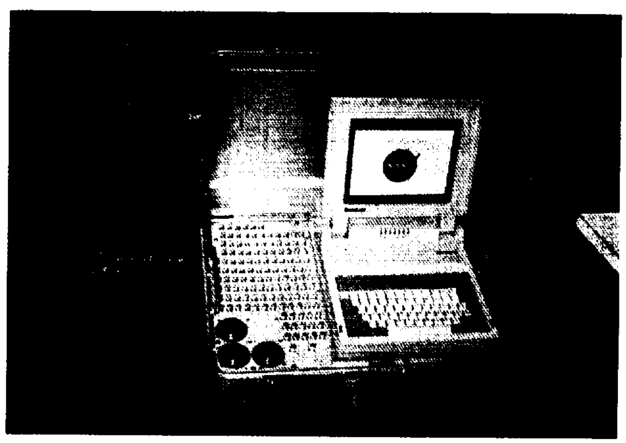
Key milestones:

- 1993: Commence testing of the prototype test unit upon delivery.
- 1994: Manufacture of production units.

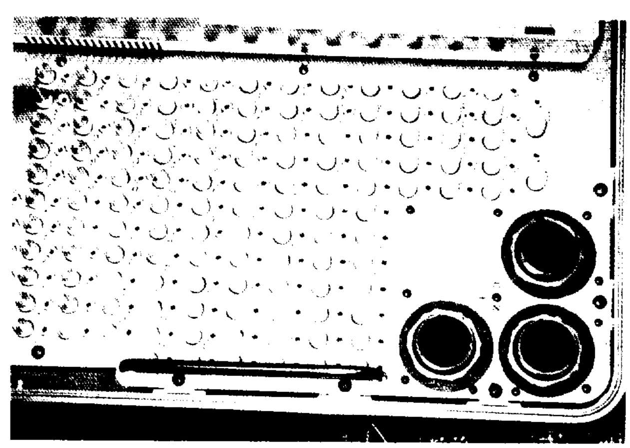
Contact: D.C. Knoblock, TV-ETD-23, (407) 861-3690
Participating Organization: Lockheed Space Operations Company (L.T. Bird and B. Houvener)
NASA Headquarters Sponsor: Office of Space Systems Development



T-0 Cable Analysis Prototype



View Showing Case Open



Closeup of Connectors and Switches

Correction of the Infrared Spectral Baseline Using Shape Parameters

Processing of the Space Shuttle vehicle and payloads involves the use of many volatile materials, some highly reactive and toxic. The toxic materials include monomethylhydrazine fuel and dinitrogen tetroxide oxidizer for the Shuttle and ammonia refrigerant for the Space Station. NASA at KSC is developing Fourier transform infrared (FTIR) based instrumentation to monitor these materials in order to prevent damage or injury in the event of a leak. In addition to monitoring for leaks of toxic materials, the instrumentation must be insensitive to compounds such as solvents or cleaning agents. Each of the materials to be monitored has a unique infrared absorbance spectrum, and the shape of the spectrum can be used to discriminate among materials and to quantify the vapor concentrations. The shape of the spectrum can also be affected by a number of factors, including source and detector temperature. If control of the instrument temperature is not possible, the spectra obtained must be corrected for the baseline shape in order to obtain valid measurements.

In order to apply FTIR spectroscopic analysis to toxic vapor detection in an environment where the temperature is not controlled, a novel method was developed to compensate for the effects on the analysis of changing temperature. This approach is based on the classical least square fit of the shape of the unknown spectrum to the shape of the calibration spectra. When solving simultaneously for several materials (or components), a matrix of calibration spectra and concentrations is used. The baseline is treated as a spectrum of unknown shape, which is generally smooth over a limited range. This is approximated in the calibration matrix as a set of polynomials of order zero, one, and two (or higher). When the simultaneous solution is obtained, the analysis for any of the analysis spectra is independent of baseline offset, tilt, and curvature up to the order of the polynomial used.

When multivariate spectral analysis is performed using this method of baseline compensation, the baseline distortion is reported as a "component" of the analysis, and analytical results for the target materials are no longer sensitive to temperature. This allows the instrument to report accurate concentrations immediately after startup and in varying conditions of temperature encountered when monitoring ambient vapor concentrations.

Key accomplishments:

- FTIR instrumentation procured and evaluated.
- Factors determining the baseline shape studied.
- Baseline shape modeling completed.

Key milestones:

- Selection of modeling parameters.
- Implementation of corrections.
- Validation of improved FTIR instrumentation performance.

Contact: D.E. Lueck and P.A. Mogan, DL-ESS-24, (407) 867-4439

Participating Organization: I-NET, Inc. (C.J. Schwindt and C.B. Mattson)

NASA Headquarters Sponsor: Office of Space Flight

Fiber-Optic-Based Hydrogen Monitor

The object of this project is to develop a portable hydrogen monitor with a fast response time that can detect 0.1 to 5 percent gaseous hydrogen. Existing hydrogen sensors are large, bulky, and unreliable and require frequent calibration. A small, reliable sensor is preferable over existing technology, allowing sensing in confined, hazardous environments where a small sensor size may decide whether or not a measurement can be taken.

The technical approach includes the development of a fiber-optic-based hydrogen sensor in the form of an optical Fabry-Perot interferometric hydrogen sensor. Fabry-Perot film-based sensors use a three-layer film stack that is sufficiently thin to allow soap-like interference effects and high response times. The materials used in the construction are selected so the film stack shows sensitivity towards a target species. In the case of hydrogen detection, palladium is utilized. In addition to the sensor development, an optoelectronics interface for interrogating the sensor, as well as the design of a data acquisition system, is included in the approach.

Two three-layer interferometric sensors have been constructed to date. Response times of less than 20 seconds were obtained and sensitivity over the range of 1 to 5 percent hydrogen was measured. A battery-powered, handheld monitor containing the optoelectronics for interrogating the sensors and the electronics for data acquisition and display has been designed and constructed. Future plans include shortening the response time of the sensors to less than 2 seconds, achieving a limit of detection of 0.1 percent hydrogen, improving the short- and long-term stability of the sensors, and lengthening the shelf life.

Key accomplishments:

- Prototype of the optical Fabry-Perot interferometric hydrogen sensor.
- Prototype of the optoelectronics interface for interrogating sensor.
- Prototype of the electronics subsystem for data acquisition and display.

Key milestones:

- 1994: Improve sensor response time, stability, and limit of detection.
- 1995: Develop a microcontroller-based optoelectronics package.

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Participating Organization: Research International

NASA Headquarters Sponsor: Office of Commercialization

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As the NASA Center responsible for assembly, checkout, servicing, launch, recovery, and operational support of Space Transportation System elements and payloads, the John F. Kennedy Space Center is placing increasing emphasis on its advanced technology development program. This program encompasses the efforts of the Engineering Development Directorate laboratories, most of the KSC operations contractors, academia, and selected commercial industries – all working in a team effort within their own areas of expertise. This edition of the Kennedy Space Center Research and Technology 1993 Annual Report covers efforts of all these contributors to the KSC advanced technology development program, as well as our technology transfer activities.

W.J. Sheehan, Chief, Technology Development and Transfer Office (TDO), (407) 867-3017, is responsible for publication of this report and should be contacted for any desired information regarding the advanced technology program.

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