
Small Business Innovation Research • Small Business Technology Transfer

# *2004 Program Year Report*

John F. Kennedy Space Center

# Foreword

This 2004 Program Year Report is a summary and analysis of the Kennedy Space Center (KSC) Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs. It describes the work developed under 30 contracts and contains summaries of their technical accomplishments. It is important that these technologies are incorporated into KSC Spaceport Technology missions and the commercial marketplace.

I am proud of the accomplishments of these programs, the contributions of the SBIR/STTR staff at KSC, and the technical representatives from KSC's directorates. The SBIR/STTR programs have become significant contributors to mission needs at KSC and have provided valuable technical resources for the small business partners involved in the program. Through the entrepreneurial spirit of the small business concerns, the programs have provided technology innovations, which in turn lead to new jobs, products, companies, and benefits to the country's economy.

James A. Aliberti, Chief
Technology Transfer Office

Kennedy Space Center SBIR/STTR Program Office

For further information regarding either the SBIR or STTR programs please visit the NASA web site at *http://sbir.nasa.gov* or contact the SBIR/STTR Office at Kennedy Space Center.

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# Introduction

The Small Business Innovation Research and Small Business Technology Transfer (SBIR/STTR) programs are an integral part of the Kennedy Space Center's Spaceport Technology Development's missions and objectives. The SBIR/STTR programs at KSC ensure the programs goals are aligned with KSC technology needs and missions, promote the utilization of developed technologies, and advocate the programs and publicize significant accomplishments.

The SBIR/STTR programs have the following goals:

(a) To increase private sector commercialization of technology developed through Federal research and development.
(b) To increase small business participation in Federal research and development.
(c) To provide opportunities for women-owned small business concerns and socially and economically disadvantaged small business concerns to participate in Federally sponsored research and development.

The KSC SBIR/STTR programs support the missions of the Human Exploration and Development of Space (HEDS) Enterprise, Biological Physical Research (BPR) Enterprise, and Space Flight (SF) Enterprise through areas in:

- Environmental and Ecological Technologies
- Operations Industrial Engineering
- Advanced Spacecraft Life Support
- Biomass Production for Planetary Missions
- Process and Human Factors Engineering Technologies
- Spaceport Cryogenic Fluids Handling and Storage Technologies
- Spaceport/Range Instrumentation and Control Technologies
- Electromagnetic Physics Measurements, Control, and Simulation Technologies
- Spaceport Command, Control, and Monitor Technologies
- Launch and Payload Processing System
- In Situ Resource Utilization of Planetary Materials for Human Space Missions
- Understanding and Utilizing Gravitational Effects on Plants and Animals

The KSC SBIR/STTR program management functions within the Technology Transfer Office and coordinates the development of the annual subtopics with representatives of the Enterprise, identifies technical reviewers, coordinates proposal evaluations, provides the Center's ranking documents, and coordinates Contracting Officer's Technical Representatives (COTRs) to manage the awarded contracts. The program success is measured by new technology utilization, Phase III contracts, commercial success stories, patents, licenses, and publication in "Aerospace Technology Innovation" and "NASA Tech Briefs."

The KSC SBIR/STTR staff has compiled this 2004 Program Year Report to recognize the hard work and contribution of the COTRs and technology managers and to provide research and development results for your review and consideration. The Report includes the identification and significance of the innovation and the contact information (company, university, and COTR). We thank the COTRs who participated in the program and encourage interested, motivated technical individuals to serve as proposal reviewers and COTRs.

# SBIR/STTR Program Overview

The Kennedy Space Center Level III SBIR/STTR management staff is under the Technology Transfer Office within the Spaceport Engineering and Technology Directorate. The SBIR and STTR programs provide an opportunity for small high-technology companies and research institutions to participate in Government-sponsored research and development (R&D) programs in key technology areas.

The SBIR program was established by Congress in 1982 to provide increased opportunities for small businesses to participate in R&D programs, increase employment, and improve U.S. competitiveness. The program's specific objectives are to stimulate U.S. technological innovation, use small businesses to meet Federal research and development needs, increase private sector commercialization of innovations, and foster and encourage participation by socially disadvantaged businesses. Legislation enacted in December 2000 reauthorized the program and strengthened emphasis on pursuing commercial applications of SBIR projects.

An SBIR Phase I contract is the opportunity to establish the feasibility and technical merit of a proposed innovation. Selected competitively, the Phase I contract lasts for 6 months and is funded up to $70,000. SBIR Phase II contracts continue the most promising Phase I projects based on scientific/technical merit, expected value to NASA, company capability, and commercial potential. Phase II contracts are usually for a period of 24 months and may not exceed $600,000. NASA usually selects approximately 40 percent of Phase I projects to continue to the Phase II level. Phase III is the process of furthering the development of a product to make it commercially available.

The STTR program awards contracts to small business concerns for cooperative R&D with a nonprofit research institution. Research institutions include nonprofit research organizations, Federal laboratories, or universities. The goal of the program established by Congress is to facilitate the transfer of technology developed by a research institution through the entrepreneurship of a small business. The STTR program is smaller in funding than the SBIR program. While the proposal is submitted by the small business concern, at least 30 percent of the funding and work must originate with the research institution. STTR Phase I projects receive up to $100K for a one-year effort, and a Phase II contract receives up to $600K for two years.

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# Small Business Innovation Research (SBIR)

## Phase I

# Biological and Physical Research

## Fundamental Space Biology

# Fundamental Space Biology

## Understanding and Utilizing Gravitational Effects on Plants and Animals

## Aseptic Plant Culture System (APCS)

Orbital Technologies Corp. (ORBITEC)
Principal Investigator: Robert C. Morrow
Contract No: NNK04OA13C
NASA COTR: Dennis Chamberland
Phase/Solicitation Year: Phase I/2003

### Identification and Significance of Innovation

Aseptic plant culture plays a significant role in biotechnology and plant physiology research and in vegetative propagation of many plant species. The development of an Aseptic Plant Culture System provides a mechanism for experimentation as well as for transporting and storing vegetatively propagated plant material in space. Most culture systems are passive, with no environmental monitoring or control. This project developed a full environmental control and monitoring system for aseptic culture that can accommodate, without modification, a variety of standard culture vessels. The system consists of a base unit that permits culture vessels to be inserted or removed as desired. Multiple culture vessel sizes and shapes are accommodated using a generic connector system. Environmental parameters controlled and monitored include light level and spectral quality, photoperiod, air and media temperature, humidity, and atmospheric composition. Using innovative, high-precision miniature environmental control components allow each vessel to maintain independent control set points if desired. Particular challenges included developing a miniaturized humidity control system, precisely controlling the gaseous environment in small volumes, and maintaining sterility for an extended duration.

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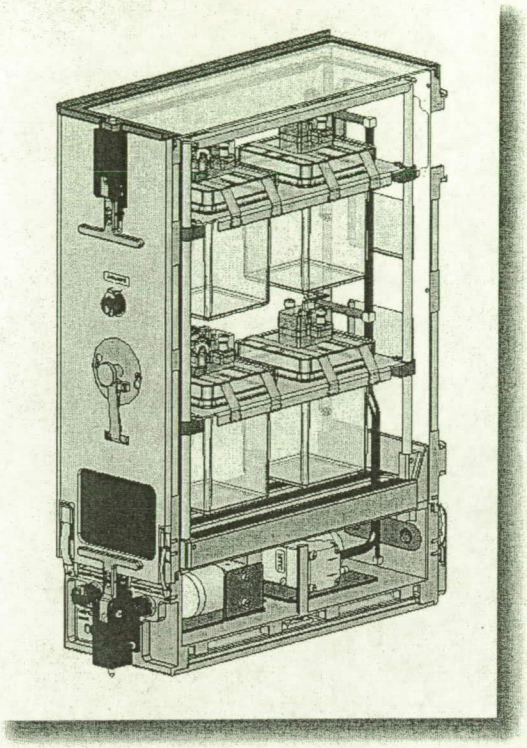
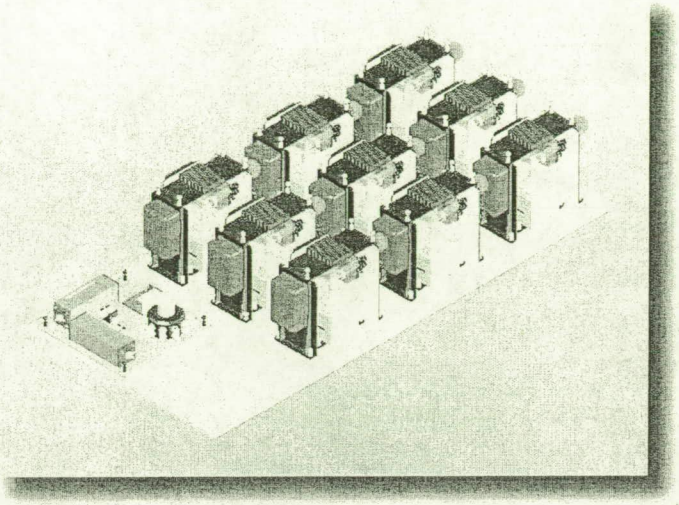
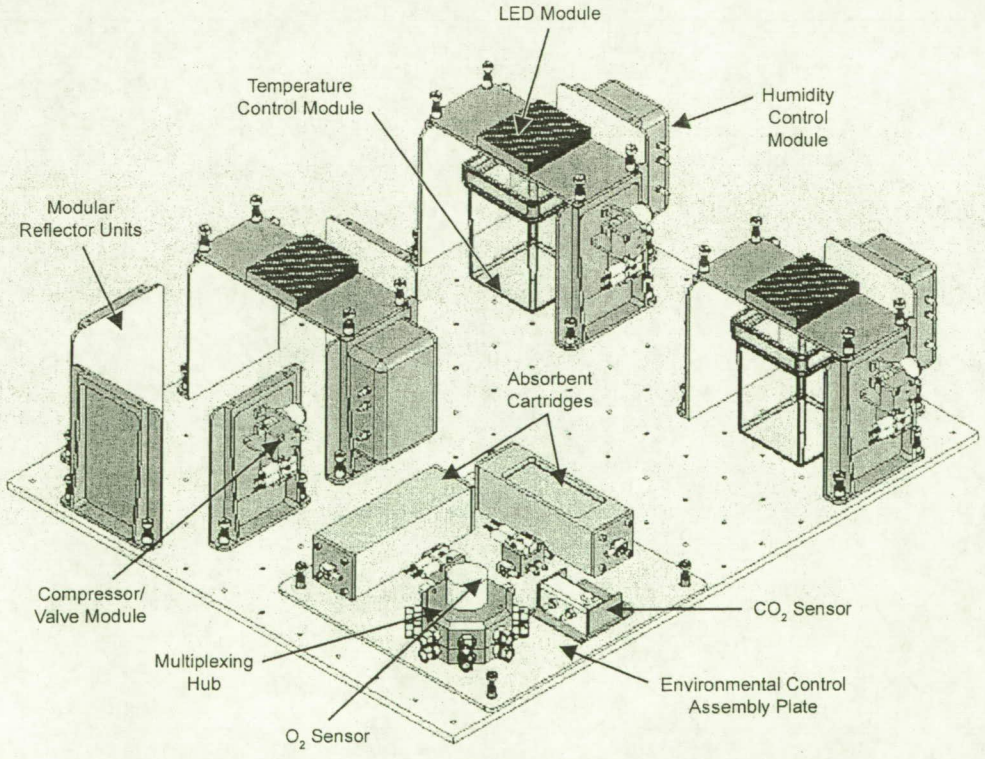
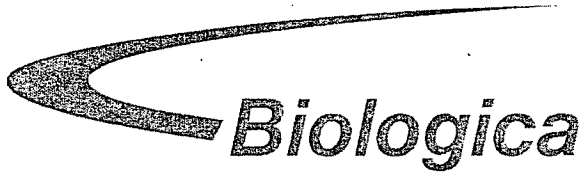





LED Module
Temperature Control Module
Humidity Control Module
Modular Reflector Units
Absorbent Cartridges
Compressor/ Valve Module
$CO_2$ Sensor
Multiplexing Hub
Environmental Control Assembly Plate
$O_2$ Sensor



# Biological and Physical Research

## Biomedical and Human Support Research

# Biomedical and Human Support Research

## Biomass Production for Planetary Missions

## Molecular-Resonance Fiber-Optic Gas Sensors

Aspen Systems, Inc.
Principal Investigator: Jae Ryu
Contract No: NNK04OA14C
NASA COTR: Dennis Chamberland
Phase/Solicitation Year: Phase I/2003

### Identification and Significance of Innovation

Aspen Systems developed an innovative smart sensor that continuously monitors ambient air compositions using resonating tunable microcavity technology. The new device will directly measure the unique vibrational resonance of gas molecules and determine the concentration of each constituent gas species. Phase I will experimentally demonstrate the proposed concept by monitoring ambient air concentrations using the resonating tunable microcavity sensor. Selectivity and sensitivity of each gas species in the air will be determined. Furthermore, the linear response ranges of the proposed air monitoring system (as a function of test gas compositions [including carbon dioxide and ethylene], temperatures, and relative humidity) will be determined. In Phase II, a prototype system for air monitoring in biomass production environments will be fabricated and tested.

The resulting smart gas sensors will be extremely compact, accurate, reliable, lightweight, and low-power-consuming. They will require no extra supplies for operation and will be fully automated and microprocessor-controllable. Furthermore, the same gas sensing and monitoring system can be used to measure relative humidity, pressures, and temperatures of ambient air by using slightly modified sensor designs.

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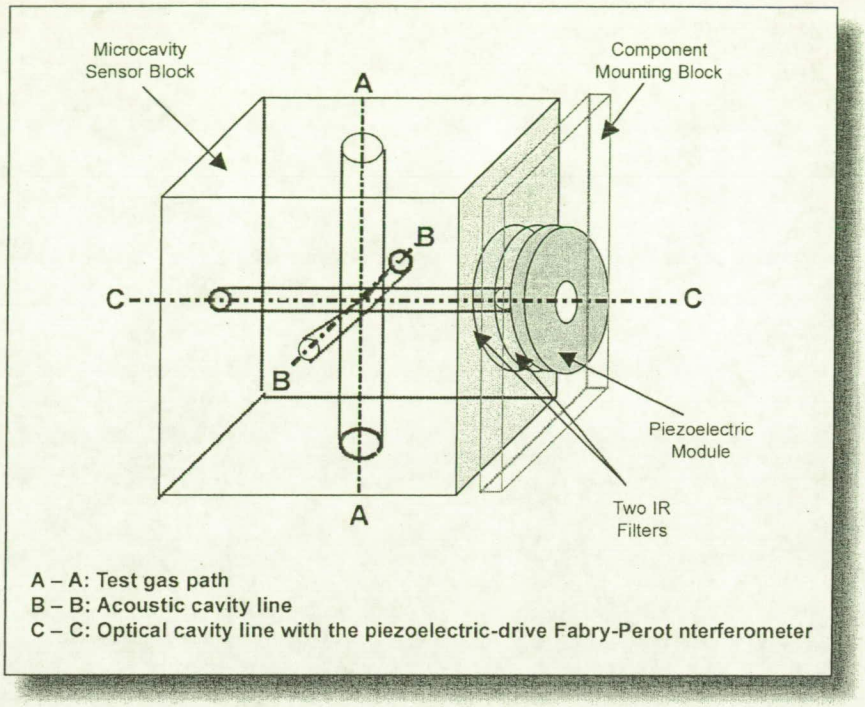
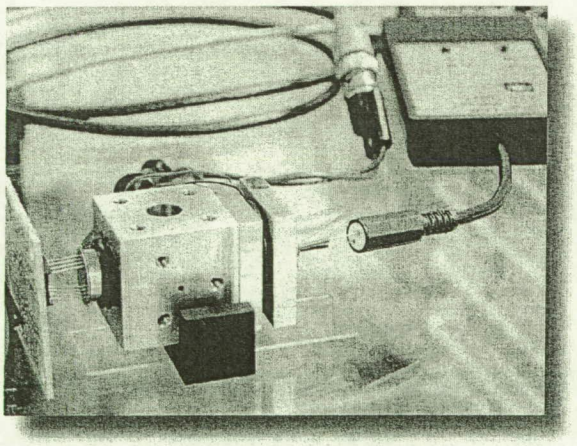
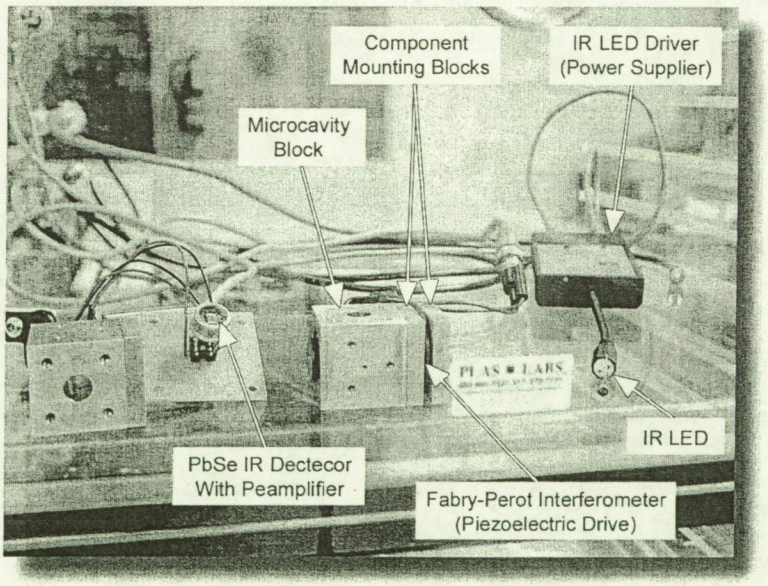



A schematic of microcavity block.



Assembled microcavity blocks in a test chamber.




Optical components in the microcavity block.

# Biomedical and Human Support Research

## Biomass Production for Planetary Missions

### Electrochemical Carbon Dioxide Sensor for Plant Production Environments

Giner, Inc.
Principal Investigator: Mourad Manoukian
Contract No: NNK04OA15C
NASA COTR: Dennis Chamberland
Phase/Solicitation Year: Phase I/2003

#### Identification and Significance of Innovation

Giner developed a low-power-consuming, solid-polymer, electrolyte-based, miniaturized, electrochemical $CO_2$ sensor that can continuously, accurately, and rapidly monitor $CO_2$ concentrations in closed or nearly closed environments for monitoring and control approaches for plant production environments, to aid in NASA's biomass (edible food) production research. The sensor introduces a much simpler, lower-cost, and more accurate alternative to the existing infrared technology used to measure $CO_2$ and study its effects on plant growth. During Phase I, in addition to demonstrating the feasibility of the concept, the ability of the sensor to detect 0 to 10 percent $CO_2$ in a wide range of temperature (15 to 45 °C) and humidity (10 to 99 percent relative humidity) conditions was demonstrated. The sensor was evaluated for fast response and continuous operation for 100 hours. In Phase II, the sensor will be integrated into a complete instrument, which will be small and lightweight and will allow for independent operation of the sensor, complete with calibration routine, adjustable applied-potential settings, and digital display of numeric results. The unit will be battery-operated with an ac converter and battery charger.

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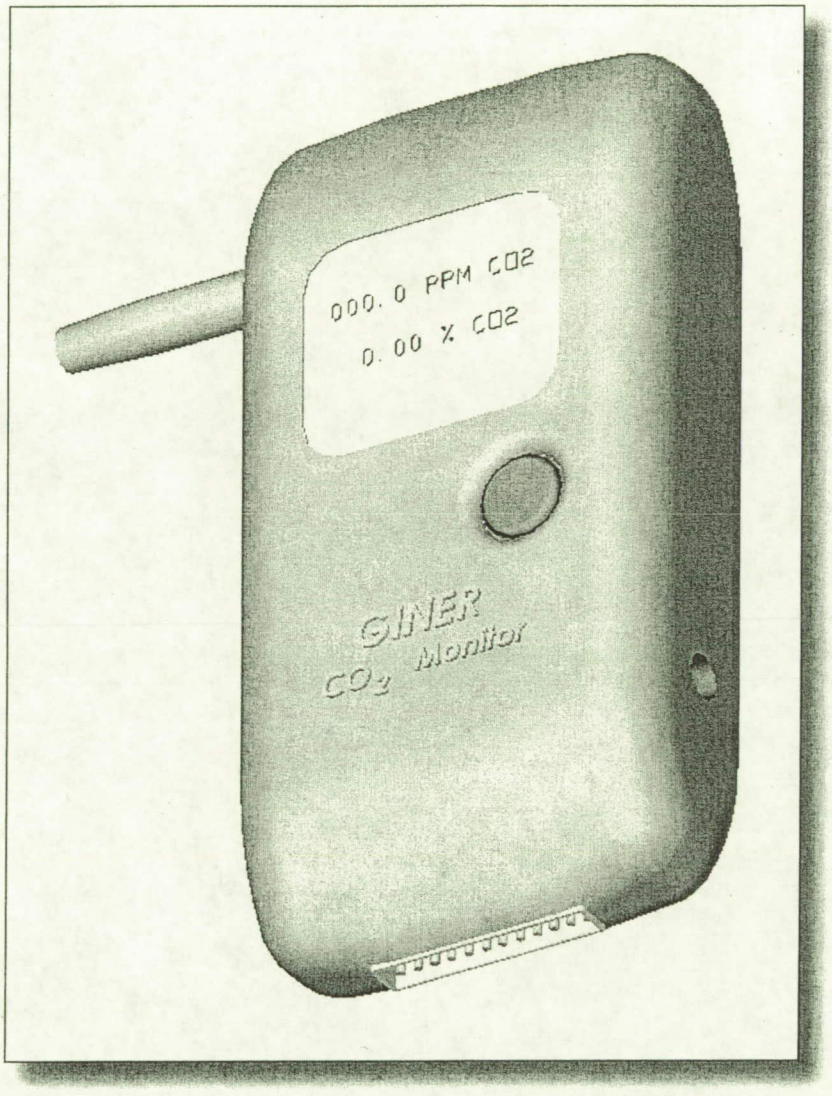
000.0 PPM CO2
0.00 % CO2
GINER
Monitor
CO2

# Space Flight (SF) Enterprise

## Systems Integration, Analysis, and Modeling

# Systems Integration, Analysis, and Modeling

## Process and Human Factors Engineering Technologies

## AreaAdvisor: Spatial, Real-Time Resource Intelligence

Stottler Henke Associates, Inc.
Principal Investigator: Richard H. Stottler
Contract No: NNK04OA17C
NASA COTR: Tracey Kickbusch
Phase/Solicitation Year: Phase I/2003

### Identification and Significance of Innovation

As processing and manufacturing facilities quickly progress from barcode to radio frequency identification (RFID) and similar technologies to track the movement of resources (tools, parts, support equipment), many related opportunities to cut costs and increase safety by reducing human error are emerging. Stottler Henke Associates developed AreaAdvisor, an artificial-intelligence (AI) software system that manages this new tracking data, featuring innovative spatial scheduler and data mining capabilities.

AreaAdvisor allows KSC planners to schedule resources to personnel and two-dimensional space within facilities and to catch errors immediately as they occur (nonarrivals, resource scanned in wrong area/by wrong personnel, etc.). The scheduling algorithms allow planners to use available spaces optimally (e.g., less-used resources can be stored farther back in dwell areas). The tool also employs Bayesian technologies to probabilistically infer the location of missing resources (even tools without identification tags, such as drill bits) based on patterns discovered in their usage and location history.

AreaAdvisor has an intuitive visual interface that allows users with mouse or pen-tablet devices to interactively edit schedules and lay out resources within critical areas.

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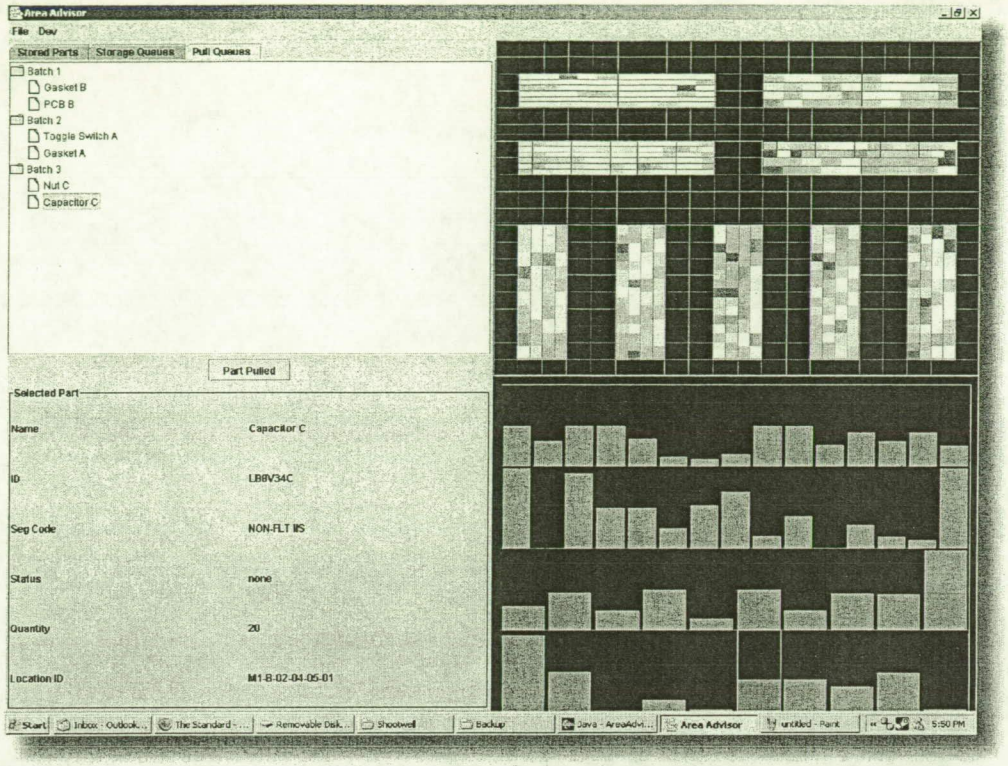
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File Dev
Stored Parts
Storage Queues
Pull Queues
Batch 1
Gasket B
PCB B
Batch 2
Toggle Switch A
Gasket A
Batch 3
Nut C
Capacitor C
Part Pulled
Selected Part
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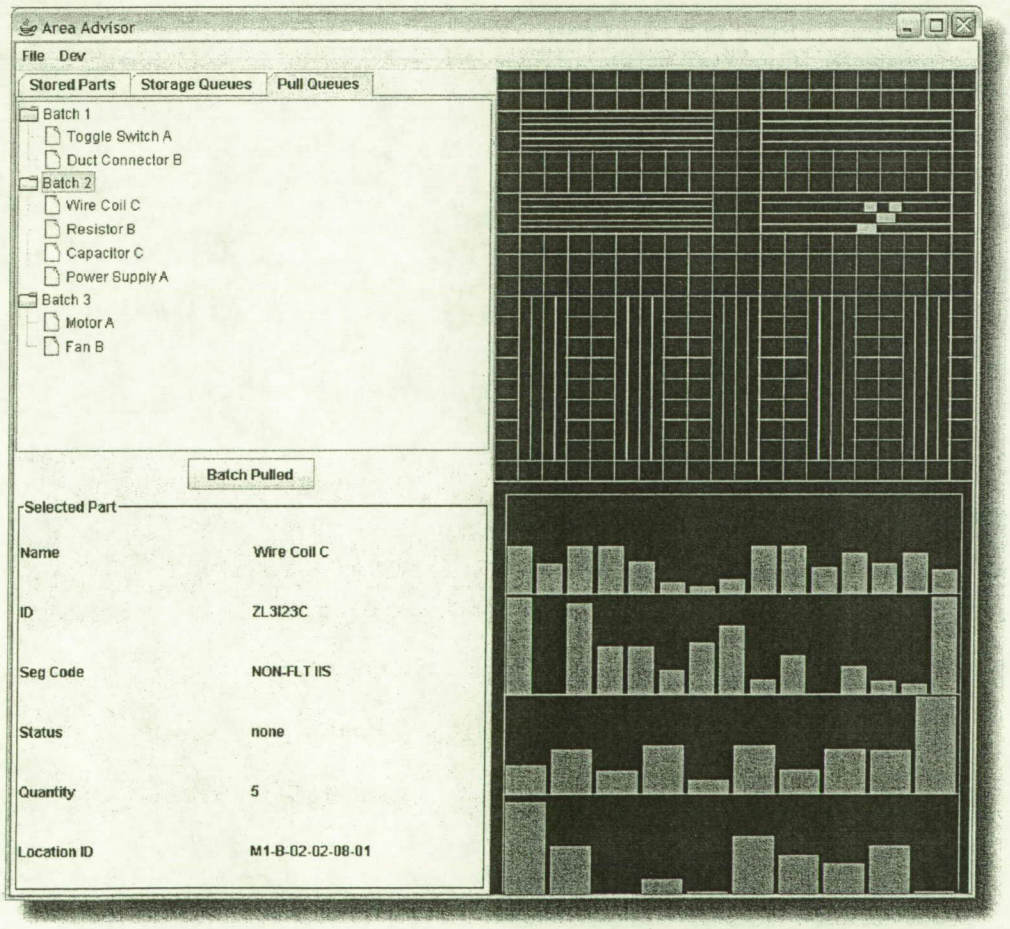
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File Dev
Stored Parts
Storage Queues
Pull Queues
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Toggle Switch A
Duct Connector B
Batch 2
Wire Coil C
Resistor B
Capacitor C
Power Supply A
Batch 3
Motor A
Fan B
Batch Pulled
Selected Part
Name
Wire Coil C
ID
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Seg Code
NON-FLT IIS
Status
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Quantity
5
Location ID
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# Systems Integration, Analysis, and Modeling

## Process and Human Factors Engineering Technologies

## Moisture-Resistant Thermal Protection System (TPS) Materials

Powdermet, Inc.
Principal Investigator: Andrew J. Sherman
Contract No: NNK04OA16C
NASA COTR: Gena Henderson
Phase/Solicitation Year: Phase I/2003

### Identification and Significance of Innovation

This NASA Phase I SBIR generated closed-cell foam thermal protection system (TPS) materials that do not need waterproofing, can be applied as a coating to replace impregnation densification processes, and can potentially protect critical structural elements from penetration of hot reentry gases in the event of damage to the external insulation. Specifically, the program demonstrated preceramic polymer-derived syntactic foams and plasma-sprayed syntactic foam coatings that can survive exposures to 2,500 °F erosive gases while being waterproof and able to withstand high-pressure water jet cleaning processes. The foams and low-density thermal barrier coatings (TBCs) could replace a portion of the foam insulation on the Space Shuttle's Solid Rocket Boosters and External Tank, as well as providing a backup TBC to protect space transportation system structures in the event of localized insulation failure.

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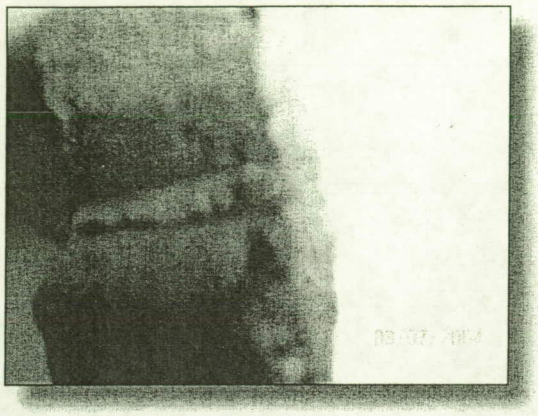

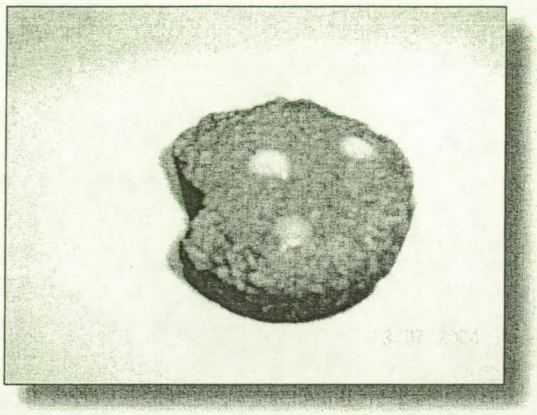

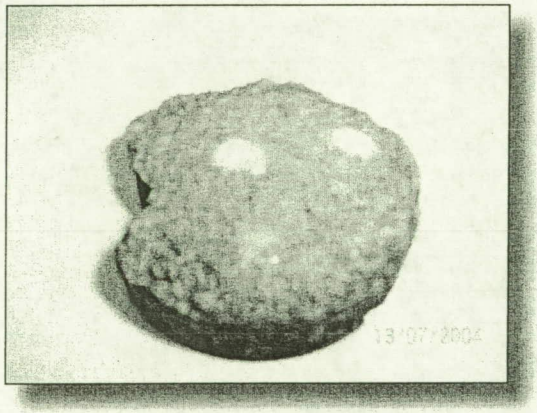

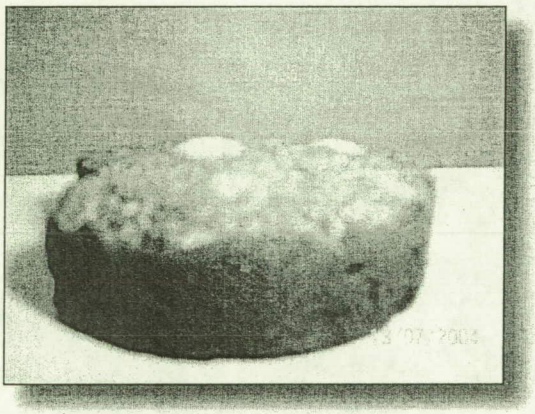


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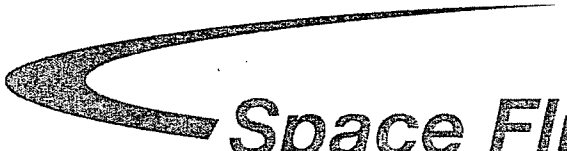

# Space Flight (SF) Enterprise

## Space Utilities and Power

# Space Utilities and Power

## Spaceport Cryogenic Fluids Handling and Storage Technologies

### Ormosil Beads for Insulation of Ground Cryogenic Storage Tanks

Aspen Aerogels, Inc.
Principal Investigator: Roxana Trifu
Contract No: NNK04OA18C
NASA COTR: Lisa Wellington
Phase/Solicitation Year: Phase I/2003

#### Identification and Significance of Innovation

Advanced materials are required to insulate cryogenic storage and distribution systems for liquid propellants, such as hydrogen and oxygen, used in orbital transfer and interplanetary missions. From the energy and economics point of view, development of cost-effective, robust cryogenic insulation systems that operate at soft vacuum level constitutes a main target for NASA.

The lightweight aerogel materials developed by Aspen Aerogels have already demonstrated excellent insulation performance at both ambient and low pressures. Aspen Aerogels developed novel organically modified aerogel beads with superior compression resistance that will successfully replace perlite insulation in large ground tanks for storage of liquid propellants. The lightweight ormosil beads with optimized thermal conductivity at cold vacuum pressures help extend propellant storage life. In addition, the stiff beads are not easily crushable and, unlike perlite, will not settle in the vacuum jacket. Reducing boiloff losses at moderate vacuum level minimizes total storage cost for cryogenic fluids. The Aspen Aerogel solution will result in a more than an 80-percent reduction of the insulation area density and save 40 percent in cost over perlite.

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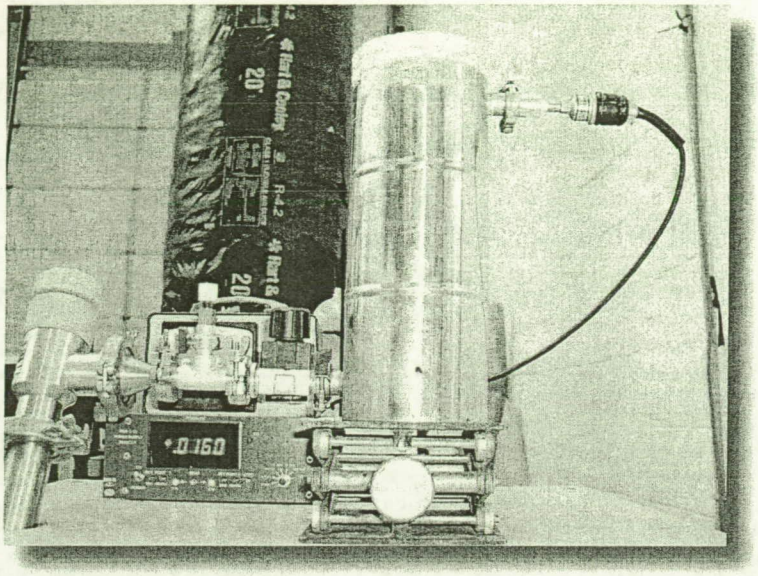

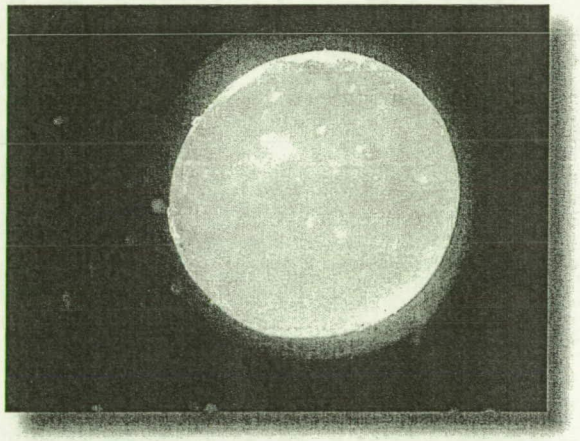

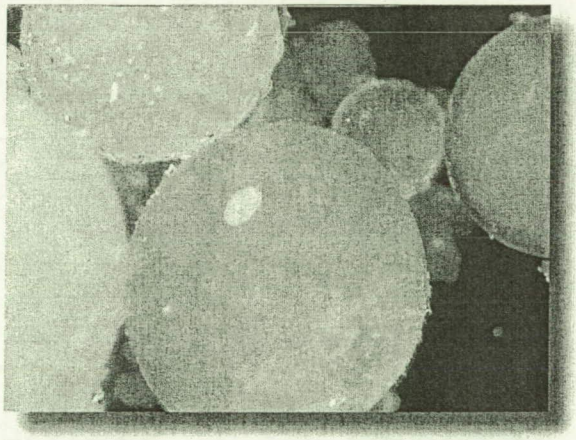

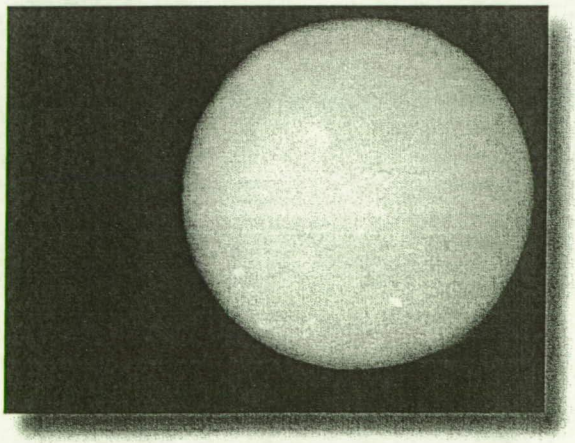

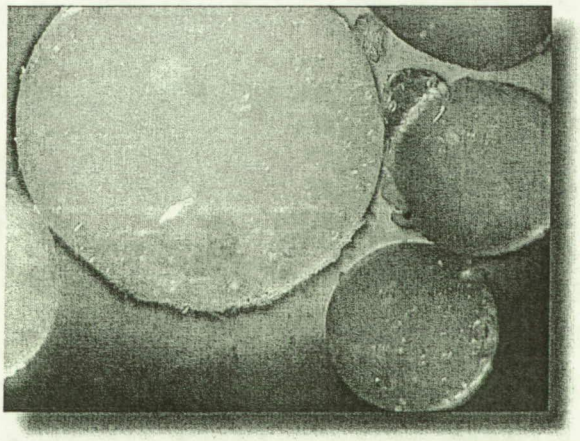

# Space Utilities and Power

## Spaceport Cryogenic Fluids Handling and Storage Technologies

### Cryogenic Cooling System for Zero-Venting Storage of Supercritical Air Packs

Creare, Inc.
Principal Investigator: Michael G. Izenson
Contract No: NNK04OA19C
NASA COTR: Don Doerr
Phase/Solicitation Year: Phase I/2003

#### Identification and Significance of Innovation

Supercritical air at cryogenic temperature is an attractive source of breathing air because of its very high density and low pressure. However, heat leakage into the cryogenic tank causes the stored air to expand and vent, thus limiting the storage life of a charged system. Creare developed a storage system for supercritical air tanks that provides cryogenic cooling and intercepts heat leaks, thus preventing venting and enabling long-term storage of charged, supercritical air tanks. The innovative mechanical cryocooling system provides flexible coupling and quick disconnection from the storage tanks, as well as high reliability and efficient low-power operation. In addition to storage, the system can be used to charge the tanks with supercritical air without using expendable cryogens. In Phase I, system feasibility was proven through design tradeoff and optimization analyses that produced a conceptual design and operational description of a supercritical air storage system. The system is designed to store multiple units of NASA's existing supercritical air self-contained breathing apparatus (SCBA) system. In Phase II, Creare will build and demonstrate a prototype storage system for supercritical air SCBAs.

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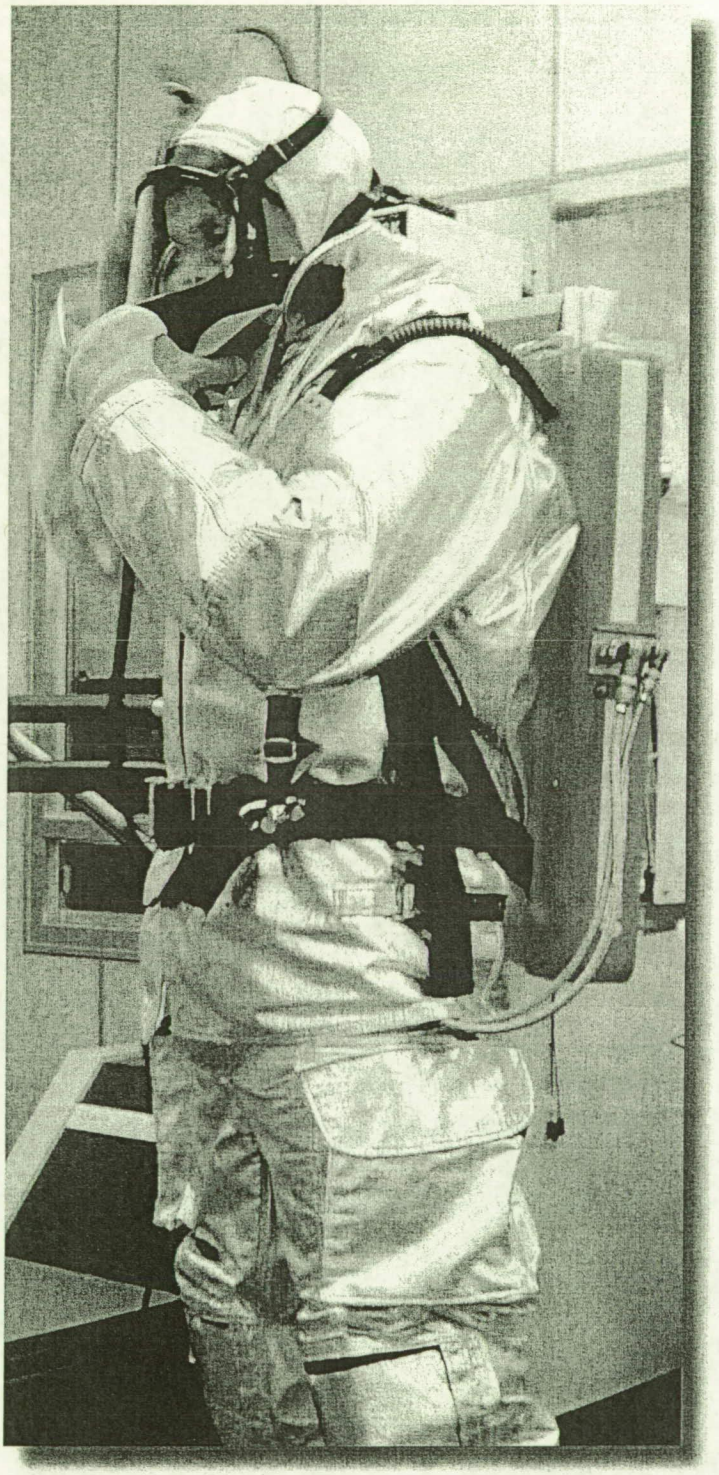

# Space Utilities and Power

## Spaceport/Range Instrumentation and Control Technologies

### Automated Multiple-Object Optical Tracking and Recognition System

OPTRA, Inc.
Principal Investigator: Michael Hercher
Contract No: NNK04OA21C
NASA COTR: James C. Simpson
Phase/Solicitation Year: Phase I/2003

#### Identification and Significance of Innovation

OPTRA developed an optical tracking system that recognizes and tracks up to 50 different objects within approximately a 2- by 3-degree field of view. The system outputs three-dimensional (3-D) trajectories for each of the objects. The primary function of the system is to monitor the first two minutes of a space vehicle launch. Following any catastrophic event at launch, this system provides a wealth of detailed information that can be used both in real time and in subsequent accident analyses. The system consists of three high-resolution digital cameras with telephoto lenses mounted on GPS-equipped servo-controlled ALT/AZ platforms. System hardware consists largely of commercial off-the-shelf components, resulting in proven performance, high reliability, and low cost. Key elements in the effort were the development of robust target identification and tracking algorithms, as well as the algorithms needed to convert the three separate 2-D trajectory sets to a single 3-D trajectory set.

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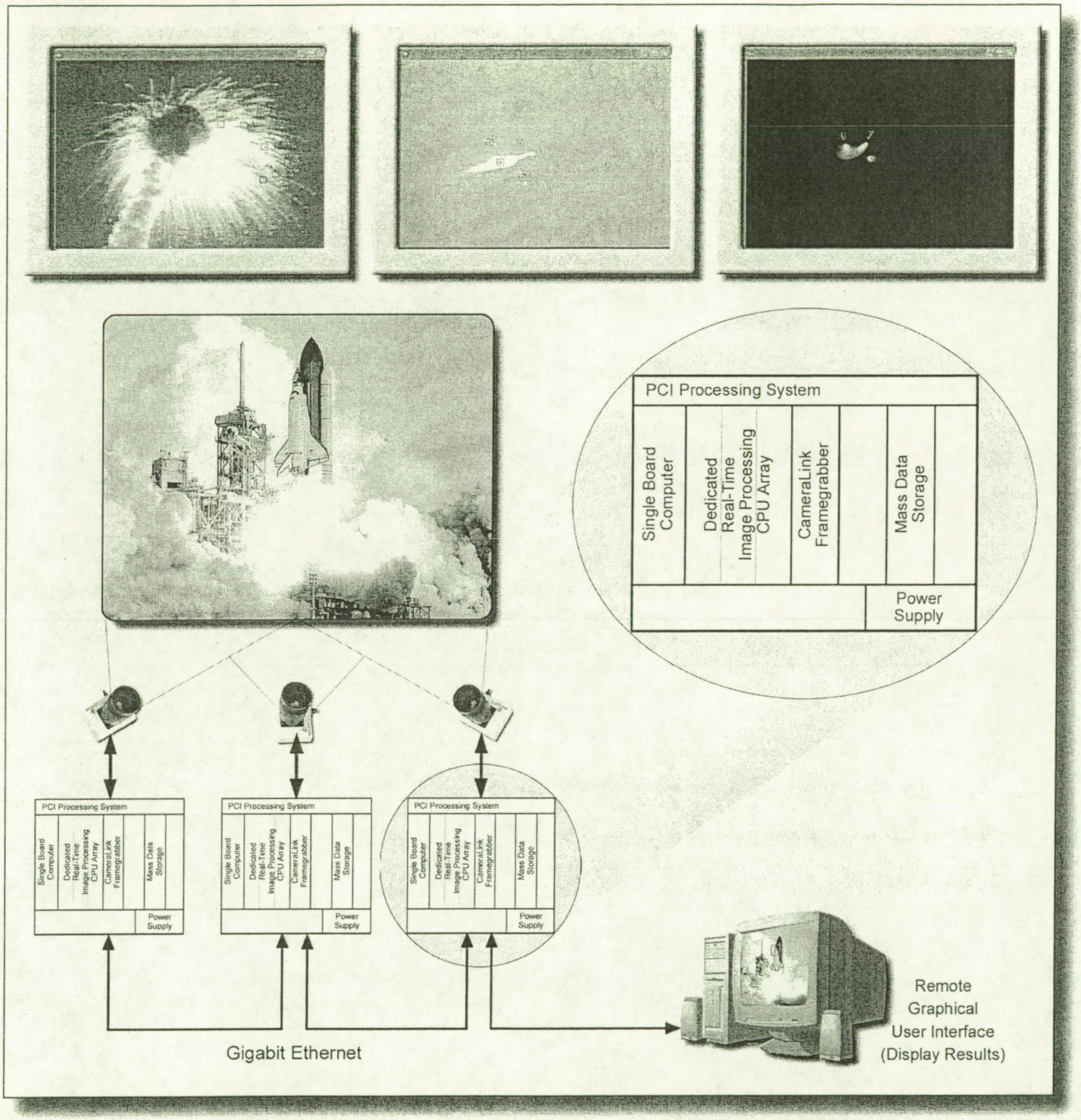


Real-time processing architecture utilizing a dedicated image processing CPU array and high-speed gigabit Ethernet and data storage. Acquired images are processed and objects of interest are highlighted and tracked. End-point predictions for each object are continuously updated.

# Space Utilities and Power

## Spaceport/Range Instrumentation and Control Technologies

### C-Band SATCOM Range Communications System for ELVs Using Earth Station Antennas and High-Dynamics Modem

Paratek Microwave, Inc.
Principal Investigator: Qinghua Kang
Contract No: NNK04OA20C
NASA COTR: Richard Nelson
Phase/Solicitation Year: Phase I/2003

#### Identification and Significance of Innovation

Improving safety while increasing the pace of space launches requires improved communications capability. An increasing volume of real-time data from numerous sensors and systems can be transmitted to the ground if connecting links can be improved. One way to accomplish this is to use existing commercial satellites to supplement overburdened NASA communications systems. Used as an adjunct service, additional commercial capacity can increase launch safety, allowing more data to be transponded to ground systems without detracting from the reliability of existing communication systems. Existing NASA links can continue to be used for mission-critical requirements.

Limitations of two technologies prevent transponding large amounts of data via commercial satellites. The first is a conformal antenna technology that can provide high gain by steering its beam toward the GEO satellite. The second is high-speed modem technology that can track a remote modem despite the wide dynamics experienced during launch and maneuvers.

Paratek designd a dual-beam, passive, electronically steered phased array (using our proprietary Parascan phase shifters) and a highly dynamic modem to provide the communications link for spaced-based range applications. The system leverages commercial Intelsat C-band transponder network (4 GHz and 6 GHz).

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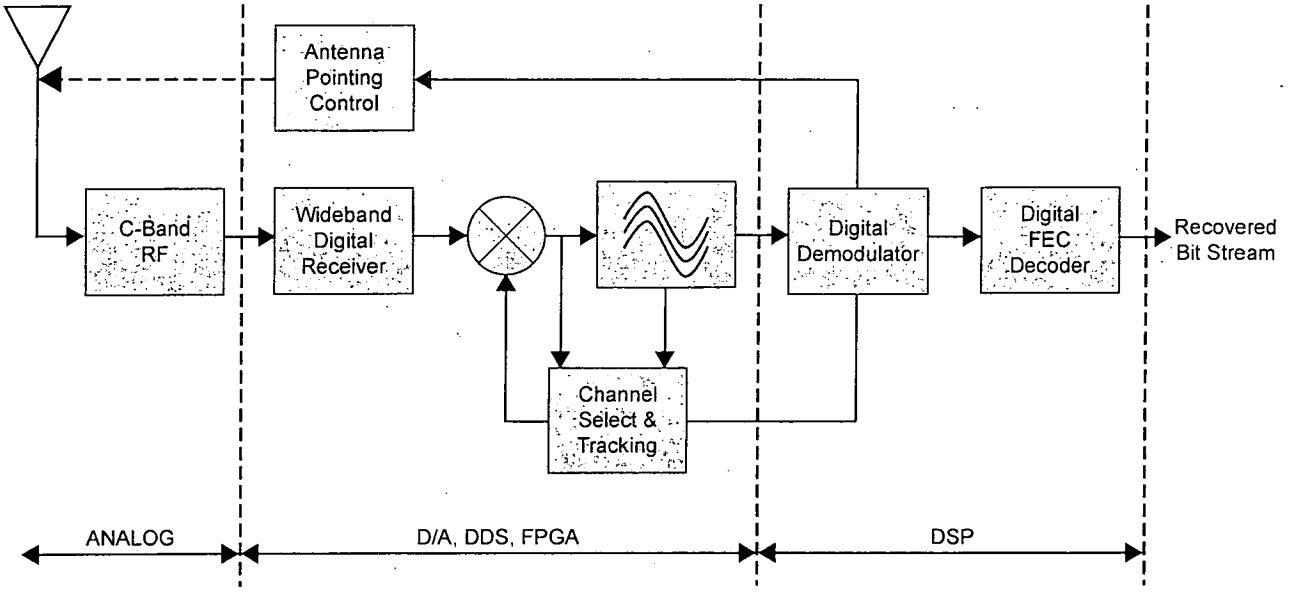
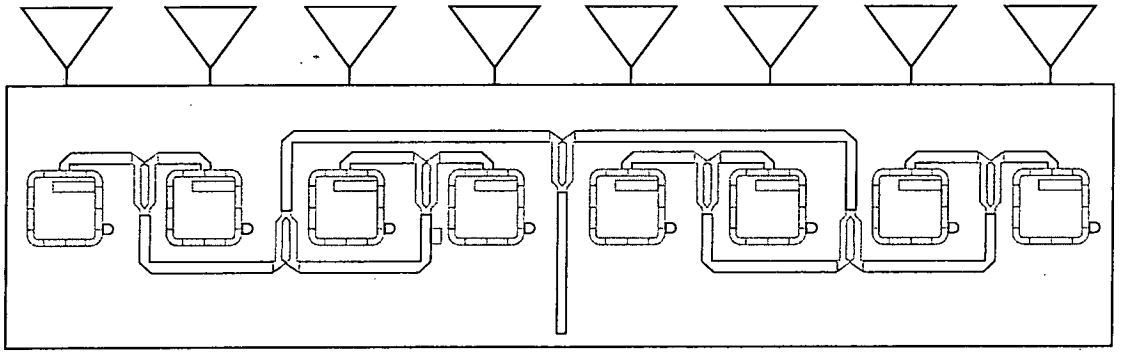



Antenna to baseband system.



Eight element array module with divider network and phase shifters.
Radiating elements are placed on opposite side.

# Space Utilities and Power

## Electromagnetic Physics Measurement, Control, and Simulation Technologies

### Multipurpose Electric Potential Sensor for Spacecraft Applications

Quantum Applied Science and Research, Inc.
Principal Investigator: Yongming Zhang
Contract No: NNK04OA22C
NASA COTR: Carlos Calle
Phase/Solicitation Year: Phase I/2003

#### Identification and Significance of Innovation

This project is based on a new, compact, solid-state electric potential sensor that has over an order of magnitude lower voltage noise than the prior state of the art. This project configured miniature sensors mounted on the extremities of a spacecraft or lander to measure the local electric potential, field, and field gradients. This technology has never before been adapted for specific NASA applications. This project was a transition from DOD applications to NASA. Quantum Applied Science and Research studied NASA requirements, set ranges for mission parameters, and optimized the electric sensor for related applications. Various configurations were designed and tested, and space-qualified components were selected to build the sensor. This sensor detects electrostatic fields and their hazards with sensitivity beyond what is offered by current technology. The sensor has applications for military use, medicine, lightning detection and prediction, geological science, and other scientific instrumentation.

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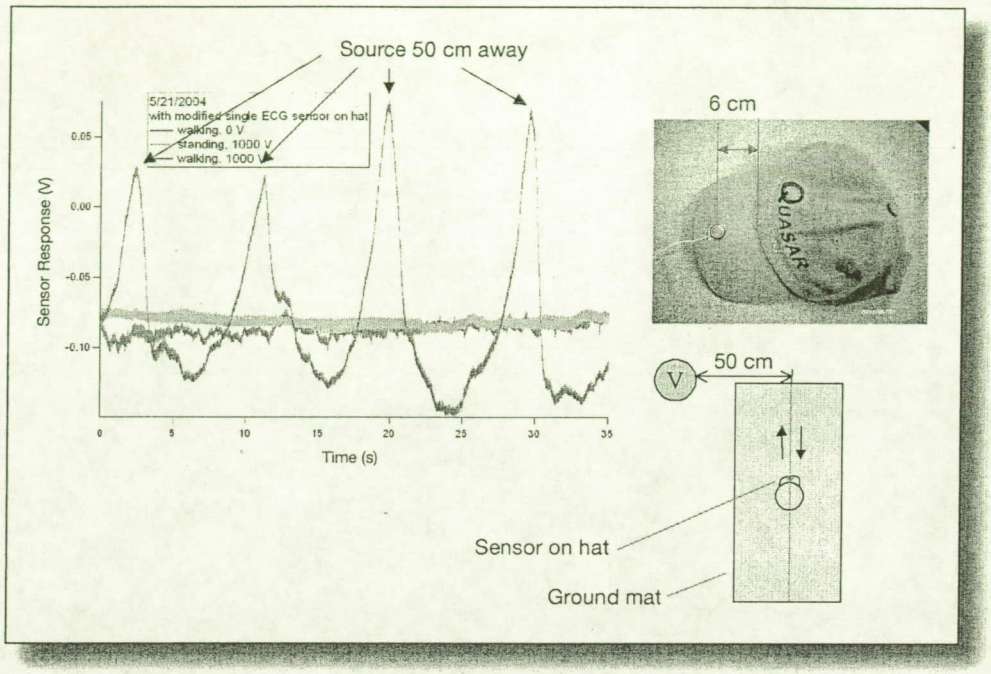
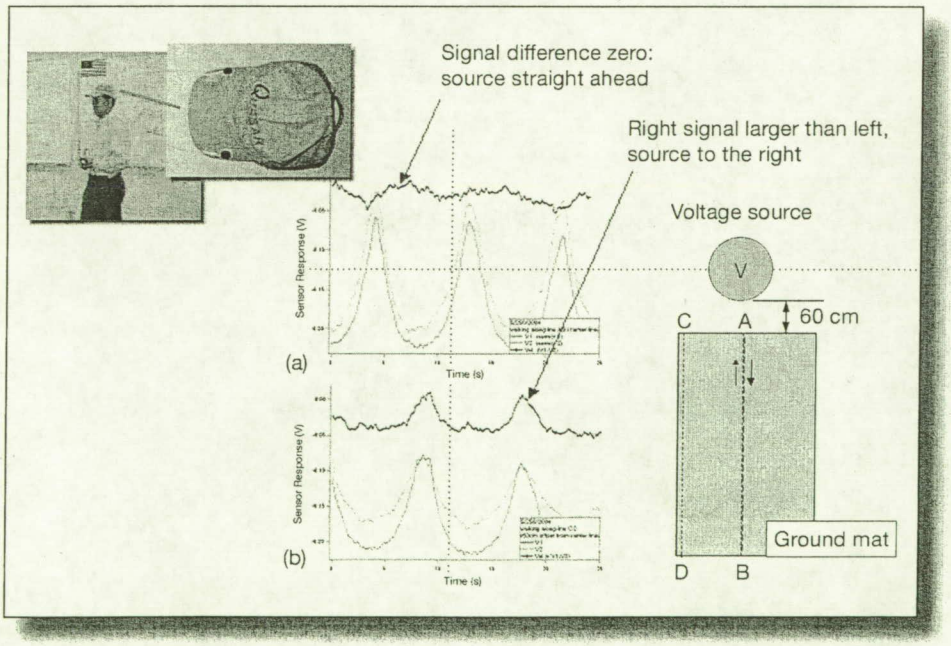



Response of a sensor mounted on a person's cap. The person is walking back and forth on a grounded mat of 1 by 1.8 m. The closest distance between the person and the voltage source (1 kV) is about 50 cm.




Detecting the direction of an electrostatic hazard. Response of the two sensors on a cap and their difference (black) when subject walked back and forth along line AB (red curves) or CD (blue curves).

# Space Utilities and Power

## Spaceport Command, Control, and Monitoring Technologies

### Automated Service Discovery Using Autonomous Control Technologies

Interface and Control Systems, Inc.
Principal Investigator: Brian Buckley
Contract No: NNK04OA24C
NASA COTR: Susan Waterman
Phase/Solicitation Year: Phase I/2003

#### Identification and Significance of Innovation

With the advent of mobile commerce technologies, the realization of pervasive computing, and the formation of ad hoc networks, these technologies can be leveraged to the benefit of the NASA Spaceports in several technical areas. The Automated Service Discovery (ASD) architecture allows a portable real-time expert system to be used to aid in the service discovery; management of communications links; and fault detection, isolation, and recovery for vehicle health management. The ASD system allows significant cost reductions for fielding and maintaining systems at the spaceports. Flight systems can save weight by relying on encrypted wireless links rather than connections to a wiring harness for data transfer. Ground-based systems can reconfigure on the fly using wireless and connection-oriented ad hoc networks.

This project also addressed the need for a standardized command, control, and monitoring system for ground and space infrastructure. ASD uses the same expert system for execution of the algorithms to derive suggestions for least-cost paths for data connectivity. The ASD system enables the expert system to query for service capabilities and adjust goals and constraints based on available resources in real time. The ASD implementation is machine-, language-, and operating-system-neutral.

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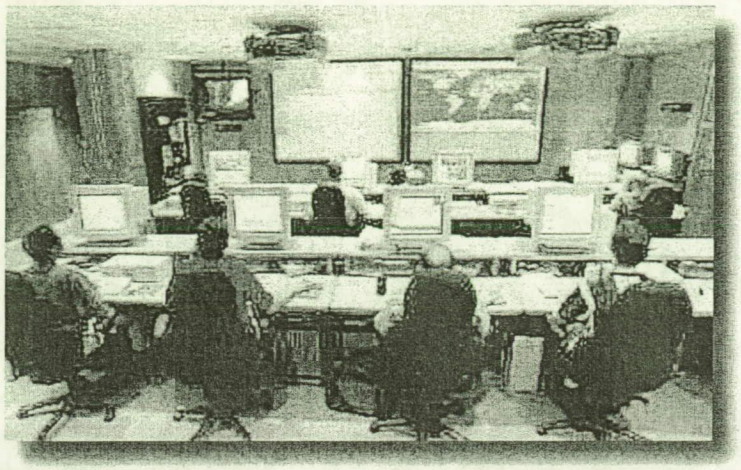

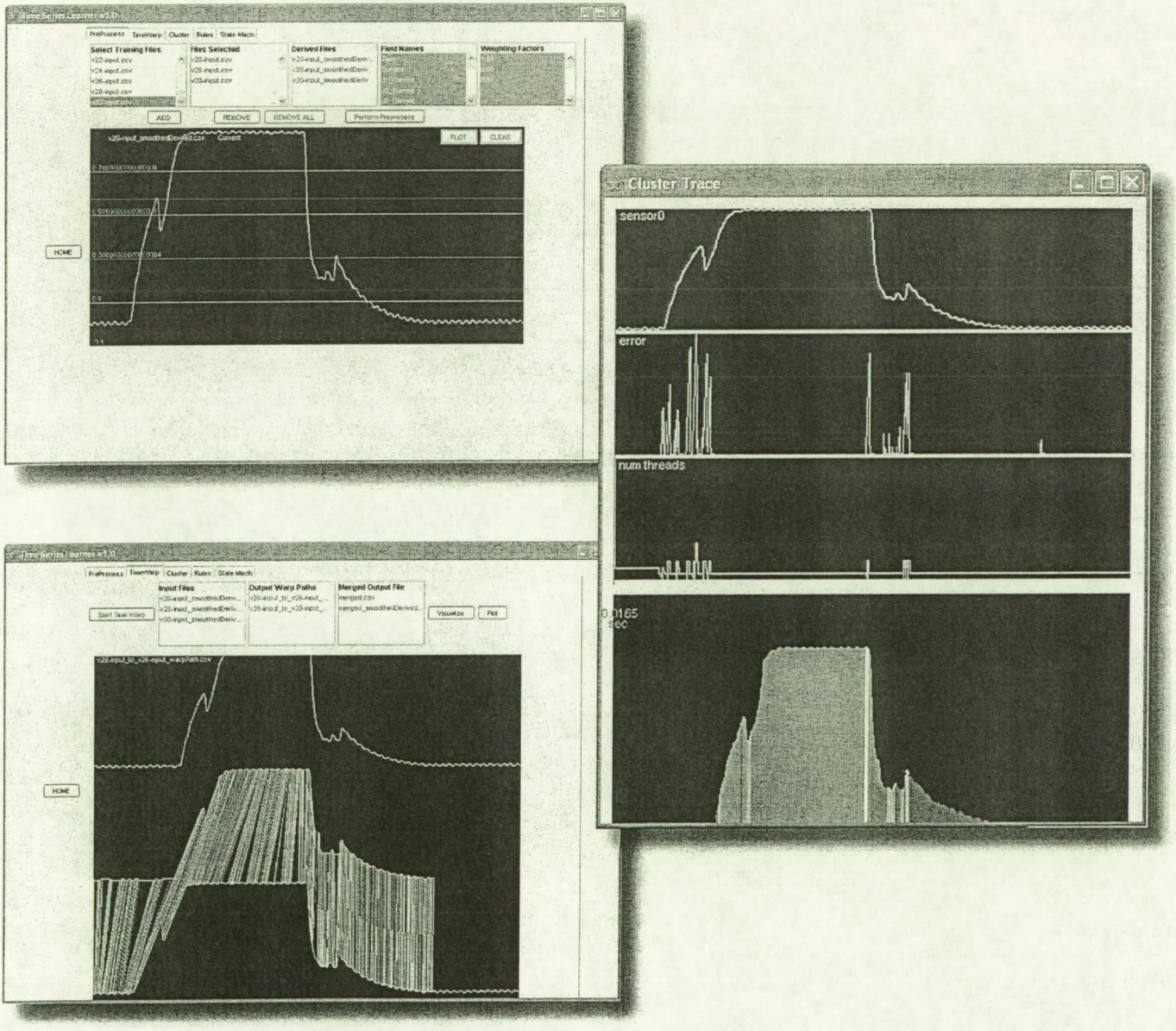
Cluster Trace
sensor0
error
num threads
HOME
PLOT
CLEAR
ADD
REMOVE
REMOVE ALL

# Space Utilities and Power

## Spaceport Command, Control, and Monitoring Technologies

### Arrays of Remote Autonomous Sensors Using Onboard Hybrid Power Supplies

Bipolar Technologies
Principal Investigator: Rodney LaFollette
Contract No: NNK04OA23C
NASA COTR: Eric Green
Phase/Solicitation Year: Phase I/2003

#### Identification and Significance of Innovation

There is significant need for completely wireless miniature sensor arrays. Ideally these sensors would be built as integrated devices including sensing elements, computation/signal conditioning, communication, and an onboard power supply. However, they have not been previously developed because of the difficulty with integrating sensing elements and the absence of miniature power supplies. This Phase I program addressed these two problems and made viable wireless miniature sensors. Bipolar Technologies has pioneered the development of microscopic rechargeable batteries built with integrated-circuit processes for direct integration into microcircuits. When combined with miniature energy scavengers, a hybrid power supply can be created to provide autonomy for wireless sensors. During Phase I, the concept of using a miniature hybrid power supply was demonstrated with arrays of prototype sensors built with commercial off-the-shelf components. Microscopic microfabricated lithium-polymer batteries were engineered, fabricated, and used as part of the hybrid power supply. Phase II will refine the batteries and sensors microfabrication processes so that completely integrated multisensors can be delivered to NASA. This micro-power supply will enable production of a new class of completely wireless sensors.

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# Space Utilities and Power

## Spaceport Command, Control, and Monitoring Technologies

### Wireless, Batteryless, Remote Sensors for Automated Monitoring, Control, and Inspection

TagSense, Inc.
Principal Investigator: Richard Fletcher
Contract No: NNK04OA25C
NASA COTR: Eric Green
Phase/Solicitation Year: Phase I/2003

#### Identification and Significance of Innovation

Two new categories of wireless batteryless sensors, magnetoelastic and LC-type, were developed. These sensors are also chipless, thus providing significantly lower cost and higher operating temperatures than chip-based sensors. This technology is an alternative to surface acoustic wave (SAW) wireless sensors that cannot operate through many materials layers, such as in a vehicle structure or fuel tank. Magnetoelastic sensors and LC sensors operate at lower frequencies that have better penetration and also enable lower-cost readers and antenna arrays to be constructed. Among the parameters that can be sensed are temperature, pressure/strain, humidity, and chemical environment.

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# Space Utilities and Power

## Spaceport Command, Control, and Monitoring Technologies

### Data Description Exchange Services for Heterogeneous Vehicle and Spaceport Control and Monitor Systems

Command and Control Technologies, Inc.
Principal Investigator: Rodney D. Davis
Contract No: NNK04OA27C
NASA COTR: José Amador
Phase/Solicitation Year: Phase I/2003

#### Identification and Significance of Innovation

Command and Control Technologies (CCT) developed an advanced data description exchange approach for space/spaceport systems that provides a generic platform-independent software capability for exchange of semantic control and monitoring information. This new strategy reduces development, operations, and support costs for legacy and future systems that are part of ground- and space-based distributed control systems. It also establishes a space systems information exchange model that can support future highly interoperable and mobile software systems. The concept provides a solution that will ease the adoption of a common data definition and exchange standard for legacy and future systems by minimizing or eliminating the need for custom software modifications.

Phase I of the research demonstrated the viability of creating common access services for the space/ground systems domain based on use of emerging exchange standards for telemetry, and drive-out architecture strategies for cross platform generation of monitoring (e.g., health and status) service middleware by creating a generic definition of the Delta II telemetry stream. Phase II seeks to expand the scope of the target domain to include control services and create a complete usable suite of services for a broader range of heterogeneous systems.

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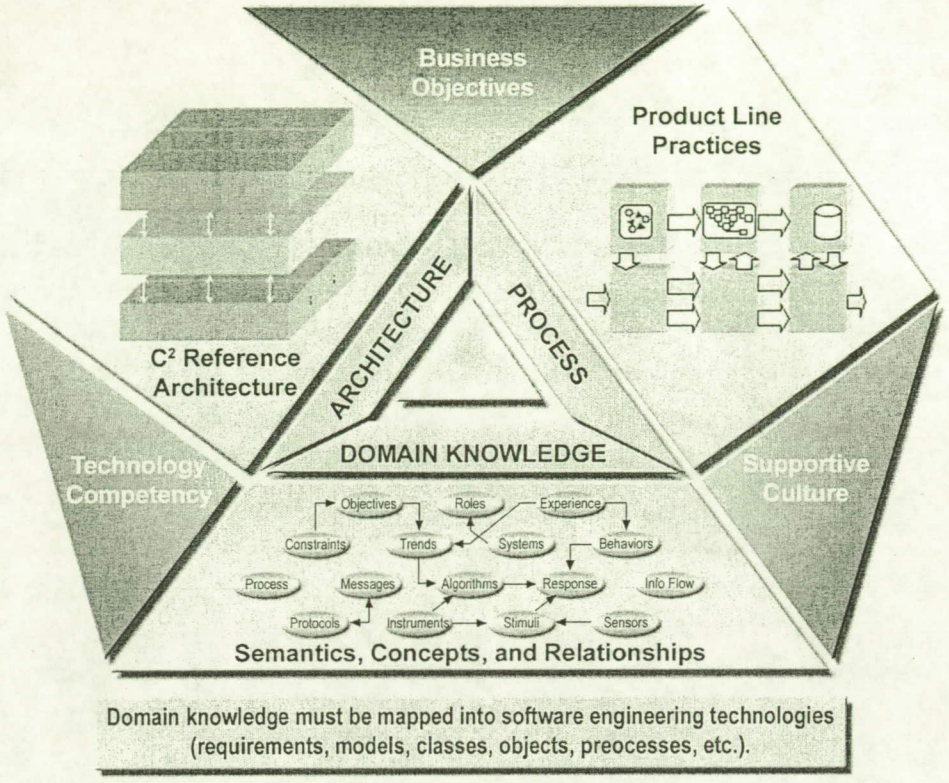
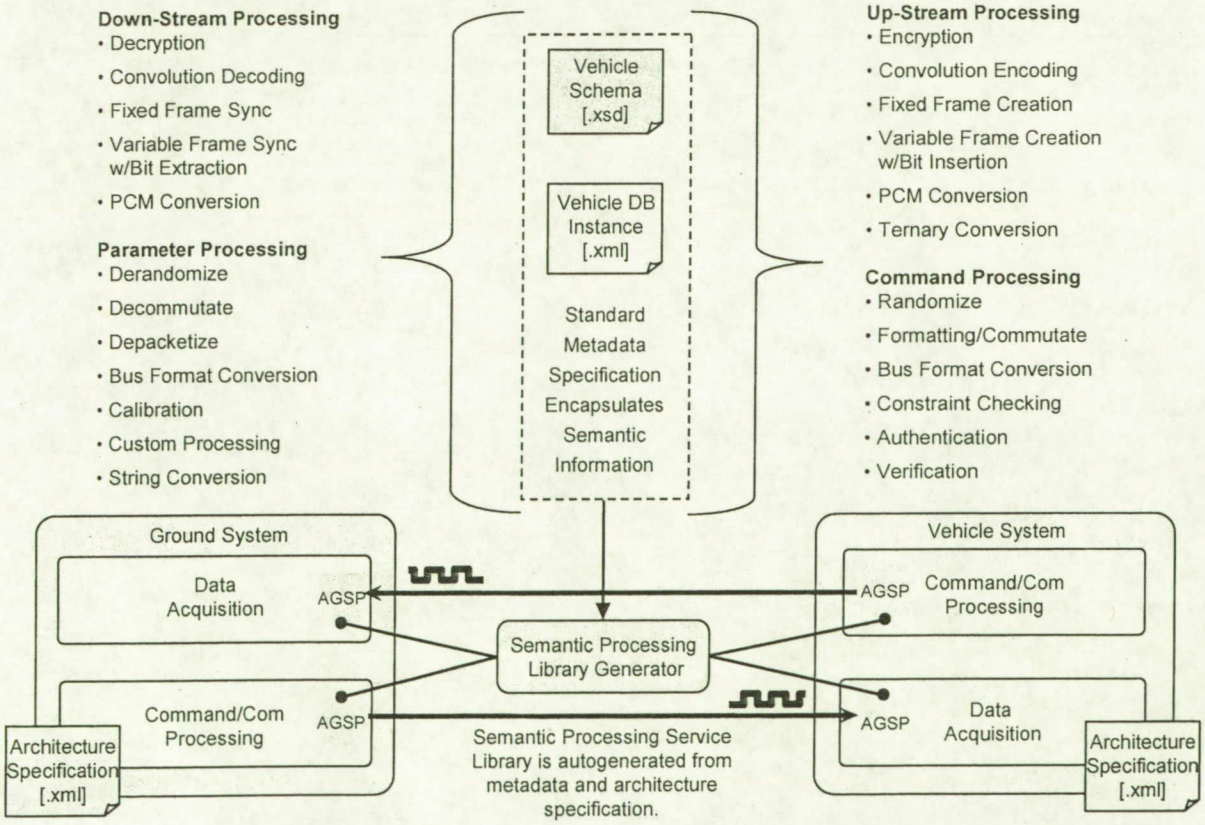

Business Objectives
Product Line Practices
C² Reference Architecture
ARCHITECTURE
PROCESS
DOMAIN KNOWLEDGE
Technology Competency
Supportive Culture
Objectives
Roles
Experience
Constraints
Trends
Systems
Behaviors
Process
Messages
Algorithms
Response
Info Flow
Protocols
Instruments
Stimuli
Sensors
Semantics, Concepts, and Relationships
Domain knowledge must be mapped into software engineering technologies (requirements, models, classes, objects, preocesses, etc.).


Down-Stream Processing
• Decryption
• Convolution Decoding
• Fixed Frame Sync
• Variable Frame Sync w/Bit Extraction
• PCM Conversion
Parameter Processing
• Derandomize
• Decommutate
• Depacketize
• Bus Format Conversion
• Calibration
• Custom Processing
• String Conversion
Vehicle Schema [.xsd]
Vehicle DB Instance [.xml]
Standard Metadata Specification Encapsulates Semantic Information
Up-Stream Processing
• Encryption
• Convolution Encoding
• Fixed Frame Creation
• Variable Frame Creation w/Bit Insertion
• PCM Conversion
• Ternary Conversion
Command Processing
• Randomize
• Formatting/Commutate
• Bus Format Conversion
• Constraint Checking
• Authentication
• Verification
Ground System
Data Acquisition
AGSP
Command/Com Processing
AGSP
Architecture Specification [.xml]
Semantic Processing Library Generator
Vehicle System
AGSP
Command/Com Processing
AGSP
Data Acquisition
Architecture Specification [.xml]
Semantic Processing Service Library is autogenerated from metadata and architecture specification.

# Space Utilities and Power

## Spaceport Command, Control, and Monitoring Technologies

### Agent Standards

Intelligent Automation, Inc.
Principal Investigator: Leonard Haynes
Contract No: NNK04OA36C
NASA COTR: Glenn Semmel
Phase/Solicitation Year: Phase I/2003

#### Identification and Significance of Innovation

This project developed innovative standards for software autonomous agents. These standards are essential to achieving software agent-based systems where the software is reusable and interoperable. To the benefit of NASA, many new developments, including scheduling, planning, resource allocation, simulation, and transportation logistics, are exploiting the emerging technology of software agents. Because software agents do not use any form of calling hierarchy to create a total system, they are inherently more interoperable and easier to reuse than conventional software. However, NASA and other users of software agent technology will not fully benefit from this advantage without a better understanding of what is required for software agents to be reusable and interoperable. Formal specifications and eventually standards will be needed to enable diverse developers to build reusable and interoperable software agents. The work performed under this Phase I project will help ensure that future software agents developed for KSC are more reusable and interoperable than what is achieved today. It also offers Intelligent Automation and KSC the opportunity to make an international impact on agent-based software for the next decade and beyond.

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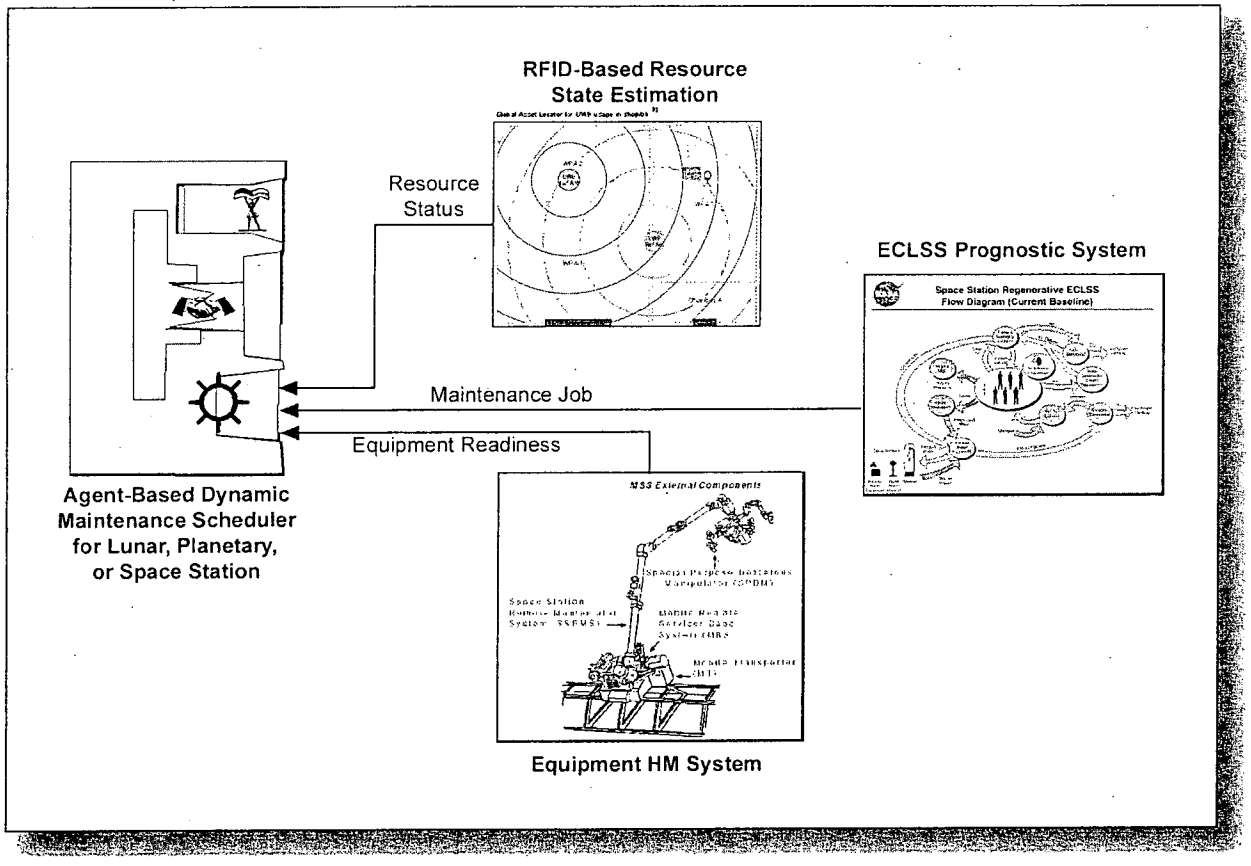
RFID-Based Resource State Estimation
Resource Status
ECLSS Prognostic System
Space Station Regenerative ECLSS Flow Diagram (Current Baseline)
Maintenance Job
Equipment Readiness
Agent-Based Dynamic Maintenance Scheduler for Lunar, Planetary, or Space Station
NSS External Components
Equipment HM System

# Small Business Innovation Research (SBIR)

## Phase II

## Batteryless Wireless Remote Sensors

# Batteryless Wireless Remote Sensors

## Passive Wireless Multisensor Temperature and Pressure Sensing System Using Acoustic Waves

Microsensor Systems, Inc.
Principal Investigator: Jacqueline Hines
Contract No: NNK04OA28C
NASA COTR: Robert Youngquist
Phase/Solicitation Year: Phase I/2003

### Identification and Significance of Innovation

This project developed innovative standards for software autonomous agents. These standards This project developed the passive surface acoustic wave (SAW) sensors and multisensor systems for NASA application to remote wireless sensing of temperature and pressure distributions in space vehicles and demanding environments. SAW devices are a mature technology used in numerous commercial wireless communication applications, satellites, and military systems. Research into the use of SAW devices as solid-state physical sensors is a relatively recent development, with such potential emerging applications as automotive tire pressure sensing. Much of the work reported has focused on single-sensor devices and systems, with little work done on dense multisensor systems. The system developed consists of multiple passive solid-state SAW sensors that can be interrogated remotely using RF signals and that respond with a signal that encodes the sensor's identity as well as measurements of temperature and pressure. The Phase I project studied several innovative aspects of SAW sensor technology, including new piezoelectric materials that can operate over large temperature ranges; new SAW device embodiments for measurement of temperature and pressure and their wireless transmission in multisensor environments; transceiver design and optimization given the SAW operating parameters; and innovative packaging and antenna considerations for small rugged devices.

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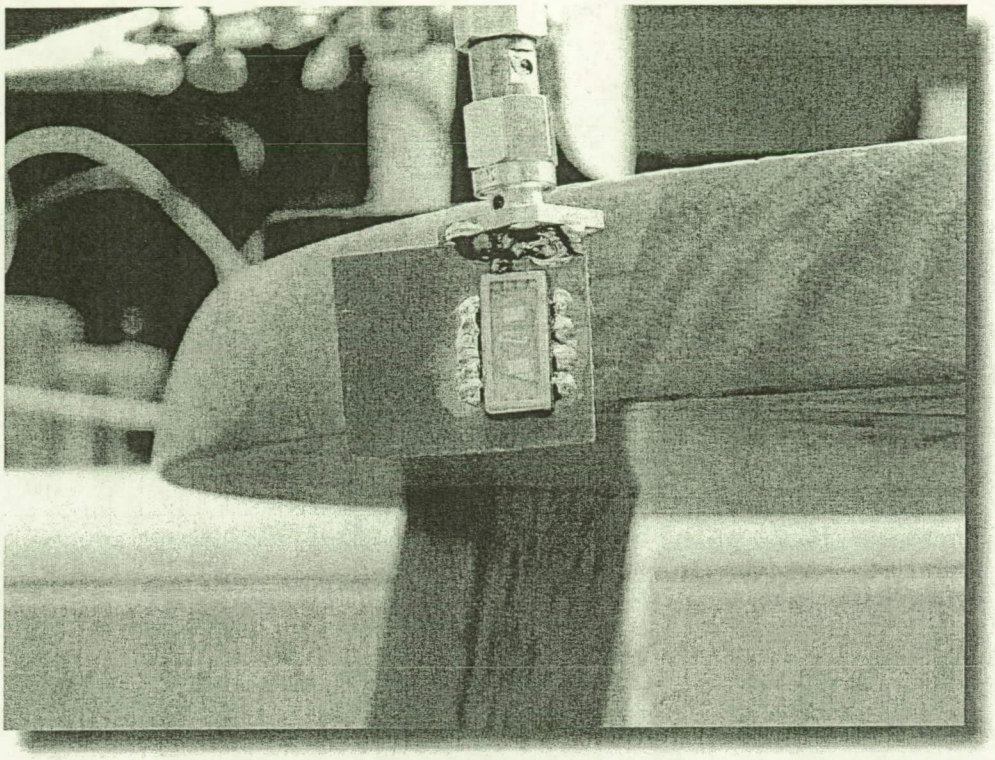

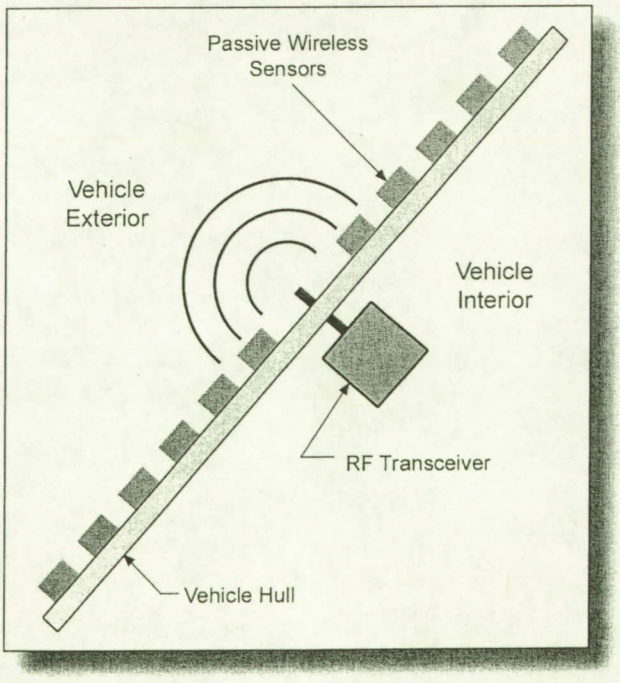
Passive Wireless Sensors
Vehicle Exterior
Vehicle Interior
RF Transceiver
Vehicle Hull

# Development of High-Temperature Acoustic Liners

# Development of High-Temperature Acoustic Liners

## High-Temperature Acoustic Noise Reduction Materials

Guigne Space Systems, Inc.
Principal Investigator: John J. Moore
Contract No: NNK04OA30C
NASA COTR: Bruce Vu
Phase/Solicitation Year: Phase I/2003

### Identification and Significance of Innovation

This Phase I project used combustion synthesis techniques to manufacture ceramic-based acoustic liners capable of withstanding temperatures up to 2,500 °C to reduce noise in rocket and jet engines. Combustion synthesis or self-propagating high-temperature synthesis (SHS) is a novel technique used by Guigne Space Systems to produce many advanced high-temperature materials and composites. The materials have a ceramic matrix (alumina Al2O3, MgO, Al2O3-MgO, TiC-Al2O3, or Al2O3-TiB2) and exhibit high porosity. These materials can also be fabricated with a functional gradient, (i.e., with a change in chemistry and/or porosity within the same sample). When compared to traditional manufacturing techniques for high-temperature materials, combustion synthesis has the advantages of energy and time-saving methods, high-purity final product, simplicity of process, and low cost.

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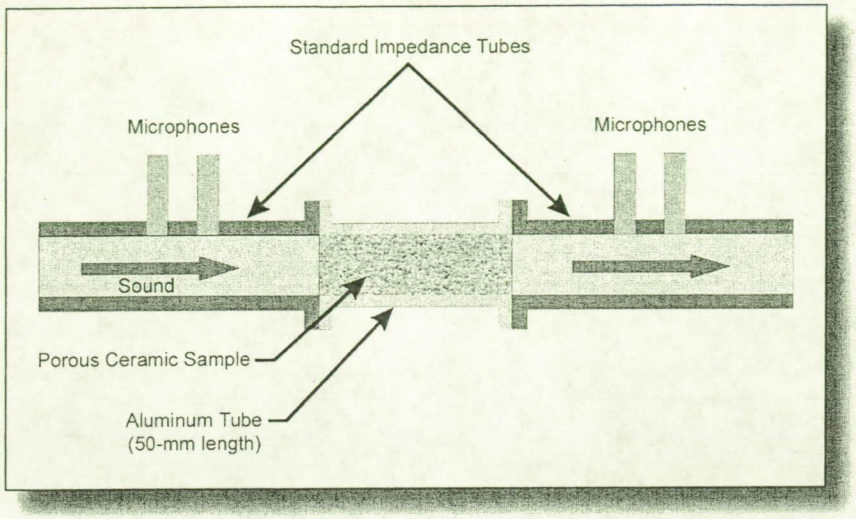
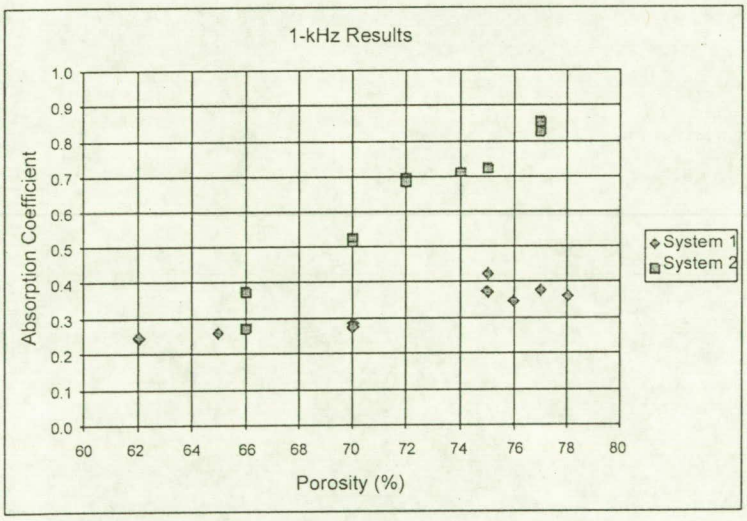
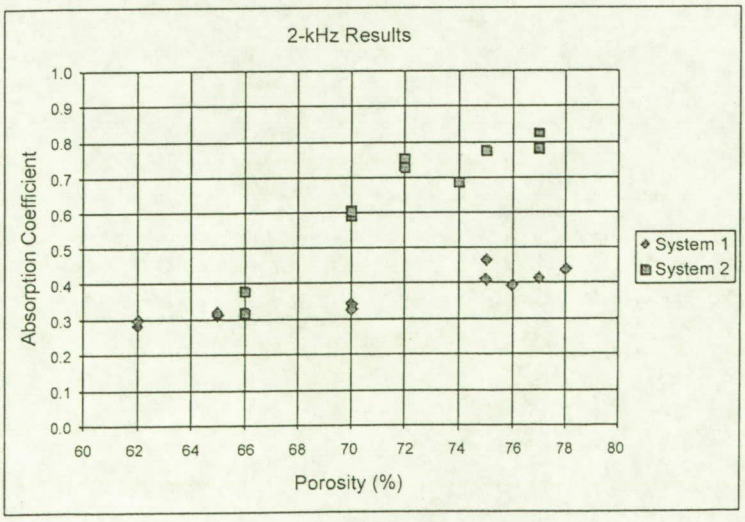
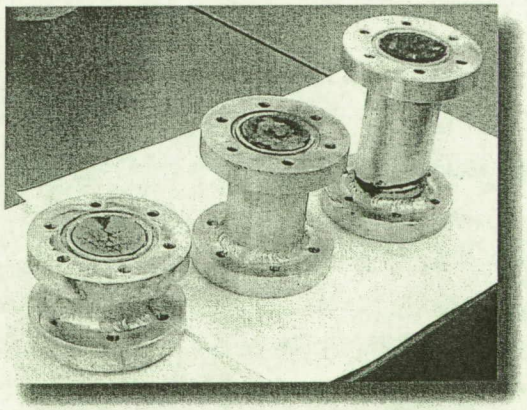



Schematic of impedance tube test setup, using two-source method.




Fifty-mm test sample results for absorption coefficient at 1-kHz frequency (top) and 2-kHz frequency (bottom), as a function of porous ceramic sample material porosity for two seperate ceramic chemistries (System 1 and System 2).



Porous ceramic material samples of 50-mm (left), 75-mm (middle), and 100-mm (right) lengths, used in impedance tube test setup to determine optimum sample length for acoustic tests.

# Development of High-Temperature Acoustic Liners

## High-Temperature Acoustic Noise Reduction Materials

### Innovative High-Temperature Acoustic Liner Development and Modeling

Ultramet
Principal Investigator: Edwin P. Stankiewicz
Contract No: NNK04OA31C
NASA COTR: Danielle Ford
Phase/Solicitation Year: Phase I/2003

#### Identification and Significance of Innovation

The massive acoustic loads produced by launch vehicles can detrimentally affect the proper functioning of vehicle components, payloads, and launch support structures. The high-velocity and high-temperature rocket engine exhaust stream mixes with ambient atmosphere to generate intense acoustic loads, which account for the majority of structural vibration during launch. Ultramet developed a unique, high-temperature material that has demonstrated passive broadband sound attenuation over a range of frequencies and can withstand temperatures in excess of 1,650 °C (3,000 °F). In this project, Ultramet teamed with the Graduate Program in Acoustics at Pennsylvania State University (PSU) to develop and test a scale model to validate the impedance of this novel high-temperature acoustic liner. An innovative, porous acoustic material was developed that demonstrated thermal, corrosion, acoustic, and mechanical load resistance at high temperatures. Porosity, pore size, pore shape, and material of construction were varied to optimize mechanical and acoustic performance over a wide range of frequencies, amplitudes, and gas flow velocities and temperatures. Ultramet and PSU also developed a basic numerical model to aid in the design of an economical and efficient liner exhaust duct system.

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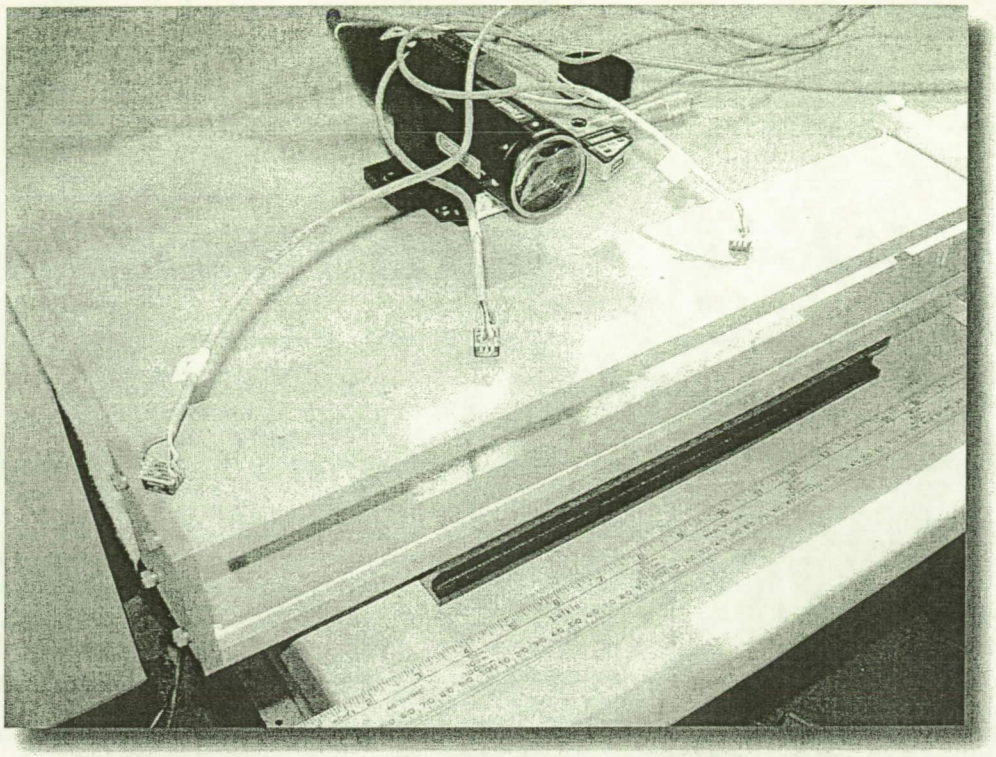

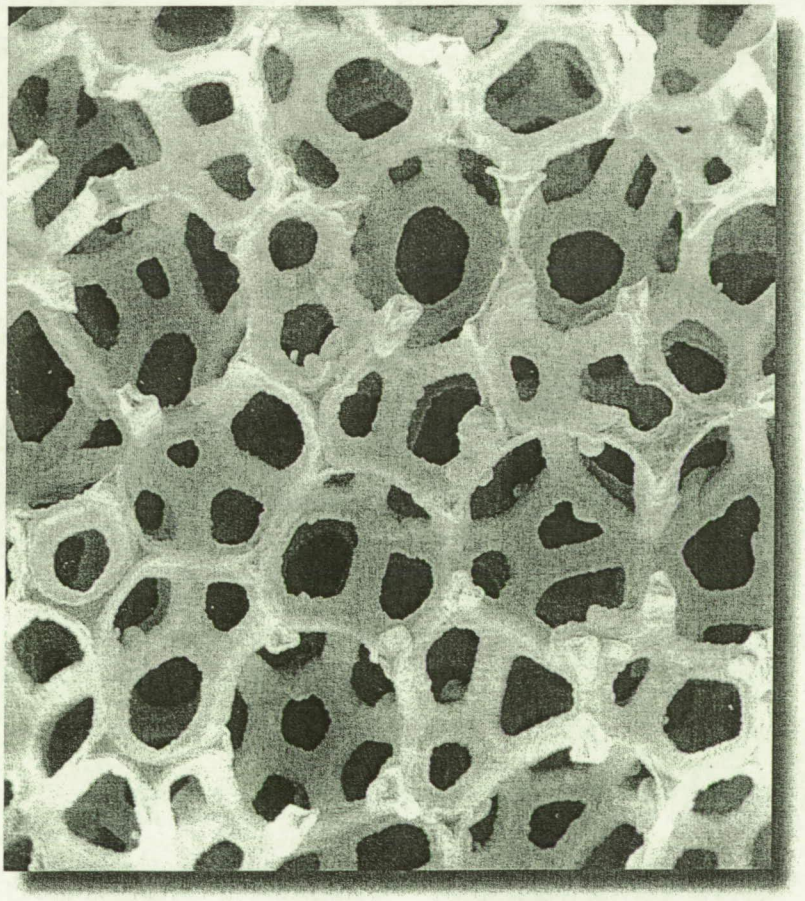

# Development of High-Temperature Acoustic Liners

## High-Temperature Acoustic Noise Reduction Materials

## Acoustic Liners Utilizing a Cementitious Material

Concrete Solutions, Inc.
Principal Investigator: Oliver Boone Bucher
Contract No: NNK04OA32C
NASA COTR: Bruce Vu
Phase/Solicitation Year: Phase I/2003

### Identification and Significance of Innovation

In this Phase I project, Concrete Solutions, Inc. (CSI), together with the University of Texas at Austin (UTA), developed a detailed research plan to provide an acoustic liner capable of withstanding high exhaust temperatures, up to 3,000 °F, over a range of sound frequencies.

Using CSI's patented product, SoundSorb, a cementitious material used extensively in the transportation industry to attenuate the reflection of highway and railway noise, the CSI-UTA team (1) formulated and tested SoundSorb/variants that meet the requirements of sound absorption, heat, and vibration for the target application, (2) developed an application system that can be used to manufacture acoustic liners of this material, and (3) developed a scale model to validate and demonstrate that the material can meet or exceed the requirements of the liners.

SoundSorb has been tested under several ASTM testing regimes required by various governmental and transportation organizations. It has passed all these tests for acoustic behavior, durability, and extreme weather conditions. This project demonstrated its feasibility for use in this application.

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# Development of High-Temperature Acoustic Liners

## High-Temperature Acoustic Noise Reduction Materials

### High-Temperature Sound Absorption Coating – Soundown HT

Mabel's Prototyping and Coffeeshop
Principal Investigator: Floyd Roberts
Contract No: NNK04OA33C
NASA COTR: Bryan Song
Phase/Solicitation Year: Phase I/2003

#### Identification and Significance of Innovation

Mabel's Prototyping and Coffeeshop (MPAC) and the University of Missouri Rolla (UMR) developed an acoustic control system for high-temperature gas flow in ducts. This control system is based on a passive inorganic acoustical coating. MPAC has applied for a patent on its development of an architectural acoustical control coating with unusually high wear resistance, a noise reduction coefficient of 0.5, and excellent low-frequency damping. UMR has long experience in modeling acoustic treatment in ducts with high-speed flow and has world-class facilities for experimental characterization of acoustic materials and systems. The team delivered a Phase I proof-of-concept deliverable consisting of passive coatings for application. This acoustic control coating provides a very low-cost, high-reliability acoustical damping for hot-gas structures.

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# Biomedical and Human Support Research

# Biomedical and Human Support Research

## Biomass Production for Planetary Missions

## Deployable Vegetable Production System (VEGGIE)

Orbital Technologies Corp. (ORBITEC)
Principal Investigator: Robert C. Morrow
Contract No: NNK04OA05C
NASA COTR: John Sager
Phase/Solicitation Year: Phase II/2002

### Identification and Significance of Innovation

ORBITEC developed a deployable facility called the Vegetable Production System (VEGGIE) to produce vegetable (salad) crops to supplement prepackaged foods during long stays in space. The innovation of the VEGGIE is in providing, within a single middeck locker, a plant-growing facility with a growing area of 0.5 to 1.0 square meter, a light source sufficiently intense for crop production, a compressible nutrient and water delivery system, and a semipassive atmospheric control system that minimizes water use without limiting gas exchange. To minimize complexity, VEGGIE utilizes the cabin environment for temperature control and as a source of $CO_2$. VEGGIE will provide the crew with a palatable, nutritious, and safe source of fresh food and source of relaxation and recreation. Phase II activities included developing high-fidelity VEGGIE prototypes, food safety protocols to prevent microbial contamination, and the necessary data and documentation to support a critical design review.

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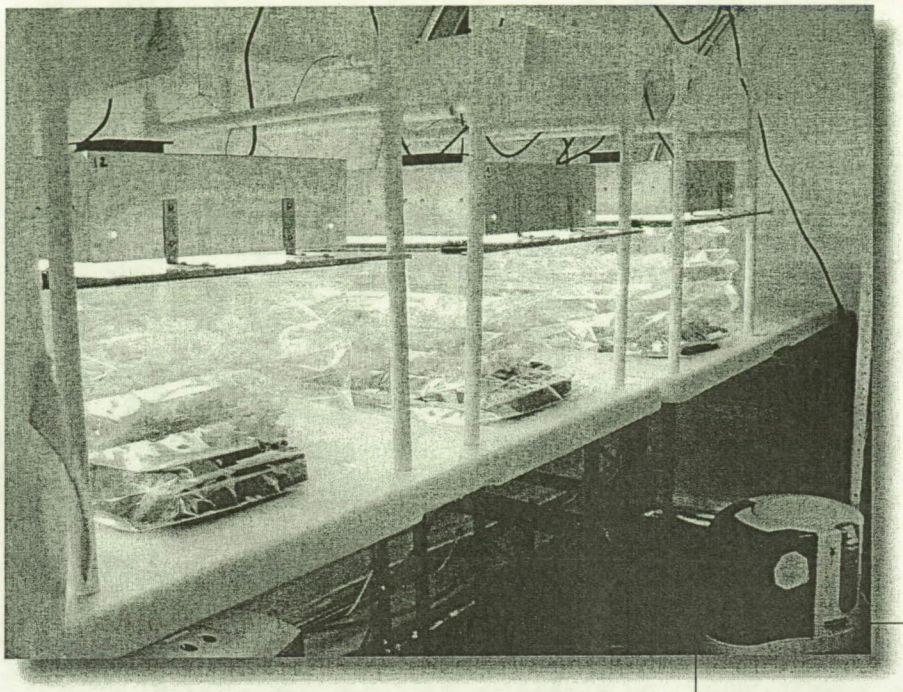

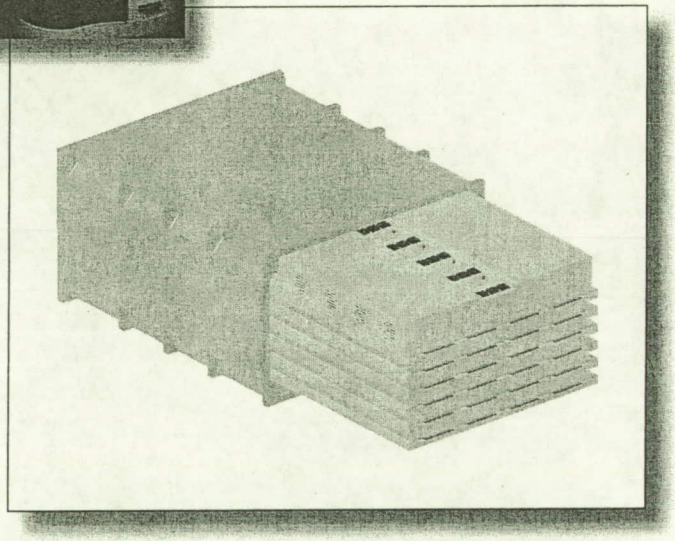

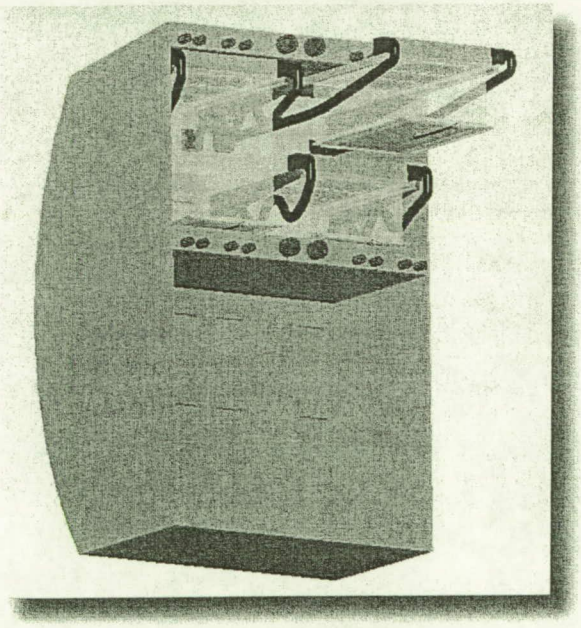

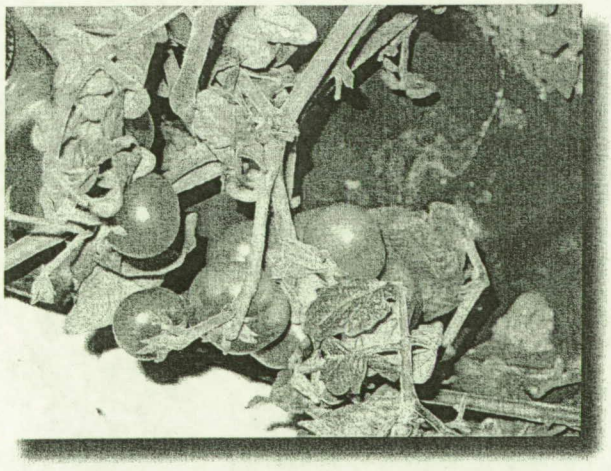

# Systems Integration, Analysis, and Modeling

# Systems Integration, Analysis, and Modeling

## Process/Industrial Engineering Technologies

## A Discrete-Event Simulation Model for Spaceport Operations (SPACESIM)

Nevins Software, Inc.
Principal Investigator: Mike Nevins
Contract No: NNK04OA04C
NASA COTR: Martin Steele
Phase/Solicitation Year: Phase II/2002

### Identification and Significance of Innovation

The NASA vision for the spaceport of the future entails transitioning over time from very high-cost, research-oriented space launches with a relatively low frequency of launches to an environment where spaceports are commercialized for the space transportation industry and are required to support multiple launches per day in a safe, cost-effective manner. The spaceport of the future may resemble, from an operational perspective, our current airports and seaports and will need to resolve many of the challenges faced by these transportation hubs. These challenges include (1) safe and secure spaceport operations, (2) efficient movement of machinery and people through the spaceport, and (3) cost-efficient, affordable, and timely spaceport operations. Discrete-event simulation has been used to assess detailed processes at modern-day seaports. Like seaport operations, spaceport operations are labor-intensive and require extensive use of personnel and machinery. The ability to conduct seaport operations efficiently has been improved significantly through effective use of seaport assets. This foundation provides a solid footing from which research for efficient spaceport operations can be based. This project resulted in an object-oriented discrete-event simulation system that addresses spaceport operations in the context of aerospace safety, mobility, and efficiency. To provide for maximum portability the simulation system was built upon the Java programming language and uses XML for standards-based data interchange. Developing the simulation model provided the underlying basis for follow-on activities such as two- and three-dimensional animation and visualization capabilities.

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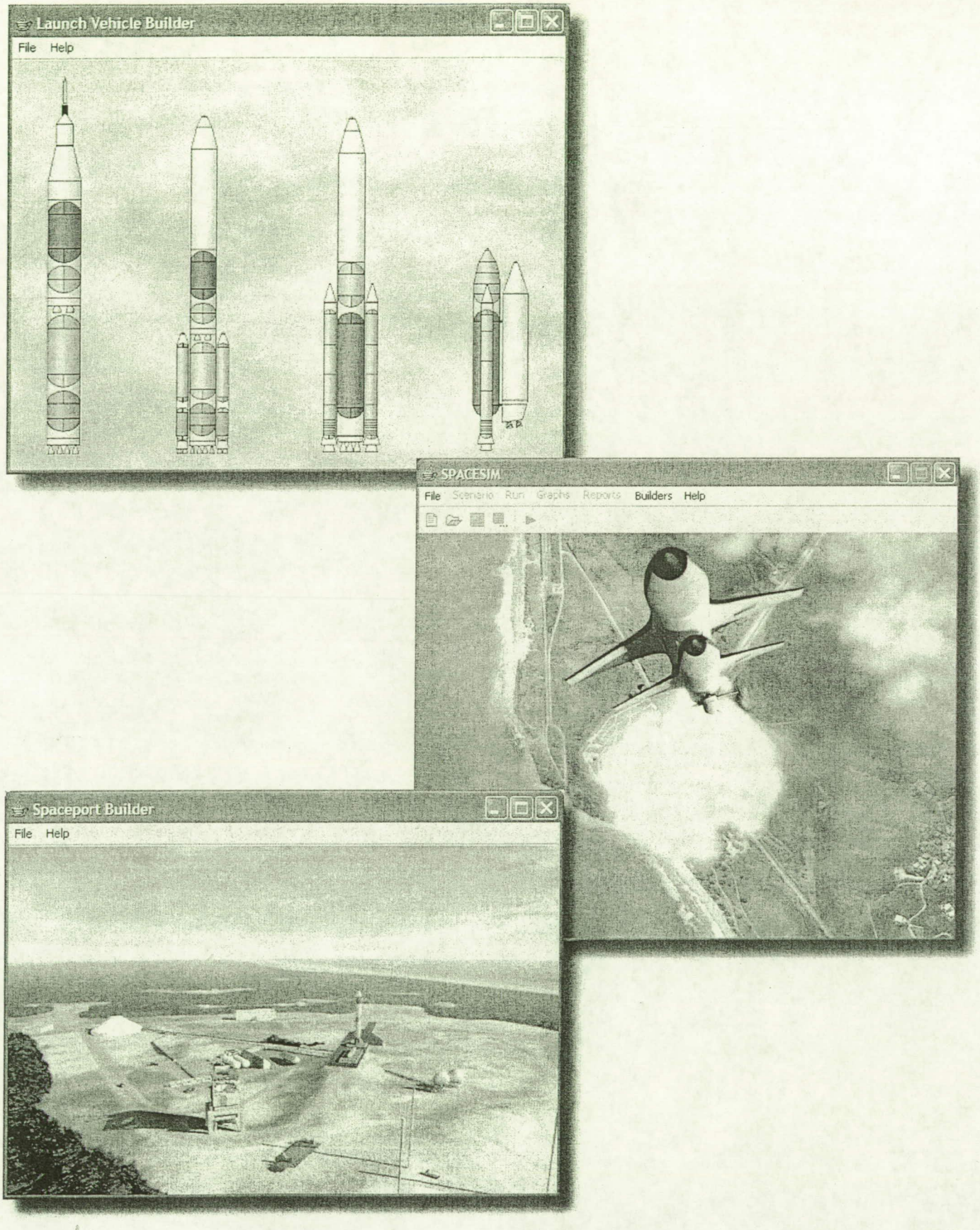
Launch Vehicle Builder
File Help
SPACESIM
File Scenario Run Graphs Reports Builders Help
Spaceport Builder
File Help

# Space Utlilities and Power

# Space Utilities and Power

## Spaceport and In-Space Cryogenic Fluids, Handling, and Storage Technologies

### Highly Reliable LOX Pump for Vehicle Loading Operations

Barber-Nichols, Inc.
Principal Investigator: Bill Batton
Contract No: NNK04OA01C
NASA COTR: Donald Pittman
Phase/Solicitation Year: Phase II/2002

#### Identification and Significance of Innovation

The current Shuttle liquid oxygen (LOX) loading pumps require high maintenance, resulting in low reliability. Phase I of the project focused on the reliability problems surrounding the primary sealing arrangement in the LOX pumps and demonstrated the feasibility of a noncontacting combination of a dynamic seal and a purged labyrinth seal set as a highly reliable sealing solution for the primary seal for LOX transfer pumps. In addition, Phase I efforts produced a unique concept for a new LOX pumping system for vehicle loading operations. The pump system concept proven in Phase II will mitigate NASA's concerns about reliability in this critical application by virtue of the seal arrangement tested in Phase I. Each pump was designed to be able to meet the current fill rates in the event of one unit's failure. Two pumps work in parallel to provide a 50-percent increase in LOX transfer rate. Phase II included the design and manufacture of this complete pump system (composed of two pumps), pump performance testing on water and cryogenic testing at KSC's Advanced Technology Development Center.

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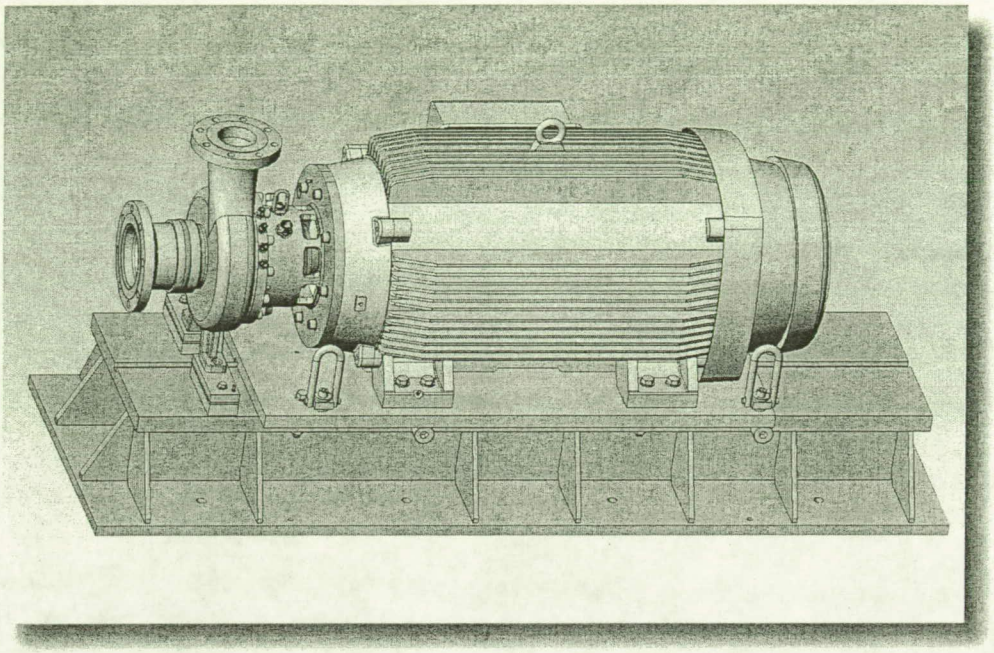

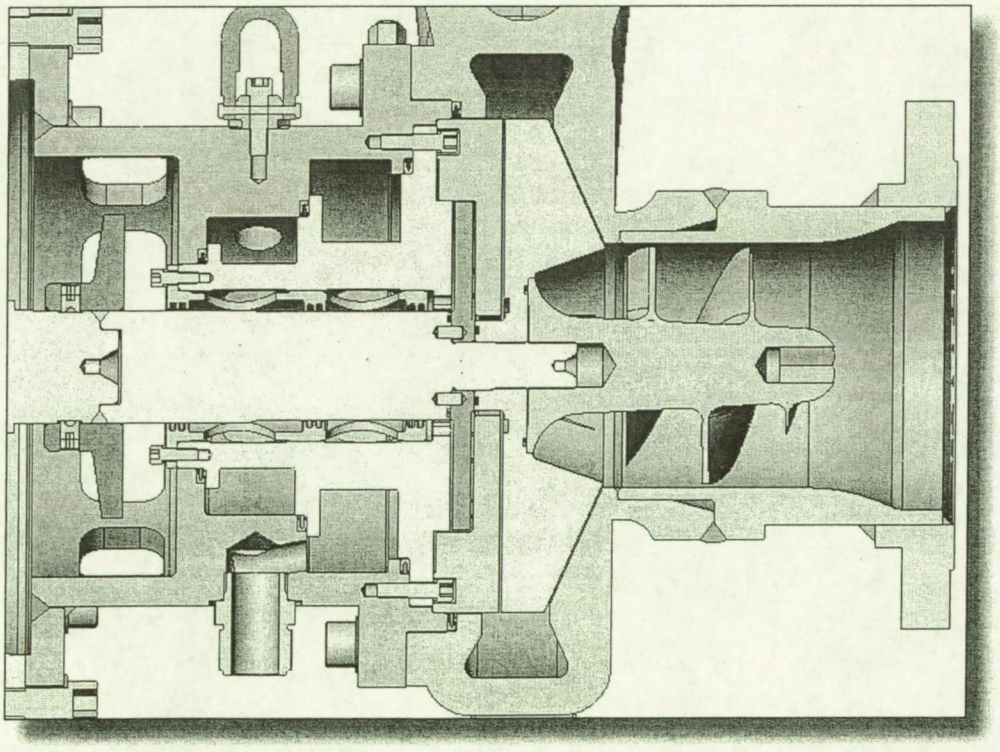

# Space Utilities and Power

## Spaceport and In-Space Cryogenic Fluids, Handling, and Storage Technologies

### System for Helium Recovery From Waste Gas Streams

PHPK Technologies, Inc.
Principal Investigator: Ken Kreinbrink
Contract No: NNK04OA06C
NASA COTR: Bill Notardonato
Phase/Solicitation Year: Phase II/2002

#### Identification and Significance of Innovation

The continuing rising cost of helium justified the construction of an economical system that separates helium gas from gas streams that would normally be considered waste. These waste gas streams are typically generated from operations where helium purging of hydrogen storage or propellant equipment is performed. As a result of these operations, helium contaminated with hydrogen, nitrogen, and small amounts of air is vented to the atmosphere where it is not recoverable. The system built during this Phase II project recovers helium from these waste gas streams and purifies it to a level where it can be recycled for use. The system could also be designed to recover hydrogen. Cryogenic processes as well as other gas separation techniques were incorporated into an integrated system to accomplish this gas recovery. The Phase II system is practical for helium recovery in both commercial and NASA-related programs where helium is routinely used and vented in significant quantities. The Phase II unit can be made to handle the full-scale helium separation for recovery for some specific helium applications at Kennedy Space Center.

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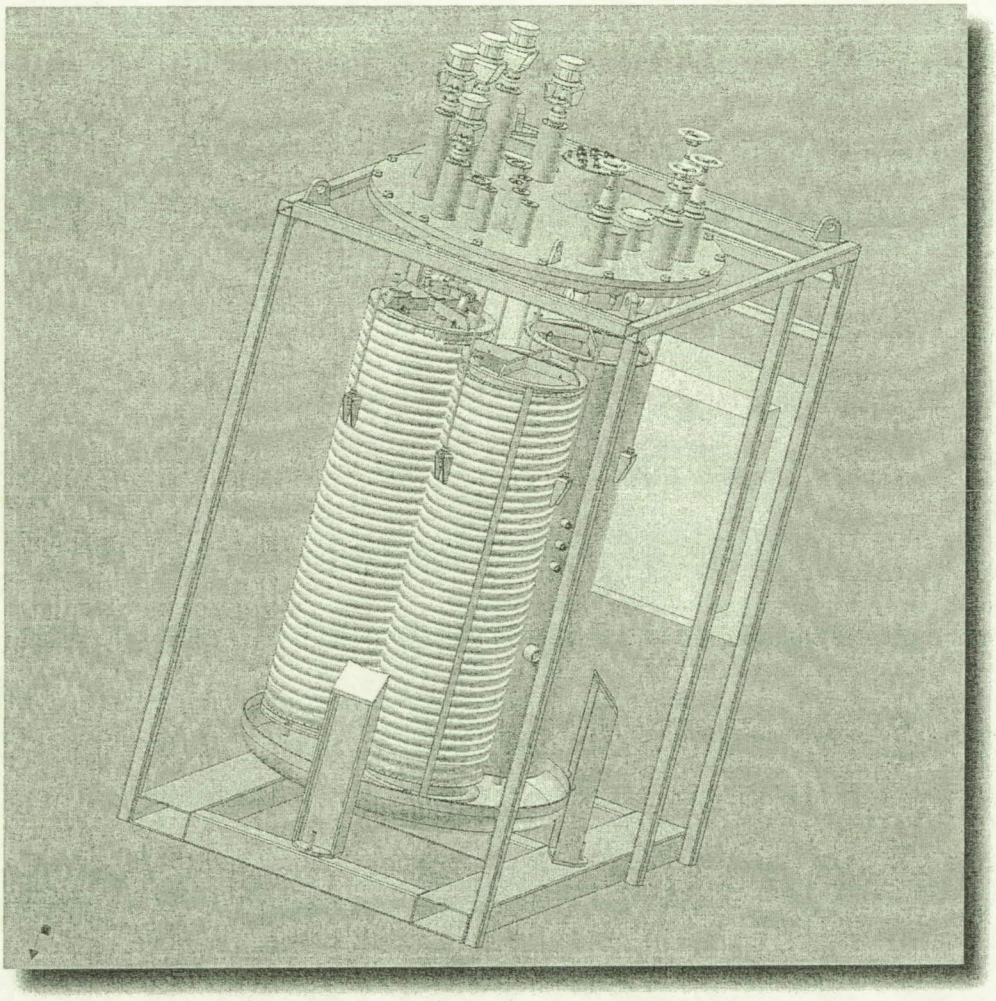

Helium seperation and recovery system.

# Space Utilities and Power

## Spaceport and In-Space Cryogenic Fluids, Handling, and Storage Technologies

### Cryogenic Propellant Insulation Program

Technology Applications, Inc.
Principal Investigator: Rolf Baumgartner
Contract No: NNK04OA09C
NASA COTR: Deborah Morris
Phase/Solicitation Year: Phase II/2002

#### Identification and Significance of Innovation

Technology Applications demonstrated a high-thermal-performance microsphere-based insulation that enabled reliable, energy-efficient, cost-effective cryogenic distribution over long distances for Earth, space, and extraterrestrial environments. The new technology, which employs a lightweight microsphere-based insulating medium, provides for robust low-maintenance storage and distribution systems. Well suited for the on/off operation that is typical for space launch operations, microsphere insulation minimizes losses in stored propellants at spaceports and for commercial liquefied gases. Microsphere insulation's inherent properties of high crush-strength and ability to flow combine to form a tough, resilient insulation system that withstands exposure to harsh launch/landing environments and ambient/vacuum pressure cycles. Based on extensive thermal testing, including recent measurements made at Kennedy Space Center's Cryogenics Test Laboratory, microspheres perform 1.5 to 3.3 times as well as perlite and limit heat leak to less than most insulation materials, particularly multilayer insulation (MLI), in a soft- or lost-vacuum condition. At $10^{-1}$-torr vacuum, microspheres outperform MLI by a factor of 2. This means significantly reduced life cycle costs from maintenance, lost cryogen, and reinsulation. Microsphere-insulated transfer line and storage tank prototypes were extensively tested to optimize performance, address microsphere handling and containment methods, and validate long-term performance benefits.

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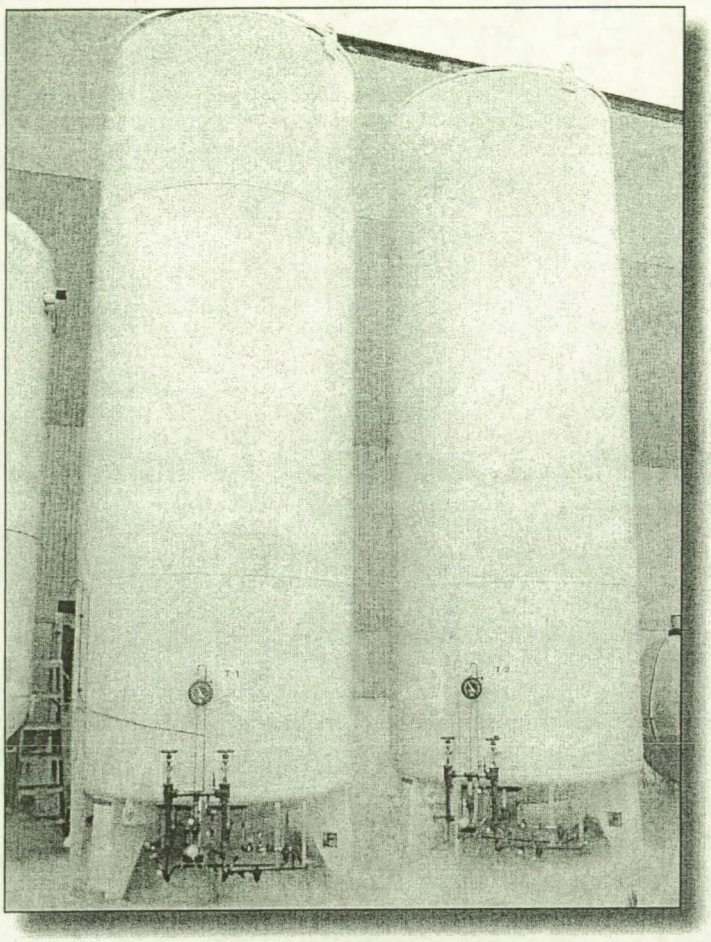
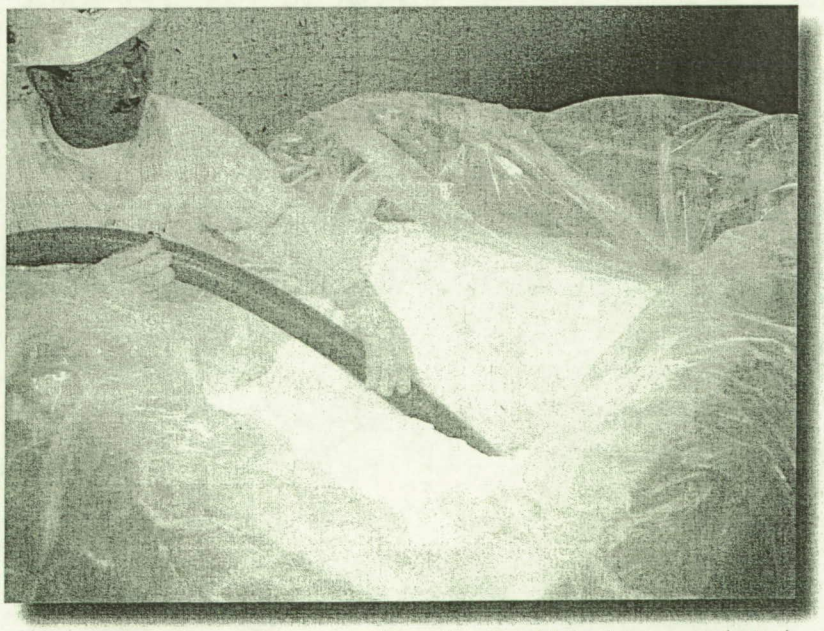


Tank comparison test with one tank insulated with the microsphere insulation being developed under this program. The other tank has standard perlite insulation.



Microspheres being transferred (with suction hose) into the cryogenic tank.

# Space Utilities and Power

## Spaceport/Range Instrumentation and Control Technologies

### Ka-Band Passive Phased-Array Antennas (PAAs) for Satellite Telemetry System for Reusable Launch Vehicles and Aircraft

Paratek Microwave, Inc.
Principal Investigator: Michael Slavin (Alt)
Contract No: NNK04OA07C
NASA COTR: Richard Nelson
Phase/Solicitation Year: Phase II/2002

#### Identification and Significance of Innovation

Passive PAAs offer significant performance benefits over the current active arrays. The key to successful development is the integration of low-loss phase shifters into modular and scaleable antenna architecture for broad use in high-data-rate communications. The Phase I effort demonstrated a 3.0-dB, 360-degree finline phase shifter at 25.25 to 27.50 GHz. Building on this Phase I phase shifter development, Phase II included the design, simulation, testing, and integration of the rest of the antenna, in addition to packaging for ease of manufacturing and scalability, such that an antenna of approximately 15-dBi gain was built and delivered to NASA for evaluation.

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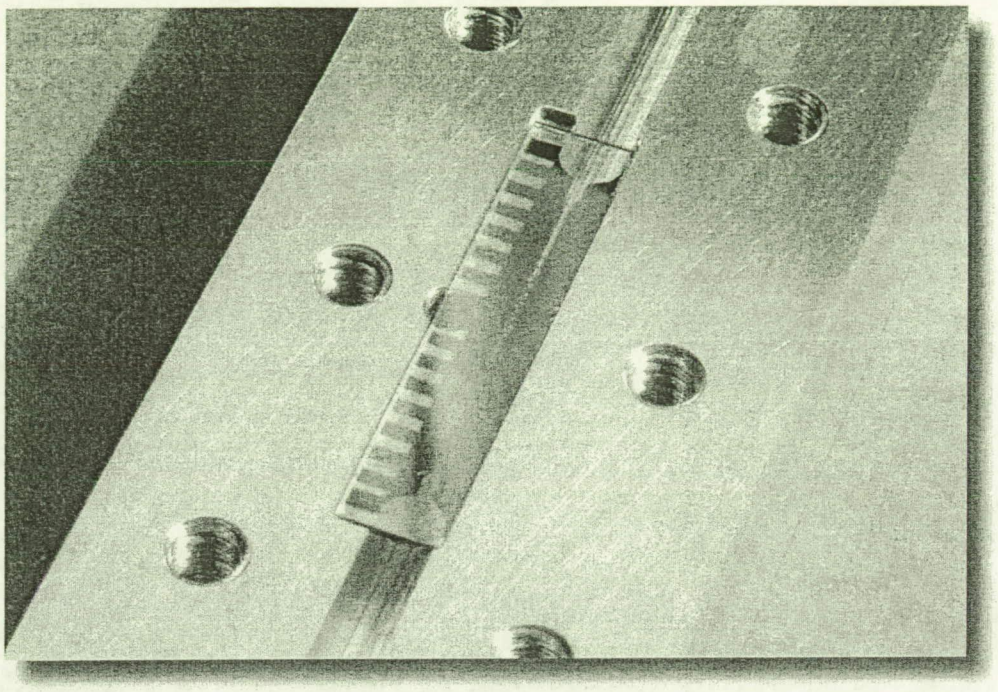
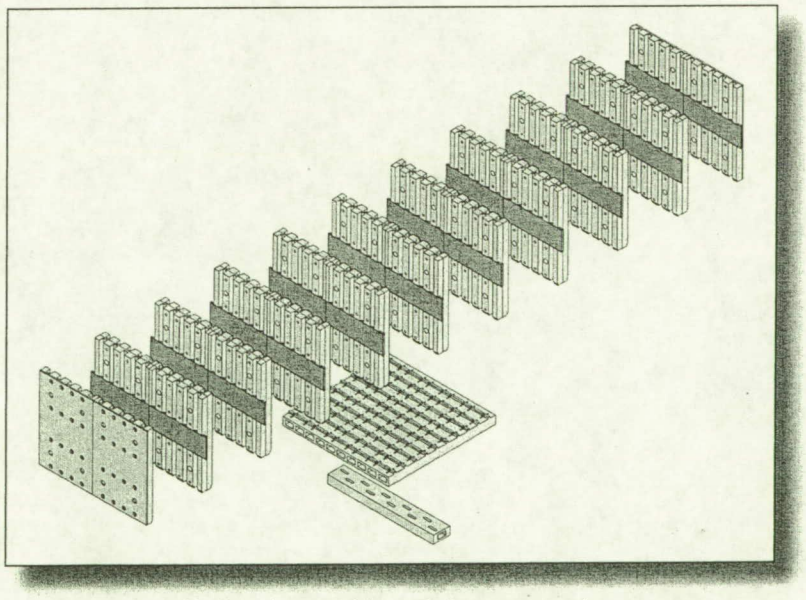


Twenty-six-GHz Finline Phase Shifter in waveguide.



Ka-band assembly prototype concept.

# Space Utilities and Power

## Spaceport/Range Instrumentation and Control Technologies

### Circular Mass Spectrometer for High-Speed Gas Analysis

Monitor Instruments Company, LLC
Principal Investigator: Guenter Voss
Contract No: NNK04OA03C
NASA COTR: Timothy Griffin
Phase/Solicitation Year: Phase II/200

#### Identification and Significance of Innovation

In Phase I, Monitor Instruments demonstrated that the combination of a circular cycloidal mass spectrometer with a new type of linear cycloidal for the light gases allows the simultaneous monitoring of the five constituents hydrogen, helium, nitrogen, oxygen, and argon. A laminar/molecular standard inlet supported by a membrane inlet is particularly selective for helium and hydrogen. Thus the low ionization probability of these gases is compensated by enrichment to achieve the required detection limits without using an electron multiplier. The high vacuum is sustained by a small, 2 liters-per-second ion getter pump. To increase the time of operation for the ion pump, a nonevaporable getter pump will capture most of the nitrogen and oxygen load from air by this getter material. The software developed provides spectra at the site (graphics display) and transmission of data via an RS 232/485 interface.

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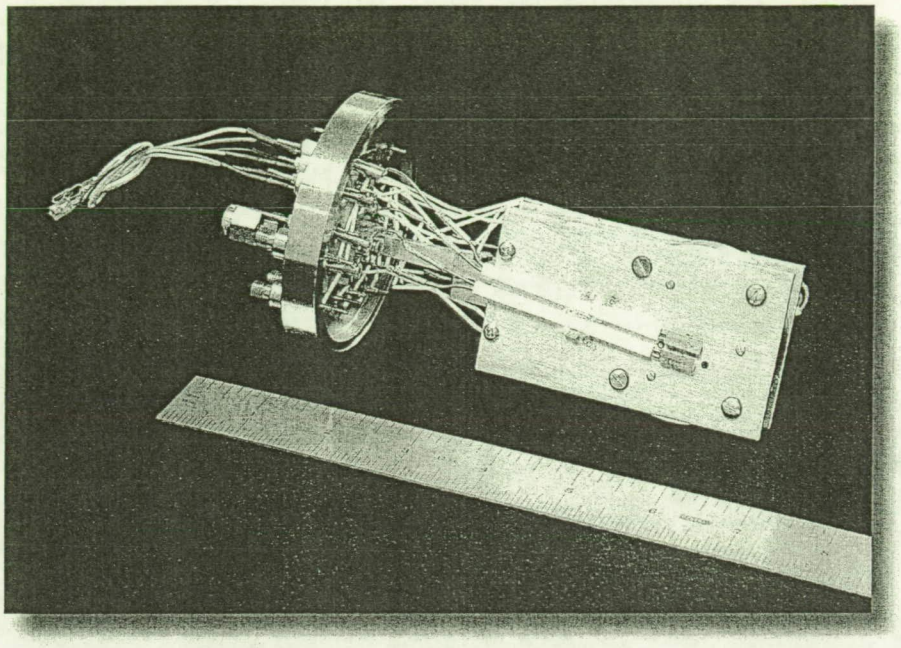

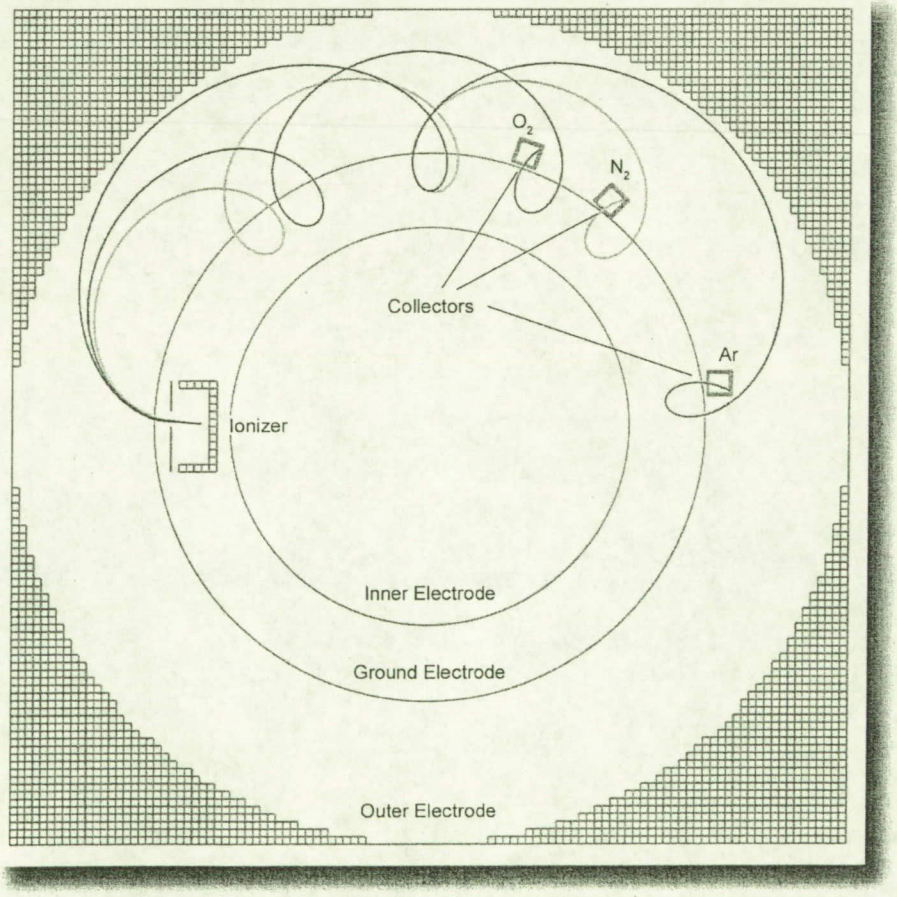


Ion Flight Model for $N_2$, $O_2$, and Ar Inside the
Circular Cycloidal Analyzer (Simon V7.0)

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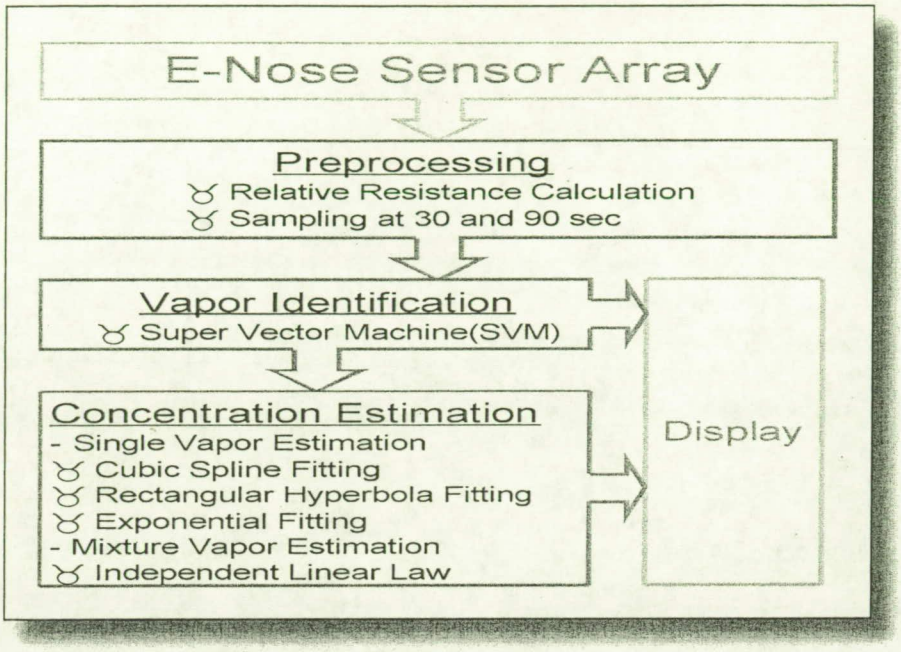
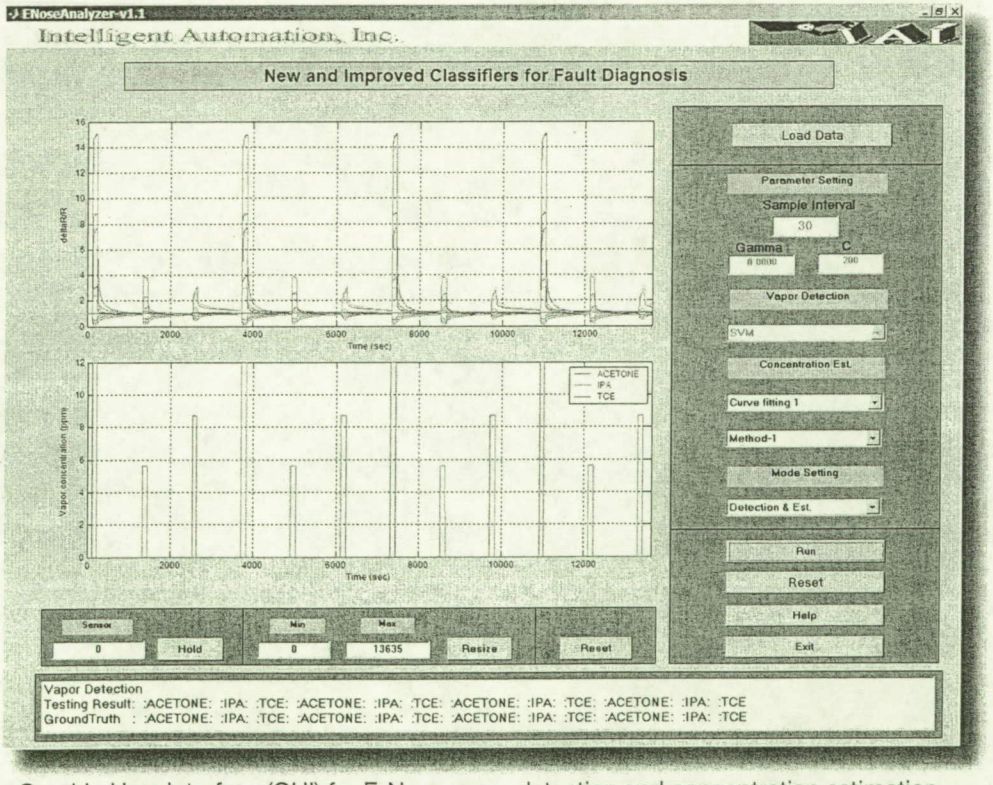



Processing Flowchart




Graphic User Interface (GUI) for E-Nose vapor detection and concentration estimation.

# Space Utilities and Power

## Electromagnetic Physics Measurements Control and Simulation Technologies

## Differencing Electrostatic Optical Sensor (DEOS)

Physical Optics Corp., EP Division
Principal Investigator: Michael Reznikov
Contract No: NNK04OA08C
NASA COTR: Michael Hogue
Phase/Solicitation Year: Phase II/2002

### Identification and Significance of Innovation

In response to NASA's need for miniature sensors to detect and measure electrostatic potential and charge distribution on payloads, spacecraft, and landers, Physical Optics Corp. (POC) in Phase I developed and demonstrated an innovative differencing electrostatic optical sensor (DEOS) to overcome the current sensor problems of electrostatic shock and electromagnetic interference (EMI) vulnerability. POC proved the feasibility of the DEOS concept and demonstrated sensitivity to an induced charge of approximately 15 mV/nC, exceeding the NASA requirement. This sensitivity to charge enables DEOS to remotely measure voltage with a sensitivity of 40 V per millivolt of output signal at a distance of 4 inches, exceeding the sensitivity of commercially available sensors by a factor of 2.5. In Phase II, POC optimized the DEOS design and completed its development, greatly advancing the accuracy and reliability of electrostatic charge and field measurements for many NASA applications. In the process, POC developed two key components: the photoacoustic modulator (PAM), which transforms induced charge to alternating electric current; and the electro-optical converter (EOC), which transforms that electric current into an alternating optical signal. Phase II culminated in testing, demonstration, and delivery of a DEOS prototype.

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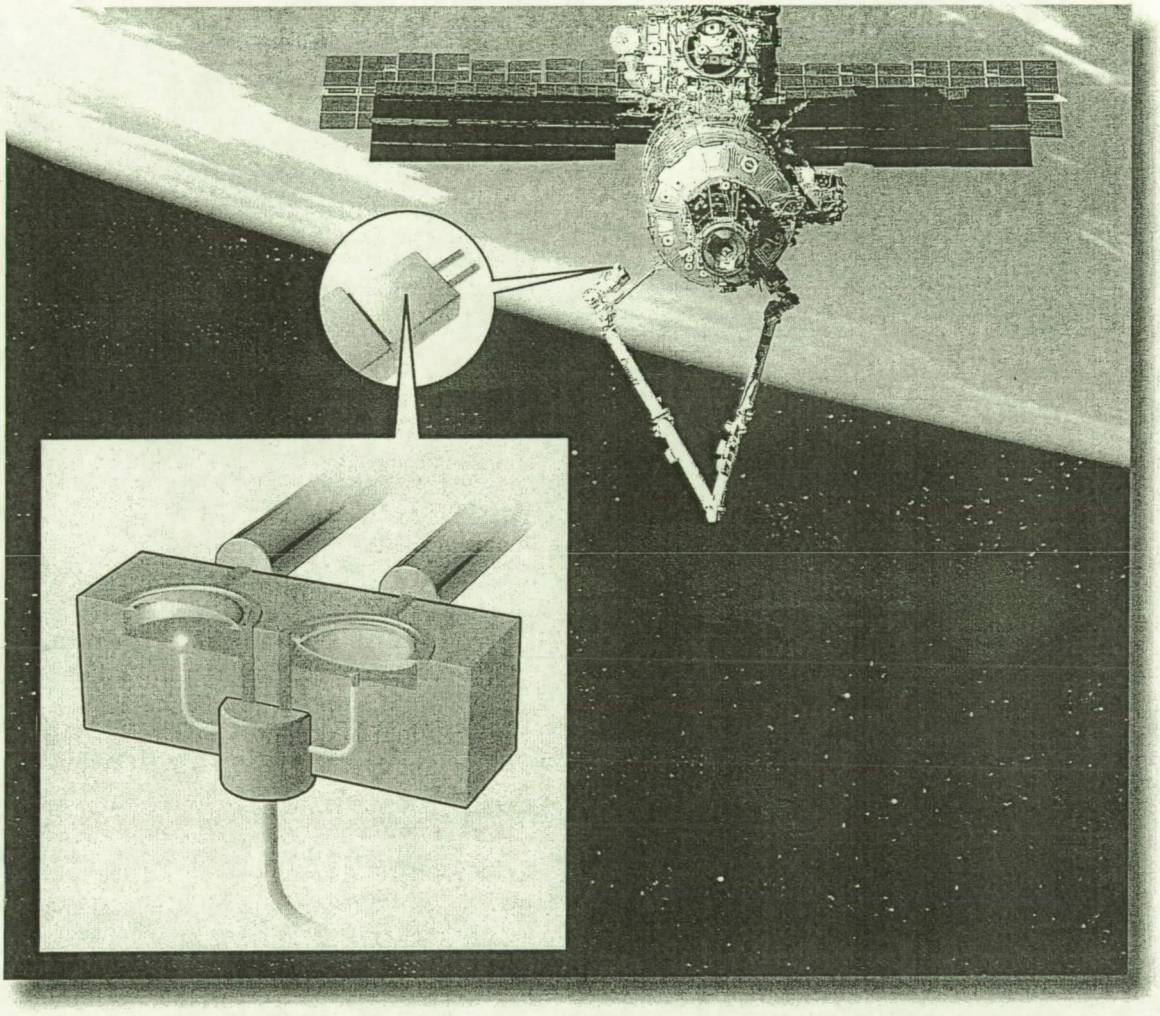

POC's proposed DEOS device in use detecting and measuring electrostatic charges.

# Space Utilities and Power

## Electromagnetic Physics Measurements Control and Simulation Technologies

### Distributed Fiber-Optic Electrostatic Potential Sensor System for Spacecraft

Renka Corp.
Principal Investigator: Binoy Somaia
Contract No: NNK04OA84C
NASA COTR: Carlos Calle
Phase/Solicitation Year: Phase II/2002

#### Identification and Significance of Innovation

Optical-fiber sensors, with intrinsic features of good electrical isolation and immunity to electromagnetic interference, lightweight, and compactness, are a perfect solution for detecting electrostatic potential and charge distribution generated on payloads, spacecraft, and landers. During Phase I, Renka successfully demonstrated the feasibility of using a distributed fiber-optic sensor system to monitor multipoint electrostatic potential and charging rate. The sensor system is based on the wavelength shift of functional material-jacketed fiber Bragg grating (FBG). A unique multichannel wavelength division multiplexing (WDM) integration approach for FBG sensors is also demonstrated by a prototype four-sensor system. This approach allows tens or hundreds of sensors to be integrated through an optical fiber and to share a single light source. In this Phase II program, Renka fabricated a 16-sensor prototype for field testing. Marketing efforts were also put forth for other applications of the developed technologies and products, such as the multisensor integration technologies, which could be very useful for large-scale temperature or pressure monitoring in oil fields or large civil structures.

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