National Aeronautics and Space Administration

John C. Stennis Space Center

Technology Development Report

CDDF, Dual Use Partnerships, SBIR/STTR

Technology Development and Transfer Office

Fiscal Year 2003 Acitivties

Foreword

The FY2003 NASA John C. Stennis Stennis Space Center (SSC) Technology Development Report provides an integrated report of all technology development activities at SSC. This report actually combines three annual reports: the Center Director's Discretionary Fund (CDDF) Program Report, Dual Use Program Report, and the Small Business Innovation Research (SBIR)/Small Business Technology Transfer (STTR) Program Report. These reports are integrated in one document to summarize all technology development activities underway in support of the NASA missions assigned to SSC.

The CDDF Program provides a way for the SSC Center Director to encourage high risk, innovative ideas in research and technology, which are not directly related to existing programs or projects. Proposals are awarded funds if they are judged by the CDDF Committee to be research and technology efforts which are directly related to improving the way SSC provides Customer Services in its established mission areas, that of Propulsion Test and Earth Science Applications, as well as the operation of the Stennis institution. There were seven (7) new projects selected to receive FY2003 funds. The section of this integrated report provides a status of both these new projects, as well as the previously funded ongoing CDDF projects at SSC. During 2003, the spectrum of CDDF projects ranged from CFD Modeling of Split Body Valves to the Development of a Sensor System for Automated Mosquito Monitoring. Much of the CDDF project work is conducted in-house by NASA SSC civil service employees or on-site support contractor personnel. In addition, SSC encourages an appropriate level of involvement of commercial industry and academia in its CDDF projects. This approach increases the amount of knowledge gained and shared between individuals at SSC and individuals in both commercial industry and academia.

The Dual Use Program Report provides a summary review of the results and status of the nine (9) Dual Use technology development partnership projects funded and managed at SSC during FY2003. The objective of these partnership projects is to develop or enhance technologies that will meet the technology needs of the two NASA SSC Mission Areas: Propulsion Test and Earth Science Applications. The Dual Use projects use cooperative agreements as the partnership mechanism to share risk between NASA and the developer, reducing development cost to NASA, and producing higher technology readiness level (TRL) products for both NASA missions and private sector applications. Since the Dual Use Program began at SSC in FY2000, the NASA Innovative Technology Transfer Partnerships (ITTP) Program has provided $1.06M in funding which has been "matched" by company contributions of $1.24M. Successes have resulted, with quantifiable cost savings to NASA SSC, while enabling commercial technology successes.

During FY2003, the TDTO managed twenty (20) SBIR Phase II Projects and two (2) STTR Phase II Projects. The SBIR contracts support low TRL technology development that supports both the Propulsion Test and the Earth Science Application missions. These projects are shown in the SBIR/STTR Report. In addition to the Phase II

contracts, the TDTO managed ten (10) SBIR Phase I contracts which are fixed price, six month feasibility study contracts. These are not listed in this report.
Together, the Dual Use Projects and the SBIR/STTR Projects constitute a technology development partnership approach that has demonstrated that success can be achieved through the identification of the technical needs of the NASA mission and using various available partnership techniques to maximize resource utilization to achieve mutual technology goals. Greater use of these partnership techniques and the resource leveraging they provide, is a goal of the TDTO, providing more support to meet the technology development needs of the mission areas at SSC.

This FY2003 Technology Development Report was prepared by the NASA SSC Technology Development and Transfer Office under the leadership of Robert Bruce. Primary assistance was provided as follows:

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Acknowledgement and appreciation is additionally extended to each respective Project Point of Contact or Principal Investigator who provided input for this report.

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Overview

The John C. Stennis Space Center (SSC), located in South Mississippi, is NASA's primary center for testing and flight certifying rocket propulsion systems for the Space Shuttle and future generations of space vehicles. Because of its important role in engine testing for more than four decades, Stennis Space Center is NASA's program manager for rocket propulsion testing with total responsibility for conducting and/or managing all NASA propulsion test programs. Today, the SSC provides test services not only for America's civil space program, but also for the Department of Defense and the private sector.

SSC was initially established as a national rocket propulsion testing center to flight-certify all first and second stages of the Saturn V rocket for the Apollo manned lunar landing program. Since 1975, the center's primary mission has been testing the main engines that propel the Space Shuttle during its 8 1/2- minute ascent to orbit. SSC's versatile three stand E Test Complex with its seven separate test cells serves as a component test facility for future generation rocket engines and related technology.

SSC is a multi-disciplinary, multi-agency site with more than 30 resident agencies sharing the cost of operating the facility, making it more cost-effective for each agency to accomplish its independent mission. With this effective cost-sharing philosophy and its reputation for state-of-the-art test facilities, highly trained, professional work force and commitment to safety and customer satisfaction, SSC serves as a model of government efficiency, showing American taxpayers positive returns on their leveraged investments.

With a work force of nearly 4,500 including more than 1,600 scientists and engineers, the center strongly influences the surrounding communities. In 2003, SSC's direct global economic impact totaled $755 million, with $533 million impact on Mississippi and Louisiana communities within a 50-mile radius of the center.

In addition to the Propulsion Test Directorate, the SSC Earth Science Applications Directorate leads NASA's efforts to help solve problems on Earth related to homeland security, agricultural efficiency, disaster preparedness and coastal management. Scientists at SSC use remote sensing technologies and their expertise to expand and improve prediction capabilities in weather and climate. Through better prediction, they can speed response time to natural hazards and man-made disasters.

The Technology Development and Transfer Office (TDTO) supports activities at SSC to research and develop new technologies, as well as assessing, certifying and acquiring technologies from outside sources. The goal of technology development is to improve the safety, efficiency and effectiveness in the various NASA Mission Areas at Stennis Space Center.

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NASA SSC Center Director's Discretionary Fund
Distribution of Resources for FY03

Project Title and Investigator	Initiation Year	Partnerships with Academia	Total Funding Authorized ($K)	Project Status	Expected Completion Date (Month/Year)
FY03 Projects					
Propulsion Test Directorate					
Split Body Valve Modeling Using Computational Fluid Dynamics (CFD) *Peter Sulyma*	03	--	30	Open	March 2004
Terahertz Sensor System *Dr. William St. Cyr*	03	--	40	Terminate FY03	---
High Speed MEMS-Fiber Optic Temperature Sensor for LOX *Dr. Fernando Figueroa*	03	--	33	Open	April 2004
H_2O_2 Detection Feasibility Study Using A Tunable Diode Laser Absorption *Dr. William St. Cyr*	03	--	30	Terminate FY03	---
Development of Novel Low-Cost Power-Free Hydrogen Peroxide Microcantilever Detector *Dr. William St. Cyr*	03	✓	37.6	Open	Dec. 2003
Earth Science Applications Directorate					
Application of Phytoplankton Photosynthetic Efficiency to the Development of Coastal Ocean-Color Algorithms and Harmful Algal Bloom Research *Callie Hall*	03	--	36.95	Open	August 2004
Automated Mosquito Monitoring: A Prototype Sensor for Vector Borne Disease Tracking and Response *Timi Vann*	03	--	50	Open	March 2004

NASA SSC Center Director's Discretionary Fund
Distribution of Resources for FY02 & FY01

Project Title and Investigator	Initiation Year	Partnerships with Academia	Total Funding Authorized ($K)	Project Status	Expected Completion Date (Month/Year)
FY02 Projects					
Propulsion Test Directorate					
Hydrogen Peroxide Sensor System *Dr. William St. Cyr*	02	--	35	Open	March 2004
Field Test Methods for Hydrogen Peroxide Stability Margin *Robert Ross*	02	✓	50	Complete FY03	--
Development of Low-cost High-Sensitivity Polymer Tunneling Accelerometers *Dr. William St. Cyr*	02	✓	40	Complete FY03	--
Concentration Ratio Measurement of N2 and O2 in a Liquid Oxygen Feed Line *Dr. William St. Cyr*	02	✓	67.5	Complete FY03	--
FY01 Projects					
Propulsion Test Directorate					
Transmitters with R-Shunt Capability *Mark Hughes*	01	--	50	Complete FY03	--
Office of External Affairs, Education					
Geospatial Education Pilot Study for the Gulf of Mexico Accord *Dr. Ramona Travis*	01	✓	40	Complete FY03	--

CDDF PROJECTS

INITIATED IN FY2003

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FY03
Propulsion Test Directorate
CDDF Projects

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PROJECT TITLE: Split-Body Valve Modeling Using Computational Fluid Dynamics (CFD)

INVESTIGATORS: Peter Sulyma/HA30
Jody Woods/LMSO
Russell Daines/LMSO

INITIATION YEAR: FY 2003

FUNDING AUTHORIZED FOR FY03: $30K

ACTUAL EXPENDITURES OF FY03 OR EARLIER YEAR FUNDING:

- In-house: $30K
- Contracts: $0
- Grants: $0

STATUS OF INVESTIGATION AT END OF FY03: To be continued in FY04 with funds remaining from FY02

EXPECTED COMPLETION DATE: March, 2004

PURPOSE:

The purpose of this CDDF project was the development, testing, and evaluation of a new CFD valve modeling software tool, CRUNCH, developed by CRAFT-Tech.

BACKGROUND AND APPROACH:

In a previous CDDF project that focused on CFD valve modeling, it was recognized that Finite-Difference Navier-Stokes (FDNS), the structured grid CFD code currently in use at SSC, was not suitable for timely analyses of large, three-dimensional valve simulations. This is due primarily to the difficulty and time required to generate a structured mesh for a complex geometry that can adequately capture the important flow phenomena. Structured grids also require a relatively large number of computational cells, which, in turn, requires a significant amount of computational (CPU) time to complete an analysis case. These two aspects of three-dimensional valve analysis using the FDNS CFD code resulted in unacceptable turn-around times for analysis tasks. For this reason, a suitable unstructured grid CFD code for valve modeling that would produce accurate solutions in a timely manner for project applications had to be developed or obtained.

CRAFT-Tech had a Phase I SBIR contract for modifying and testing their unstructured grid CFD code, CRUNCH, for three-dimensional valve modeling applications. This CDDF project was initiated during the CRAFT-Tech Phase I SBIR contract and utilized some of the code from that contract. Preliminary results from the CRAFT-Tech effort were very promising, showing good comparisons between the results of the newly modified unstructured grid CFD solver, CRUNCH, and existing solutions from FDNS.

FY03 ACCOMPLISHMENTS:

During the CDDF project, one Lockheed Martin CFD engineer was trained by CRAFT-Tech in the new CFD code and the associated tools required to use the code. Training on the CRUNCH CFD code included pre and post-processing tools, grid generation techniques for hybrid unstructured grids, grid adaptation, code methodology, and discussions on the installation and use of Message Passing Interface (MPI) for parallel operations. MPI routines, used by the CRUNCH CFD code, are a set of general library functions that can be called from computer codes to allow parallel execution. Running in parallel is necessary for rapid turn-around of large complex analysis problems.

Development and testing of the CRAFT-Tech CFD code on the SSC Beowulf computational cluster was a high priority at SSC and was implemented as part of this effort. MPI, required by CRUNCH, was installed, debugged, and tested as part of this CDDF. Once MPI was

PROJECT TITLE: Split-Body Valve Modeling Using Computational Fluid Dynamics (Cont.)

FY03 ACCOMPLISHMENTS (Cont.)

operational, the CRUNCH CFD code was installed, tested and evaluated.

One unexpected finding of our work was the benefit of using unstructured grids for two-dimensional valve analysis tasks. When comparing FDNS and CRUNCH, it was found that using an unstructured solver reduced the analysis time for three-dimensional analyses because of the significantly reduced grid generation time as expected.

A more surprising finding was that the generation of two-dimensional valve grids could be completed in less than five minutes once a grid generation script was generated, instead of the two to four hours required for the generation of structured grids for these relatively simple geometries. Grid generation scripting is only possible for these geometries because of the hybrid unstructured nature of the grid – it cannot be done with structured grids. This represents a significant saving in labor time for this class of problems. Two-dimensional valve analysis is a very important application at SSC and is required for the rapid and timely generation of C_v curves.

PLANNED FUTURE WORK:

Our experience with the CRUNCH code has been very positive. It appears to meet all of SSC's requirements for a CFD code capable of performing accurate analyses of complex three-dimensional valve geometries in a timely manner. Grid generation time is significantly reduced, and grid generation scripting for frequently modeled geometries could further streamline the analysis process. As a result of this CDDF effort, initial training, installation and application of this new unstructured CFD code has been completed.

It is recommended that additional evaluation and testing of this code for two-dimensional and three-dimensional valve analyses be performed. Additional work will be required to make the CRUNCH CFD code operational for weekly production-level tasks. Code verification needs to be carried out to better understand the effects of grid density on the model output. This is particularly important in conjunction with the grid adaptation capabilities of the code. Proper application of the grid adaptation capabilities will reduce the overall number of computational nodes and CPU hours required, while maintaining the level of accuracy of the analysis. Further training on the hybrid grid generation process is recommended to better achieve high-quality grids and minimize the time required to generate grids. Further experience in applying grid generation scripting should be obtained, and the possibility of generating a catalog of scripts for frequently used geometries should be investigated. Experience in these areas will decrease the time required by CFD engineers to achieve reliable results in the future. Finally, additional CFD training and experience needs to be developed.

PROJECT TITLE: Terahertz Sensor System

INVESTIGATORS: Dr. William St. Cyr/HA30
Harvey Smith/LMSO

INITIATION YEAR: FY 2003

FUNDING AUTHORIZED FOR FY03: $40K

ACTUAL EXPENDITURES OF FY03 OR EARLIER YEAR FUNDING:

- In-house: $40K
- Contracts: $0
- Grants: $0

STATUS OF INVESTIGATION AT END OF FY03: Terminated in FY03

PURPOSE:

To explore current developments in Terahertz Sensor Systems, and to assess the feasibility of employing sensor systems to enhance SSC test capabilities. Immediate applications would include the monitoring of the dynamics of gases inside the combustion chamber of rocket engines, view substrate (underlying) conditions of jacketed vacuum lines and assess the condition of perlite that is used for insulation in storage tanks.

BACKGROUND AND APPROACH:

The terahertz spectrum is defined as the region encompassing frequencies in the range from 100 *GHz* up to 30 *THz*. The lower frequency boundary lies just above the microwave region where satellite dishes and mobile phones operate, whereas the higher frequency boundary is adjacent to infrared (IR) frequencies. This region represented the last underutilized area (unexplored frontier) of the electromagnetic spectrum and can be thought of as the fusion between microwaves and infrared radiation. The generation and means of detection have been developed only in the last few years.

Biological and organic compounds radiate distinct signatures in the terahertz band. Hence, these radiations can be used to detect and to interact with most molecules.

Similar to *x-rays,* terahertz (THz) radiation or *T-rays* pass through objects, producing internal images that can be viewed with recently developed detection systems. This development can be applied to the nondestructive evaluation of a multitude of opaque materials. Terahertz and Near Infrared (NIR) technologies are applicable to telecommunications, monitoring atmospheric gases, environmental surveillance, astronomical exploration, medical diagnosis, inspecting luggage and bulk goods shipments, detecting subsurface rust, and penetrating walls and clothing to detect hidden objects or contraband.

A common way to generate terahertz radiation or waves is to illuminate a tailored semiconductor crystal, such as gallium arsenide (GaAs), with very short (*femto-second* or *fs*) pulses of visible laser light. The bombardment creates very short pulses of terahertz radiation (typically of the order 100 *fs* pulses). These pulses then can be used for imaging and spectroscopy. Pulses reflect from different depths within an object. An *image slice* at a desired depth can be built up by carefully controlling the timing of the pulse detection. A 3D image can then be constructed by putting together these image slices. Coherent detection of the pulses can be achieved by illuminating a second crystal with both the terahertz pulses and a delayed portion of the visible laser pulses that is split off from the original beam Coherent detection leads to both amplitude and phase measurements. Optical spectroscopic techniques only measure the intensity of light at specific frequencies, whereas with terahertz detection, the temporal electric field of terahertz pulses that have interacted with a sample through reflection or by direct transmission, is measured.

PROJECT TITLE: Terahertz Sensor System (Cont.)

FY03 ACCOMPLISHMENTS:

A limited evaluation of existing technology and leading edge research in terahertz systems sensor has been explored. From the information and data reviewed, it was discovered that the Los Alamos National Laboratory has an existing exclusive licensing agreement with *Molecular Opto-Electronics Corporation* (MOEC). MOEC has also received a technology transfer grant from the National Science Foundation. The grant from the NSF will support the development of an electro-optic terahertz detector with prospective applications in imaging and remote sensing.

The Los Alamos project grants MOEC exclusive rights to the invention *Electro-optic Crystal Mosaics for the Generation of Terahertz Radiation*. Researchers from both labs developed this class of terahertz emitters. Also, MOEC has exclusive rights to Rensselaer Polytechnic Institute (RPI) developments.

It must be mentioned too that NASA is already getting into the deployment of systems. A startup company, *Picometrix* of Ann Arbor Michigan, has recently sold a scanner to a division of NASA. This scanner will be used to search for gaps or anomalies in the foam insulation of the space shuttle.

At present, it would be in NASA-SSC's best interest to monitor on-going work in the development of terahertz technology.

PLANNED FUTURE WORK:

There is no future work planned in the area of Terahertz sensors.

PROJECT TITLE: High Speed MEMS-Fiber Optic Temperature Sensor for LOX

INVESTIGATORS: Fernando Figueroa/HA30
Harvey Smith/LMSO

INITIATION YEAR: FY 2003

FUNDING AUTHORIZED FOR FY03: $33K

ACTUAL EXPENDITURES OF FY03 OR EARLIER YEAR FUNDING:

- In-house: $33K
- Contracts: $0
- Grants: $0

STATUS OF INVESTIGATION AT END OF FY03: To be continued in FY04 with remaining FY03 funds

EXPECTED COMPLETION DATE: April, 2004

PURPOSE:

To build and test a prototype fiber-optic temperature sensor (FOTS) that can outperform and address shortcomings of the Resistance Temperature Detector (RTD) sensors now in use.

BACKGROUND AND APPROACH:

BACKGROUND

The RTD sensors currently used to measure temperature in the LOX lines are made by Rosemount Corporation at an elevated cost and requiring a long procurement lead-time. Other RTD suppliers have provided less expensive units with shorter procurement lead-time, but important improvements can be achieved by considering fiber optic and MEMS technologies for temperature sensing. RTD's speed of response is slower than desired (time constant of about 400 ms), RTD's introduce an electric current through the resistor that is in direct contact with LOX, and create a possibility of sparking. These sensors may also corrode and degrade rapidly in the harsh cryogenic operating conditions. Luna Innovations, Inc. (Blacksburg, VA), developed a temperature sensing technology based on MEMS and Extrinsic Fabry Perót Interferometry, but the technology had undergone limited testing in the context of potential application to SSC test facilities. The company built a FOTS and tested it at temperatures ranging from –196 ºC to 300 ºC. The technology is very promising, but further development and testing was needed to have it operate in combined conditions of high pressure and flow rate, and at cryogenic temperatures. Furthermore, FOTS are so small that multiple sensing units could be mounted in one enclosure (easily three) to have redundancy. Such a redundant sensor based on fiber optic technology would greatly increase the integrity, reliability and accuracy of the data.

APPROACH

Two separate and simultaneous tasks were carried out: (1) design of a housing that could withstand pressures of up to 8,500 PSI and allowed a fast speed of response (time constant better than 400 ms, and (2) verification of the operating specifications of the sensing element, particularly speed of response, and first time exploration of the operability of the sensing element (SE) at Liquid Helium temperature.

SENSOR HOUSING

Two approaches were explored: (1) a thermal well, and (2) an open ended housing for direct fluid-sensor contact.

Thermal Well

A standard well was purchased from Omega Engineering, with a very small tip so as to optimize speed of response. The existing thermocouple was extracted and the tip was modified to insert a stainless steel sleeve that was welded to the tip. Further, an Omega-Lit tubing was used to protect the fiber optic sensor.

PROJECT TITLE: High Speed MEMS-Fiber Optic Temperature Sensor for LOX (Cont.)

BACKGROUND AND APPROACH (Cont.):

The tubing and sensor were inserted through the sleeve, with the tip of the sensor protruding and reaching the very end of the housing tip. To further improve speed of response, a heat conducting grease was injected to fill the tip, thus making contact with the sensor element and the housing tip. At the connector side, parts were made to take the optical fiber to the signal conditioning unit (Figure 1). The enclosure was successfully tested under hydrostatic pressure to 12,750 PSI.

Figure 1 Prototype Fiber Optic Temperature Sensors (well enclosure above, and open-end enclosure below).

Open-Ended Housing

A Rosemount RTD housing was used as a basis. The RTD element was removed completely. The tip was modified to house a porous stainless steel (316 Stainless) end, with the expectation that the fluid would permeate through and reach the sensing element. The porous end was held in place by a perforated enclosure from an original RTD housing. To achieve a seal that could withstand high pressure, a compression ferrul was mounted around a stainless steel capillary tubing to form a tight fit. The capillary tubing has an inside diameter of 0.010" and the optical fiber (0.005") was inserted through the tubing and squeezed using the compressin ferrul (Figure 1). The seal technology was successfully tested under hydrostatic pressure to 12,750 PSI. A method to tighten the ferrule was developed so as to achieve the desired level of seal, while maintaining the fiber's light conducting properties.

SENSING ELEMENT

The sensing technology was developed by Luna Innovations (Blacksburg, VA) during a SBIR Phase I Project. Five sensing elements (SE) and a signal conditioning box were purchased to carry out experiments to determine the operating specifications. Two sets of experiments were carried out at the Measurements and Calibration Laboratory to determine accuracy and speed of response. In the first set, SE without enclosures were plunged into baths at five temperature points: Liquid Nitrogen, -195 ºC, -50 ºC, -25 ºC, 0 ºC, 22 ºC, and 50 ºC. In the second set of tests, the sensors were immersed in Liquid Helium as well as previous temperature baths (except 22 ºC). The SE were immersed (or plunged) three or four times at each temperature point. The second set of tests included the two sensors with enclosures.

Data from the tests are currently being reduced, and accuracy, repeatability, and resolution have not yet been infered. However, the manufacturer of the SE claims that the sensors have a resolution of 0.1 ºC, combined non-linearity, non-repeatibility, and hysteresis of +/- 1% FS, and a FS range from -200 to 300 ºC. Our tests with Liquid Helium extend this range to -270 ºC. The sensors maintained operability as they were submerged in the test media and taken back to room temperature after each test point (Figure 1). The response time constant for the SE was on the order of 7.0 ms (Figure 2). This speed of response is about 60 times faster than RTDs currently used to measure LOX temperature in the test stands.

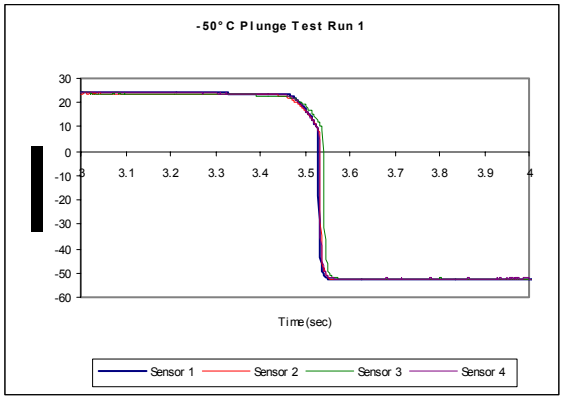

Figure 2 Sensing Element Plunge Test from Room Temperature to -50C.

PROJECT TITLE: High Speed MEMS-Fiber Optic Temperature Sensor for LOX (Cont.)

FY03 ACCOMPLISHMENTS:

SENSOR HOUSING

Both, an open-ended and a well housing were developed. A seal technology was developed for the open-ended housing, and successfully tested to 12,750 PSI under hydrostatic pressure.

FIBER OPTIC SENSOR ELEMENT

Data reduction is not complete, and experimental validation of the specifications claimed by the manufacturer has not yet been done. However, three important results have been derived: (1) the speed of response corresponds to a time constant on the order of 7.0 ms, which is 60 times faster than RTDs used to measure LOX temperature in the test stands, (2) the temperature range has been extended to include Liquid Helium temperature (-270 C), and (3) operability of the SE from 50 C to -270 C has been verified.

PLANNED FUTURE WORK:

1. Install the sensors in actual operating conditions in the E-Complex to evaluate their performance. The seal system of the open-ended sensor has been tested in hydrostatic conditions, and the unit has been tested down to Hellium temperatures. Installing them in an operating environment will allow testing of the seal in both high pressure and cryogenic conditions. The fittings of the sensor enclosures are standard and can be screwed into standard ports. This work may be done using the new cryogenic test apparatus being built in the E-Complex.
2. Submit New Technology Reports.
3. Write papers for conferences/journals.
4. If the test in Item 1 is successful, then seek funding to re-design the end of the open-ended unit so as to maximize the speed of response and its ability to withstand high flow conditions.
5. Luna Innovations is currently working on improving the signal conditioning for the sensors. The signal shows sporadic jumps related to 1/4 wavelength of the operating optical frequency of the sensors.
6. If the test in Item 1 is successful, additional funding is needed to explore development of a multi-element probe that can offer all the benefits associated with redundancy.

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PROJECT TITLE: H_2O_2 Detection Feasibility Study Using A Tunable Diode Laser Absorption

INVESTIGATORS: William St. Cyr/HA30
Dr. Gopal Tejwani/LMSO

INITIATION YEAR: FY 2003

FUNDING AUTHORIZED FOR FY03: $30K

ACTUAL EXPENDITURES OF FY03 OR EARLIER YEAR FUNDING:

- In-house: $30K
- Contracts: $0
- Grants: $0

STATUS OF INVESTIGATION AT END OF FY03: Terminated in FY03

PURPOSE:

The main objective of this study is the remote and instantaneous detection of H_2O_2 *in situ* at high sensitivity (ppm levels) by means of tunable diode laser absorption spectroscopy. A thorough spectroscopic study is a prerequisite for selection/design of an appropriate diode laser system for remote detection of H_2O_2 at or near the SSC test stands. During, the first phase, the H_2O_2 vapor and the H_2O_2 liquid spectral data available in the literature will be compiled and searched for a few suitable bands for a laser diode system.

BACKGROUND AND APPROACH:

Hydrogen peroxide at high concentrations has been used previously at Stennis Space Center (SSC) as a propellant oxidizer in engine test programs at E3 Cell 2. It creates potential environmental hazard for personnel working not only at E3 Cell 2, but also at adjacent test stands. It is important to monitor the H_2O_2 concentrations in the test cell and the surrounding environment remotely and accurately during and subsequent to the testing. Laser absorption systems have several advantages such as remote operation, high sensitivity, and easily quantifiable results. These measurements can be carried out instantaneously at as high a frequency of observation as desired.

During the first phase of this project, it was planned to conduct a comprehensive literature search for H_2O_2 vapor and H_2O_2 liquid spectral data. Because of experimental difficulties, H_2O_2 molecule has not been investigated widely for its spectral properties. Even its structure was not unambiguously determined until recently. We planned to collect and compile all the essential spectroscopic information available on H_2O_2. Our goal was to find stronger bands which are free from interference from various atmospheric species such as H_2O, CO, CO_2, CH_4, N_2O, NO and NO_2. Several isolated transitions or sub-bands will be selected from these strong H_2O_2 bands as appropriate for monitoring by a diode laser absorption system. Several “ideal” spectral lines for H_2O_2 detection have been identified during Phase I.

FY03 ACCOMPLISHMENTS:

Hydrogen peroxide works best as a propellant in extremely high concentrations of 90% or better. At such high concentrations, H_2O_2 can be very hazardous and it is necessary to monitor its concentration at or near the rocket engine test site. The tunable diode laser absorption spectrometer (TDLAS) method fulfills the requirement of detecting H_2O_2 directly in the gas phase, removing the possibility of such artifacts as may occur in the aqueous trapping methods. Further advantage is its very high specificity towards the target molecule by virtue of the high spectral resolution employed and unlike methods that depend on the chemical properties of the molecule, no special procedures are required to avoid interferences from, for example, organic peroxides. TDLAS is a highly sensitive method capable of providing accurate measurements with detection limits in sub-ppbv

PROJECT TITLE: H_2O_2 Detection Feasibility Study Using A Tunable Diode Laser Absorption (Cont.)

FY03 ACCOMPLISHMENTS (Cont.):

(parts per billion volume) range. Our project work has not progressed far enough to get into the details of TDLAS system design and configuration details for application to H_2O_2 detection at test stands. One of the essential ingredients for a TDLAS system design for a specific molecular application is the selection of a few "ideal" transitions or lines for the given molecule. The rest of this report will focus on this aspect.

The hydrogen peroxide molecule is a non-planar molecule of point group C_2 symmetry with hindered rotation of two OH groups relative to each other and with two skew configurations being the most stable. The H_2O_2 molecule is only very slightly asymmetric and therefore usually may be considered a prolate symmetric top. Reliable descriptions of the molecular geometry and rotational motions have been obtained recently.

H_2O_2 has six fundamental bands, with five of these bands υ_1, υ_2, υ_3, υ_5, and υ_6 centered at 3598.7, 1387.5, 875.0, 3610.7, and 1260.0 cm^{-1}, respectively. υ_4 is a torsional mode with no well defined band center.[16] For, liquid phase, υ_3 has very strong Raman band. In the vapor phase, stronger infrared bands are υ_1, υ_2, and υ_6, with υ_6 being the strongest of these. According to the Air Force Geophysics Laboratory (AFGL) absorption line compilation, the strongest group of rotational lines in the υ_6 band are near the center of R branch.

The selection of an individual line for air-monitoring purposes involves a number of compromises between the properties of available lasers, the strengths of the absorption lines of the target molecules, and the avoidance of absorption lines from other atmospheric species that may interfere spectroscopically. The important laser characteristics for this application relate to output wavelength range, output mode structure, frequency and amplitude stability, and beam profile intensity distribution. Since our research on availability of diode lasers in the spectral range of our interest is not complete, we have selected several appropriate H_2O_2 spectral lines that are free from interference from other atmospheric species such as H_2O, and N_2O which also have many transitions in the υ_6 spectral region of H_2O_2.

The "best" line appears to be the H_2O_2 line at 1284.2044 cm^{-1}, which has a line strength of 3.6 x 10^{-20} cm^2 $molecule^{-1}cm^{-1}$. Only the line at 1283.740 cm^{-1}, of the several hundred lines in the υ_6 band of H_2O_2, has a significantly greater intensity. That line is, however, overlaid by an interfering absorption in ambient air and therefore can not be used for air monitoring. In addition, we found two other H_2O_2 lines located at 1264.590 cm^{-1} and 1264.622 cm^{-1}, respectively, as desirable and suitable for TDLAS. These lines have integrated line strengths of 0.4 and 1.6 x 10^{-20} cm^2 $molecule^{-1}$ cm^{-1}, respectively. It should be noted that neither the assignment of a selected line to a particular transition in the molecule nor knowledge of its integrated line strength is strictly necessary for the present purpose. However, if the selected line can be identified and its integrated line strength is known, it is possible to ascertain whether other lines which are significantly stronger than the one selected exist elsewhere in the spectrum of the molecule, and hence, whether further work on laser and absorption line selection procedure are warranted.

RECOMMENDATIONS:

Selection of "ideal" spectral lines for H_2O_2 detection and monitoring by TDLAS appears to be a good stopping point for this project. Based on the integrated line strengths of these lines, it should be feasible to identify H_2O_2 at mixing ratios of 1 ppbv. The actual selection of suitable laser operating conditions, and the determination of system detection limits, and the investigation of interferences are not independent tasks. These need to be carried out simultaneously by utilizing spectral simulations or by experimental means using iterative procedures. Also, calibration techniques need to be identified and developed. It is clear that TDLAS method can achieve the degree of specificity and sensitivity necessary for atmospheric assessment at the engine test stands. TDLAS provides direct measurement with high time resolution and specificity with high accuracy and consistency of performance not to mention remote sensing and portability of the system.

PROJECT TITLE: Development of Novel Low-Cost Power-Free Hydrogen Peroxide Microcantilever Detector

INVESTIGATORS: William St. Cyr/HA30
Dr. Haifeng Ji/Louisiana Tech Univ.

INITIATION YEAR: FY 2003

FUNDING AUTHORIZED FOR FY03: $37.6K

ACTUAL EXPENDITURES OF FY03 OR EARLIER YEAR FUNDING:

- In-house: $0
- Contracts: $37.6K
- Grants: $0

STATUS OF INVESTIGATION AT END OF FY03: Expected completion - December, 2003

PURPOSE:

The main objective of this study is to develop an ultra sensitive, low-cost badge-size detector for on-site monitoring of vapor hydrogen peroxide based on micro-cantilever technology.

BACKGROUND AND APPROACH:

In recent years, high concentrated hydrogen peroxide has been used as a propellant for rocket engines at NASA. There have been a few reports of hydrogen peroxide leakage from the storage containers. High concentration of hydrogen peroxide could cause severe skin and eye damage. Long term accumulation of low concentrations of hydrogen peroxide is also very detrimental to the eyes and lung tissue. The current method for vapor hydrogen peroxide measurements is based on bubbling in acid solution with subsequent laboratory analysis, which is inconvenient for personal monitoring. Successful sensors for in-situ characterization should have a fast, real-time response and be small enough (miniaturized) to be integrated into other devices. The ultimate goal of this research is to build a power-free, low-cost badge-size detector for on-site monitoring of vapor hydrogen peroxide at NASA-SSC. Chemical reaction can be sensitively monitored by microcantilevers. The reaction causes heat that bends the bimetallic microcantilever beam. The challenge in this approach is to adapt known chemically selective reaction to a micro-cantilever. One approach is to incorporate a reducing agent into a polymer on the microcantilever surface. Two reducing agents, dihydroxybenzene and urea, will be initially tested for such purpose. The reducing agents will be incorporated into a porous polydi-methylsilicon (PDMS) polymer or other polymeric films. Another approach is to use horseradish peroxidase (HRP). HRP is an effective catalyzing agent of hydrogen peroxide. Two methods, hydrogel incorporation and layer-by-layer film will be used to immobilize the HRP on the microcantilever surface.

FY03 ACCOMPLISHMENTS:

1. Developed sensor for H_2O_2 in water

Polyethyleneimine (PEI), poly(sulfonate styrene) (PSS), and Horseradish Peroxidase(HRP)(EC 1.11.7, type VI) were used for modification of the cantilever surface by using layer-by-layer self-assembly technique. The formation of multilayer on the micro-cantilever was conducted using a modified multilayer formation procedure: A TTS25 treated microcantilever was immersed into a 1.5 mg/mL solution of PEI (or HRP 1mg/ml) for 20 min, and rinsed with a stream (~100 ml/min) of water. The cantilever was then immersed into a 3 mg/mL solution of PSS also for a duration of 20 min and again rinsed with the water stream. This procedure was repeated several times until a desired multilayer film

PROJECT TITLE: Development of Novel Low-Cost Power-Free Hydrogen Peroxide Microcantilever Detector (Cont.)

FY03 ACCOMPLISHMENTS (Cont.):

was formed. In our experiments, the multilayer on microcantilevers were (PEI/PSS)3, followed by (HRP/PSS)3.

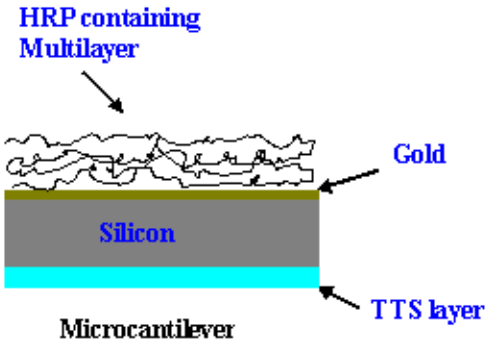

Figure 1: Schematic of microantilever modification.

The microcantilever was initially exposed to a constant flow (4mL/h) of a 0.01M solution of NaCl in a fluid cell. The NaCl solution was circulated through the cell using a syringe pump. When a solution containing a 1mM hydrogen peroxide in the 0.01M NaCl solution was injected into the fluid cell, the microcantilever started to bend down quickly, in about 2 minutes (Figure 2b). In less than 10 minutes it reached its deflection maximum. For each measurement, a 2.0-mL aliquot of the glucose solution in 0.01 M of NaCl was switched into the fluid cell where the microcantilever was held. It took 30 minutes for the injected hydrogen peroxide solution to flow through the fluid cell, and at this time, the original 0.01 M NaCl solution was circulated back into the fluid cell. This correlates well with our observations that the deflection of the microcantilever quickly returned to its original position ~30 min after the injection of hydrogen peroxide solution. A control experiment was carried out with microcantilever modified with the same number of layers, but only by PSS and PEI layer without the enzyme, HRP. When this cantilever was exposured to 1mM hydrogen peroxide, no corresponding deflection was found (Figure 2).

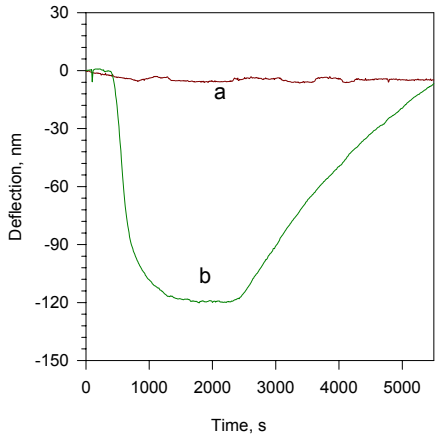

Figure 2: MC deflections upon exposure to 1mM hydrogen peroxide in solution. MC was modified with a) (PSS/PEI)6, b) (PSS/PEI)3/(PSS/HRP)3.

This confirms that it is the enzyme, HRP, which was immobilized in the multilayer, and its reaction with the injected hydrogen peroxide causes the deflection of microcantilever. The deflection magnificence varies accordingly to the concentration of injected hydrogen peroxide. The higher the concentration of hydrogen peroxide, the bigger the microcantilever deflection. Figure 3 shows the microcantlever deflection changes with time upon exposure to different concentration of hydrogen peroxide. The curve of “Blank” in Figure 3 is another control experiment, with injection of 2ml buffer solution. No specific deflection was found. Figure 4 shows the maximum deflection at different hydrogen peroxide concentration.

PROJECT TITLE: Development of Novel Low-Cost Power-Free Hydrogen Peroxide Microcantilever Detector (Cont.)

FY03 ACCOMPLISHMENTS (Cont.):

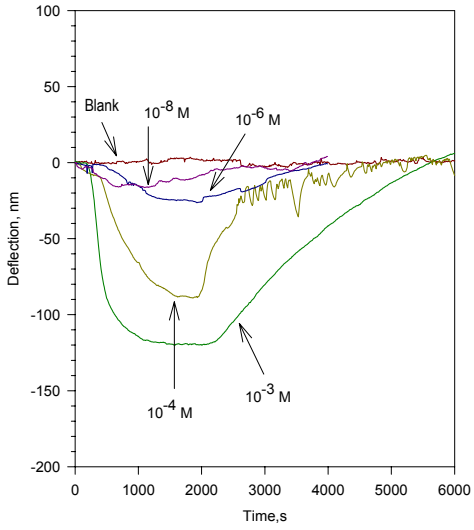

Figure 3: The bending response of a microcantilever to various concentrations of hydrogen peroxide in a 0.01M NaCl solution.

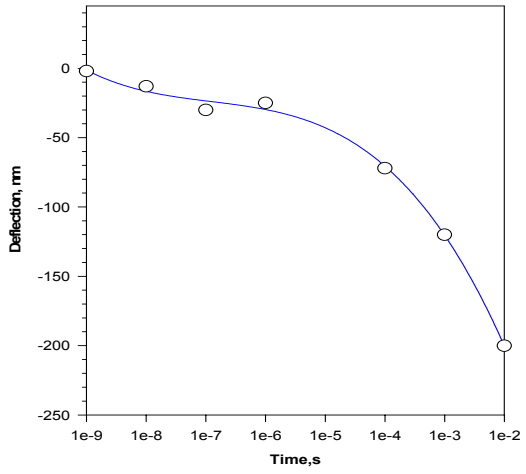

Figure 4: The maximum of deflection of microcantilever at different hydrogen peroxide concentration.

Sensing Mechanism Horseradish peroxidase (HRP) is the key part in this sensing process. HRP belongs to the super family of heme-containing plant peroxidases (EC 1.11.1.7) and it is the most studied enzyme among classic plant peroxidases due to its numerous analytical applications. The reaction of HRP with hydrogen peroxide (H_2O_2) to form an active oxidant is well documented. The enzyme catalyses a three-step process of oxidation of a donor substrate with hydrogen peroxides:

$$E + H2O2 \rightarrow EI + H2O \quad [1]$$

$$EI + S \rightarrow EII + S\bullet \quad [2]$$

$$EII + S + 2H+ \rightarrow E + S\bullet + H2O \quad [3]$$

where E is ferric enzyme, EI and EII are the oxidized intermediates, Compounds I and II, respectively, and S and S• are the electron donor substrate and the radical product of its one-electron oxidation. The reduction of Compound II with a donor substrate is usually the rate-limiting step in peroxidase catalysis (1). In the absence of donor substrates HRP Compound I quickly converts into Compound II and subsequently to the native ferric enzyme. In this experiment, no mediator was added. It is likely that the role of a donor substrate in this case is played by the enzyme itself, i.e., the active heme center is reduced with concomitant oxidation of protein amino acid residues.

HRP involved in the three-step reaction, which caused the change of the architecture of nano-assembling on the microcantilever surface, and then the surface stress. This change in surface stress only happened on the side of microcantilever with the nano-assembling, so it made the cantilever bended downward. When hydrogen peroxide flooded out of the cell and the reaction stopped, the cantilever started to bend back. At higher concentration of hydrogen peroxide, more HRP was involved in the reactions, so it causes a bigger bending. The thermal output of the enzymatic catalyzed reaction can also contribute to the bending of MC, but it is a very small scale. Similar research has demonstrated that the thermal loss that needs to cause bending is far in excess of what

PROJECT TITLE: Development of Novel Low-Cost Power-Free Hydrogen Peroxide Microcantilever Detector (Cont.)

FY03 ACCOMPLISHMENTS (Cont.):

should be produced from the enzyme-catalyzed reaction, indicating that the magnitude of the cantilever deflection is not likely due to thermal energy.

The multilayer film expanded 0.37% according to the following equation (see supporting information):

$$\Delta L = L' - L = L' - \sqrt{2\Delta ZR} = L' - \sqrt{L'^2 - 2\Delta Zt} \quad [3]$$

For the maximum 120nm deflection observed in the presence of 1mM hydrogen peroxide, the surface stress change was only 0.25 N/m according to the following equation.

$$\Delta Z = \left(\frac{3(1-\upsilon)L^2}{Et^2} \right) \delta s \quad [4]$$

Where ΔZ is the observed deflection at the end of the cantilever, ν and *E* are Poisson's ratio (0.2152) and Young's modulus (155.8 GPa) for the silicon substrate, respectively, t is the thickness of the cantilever (1 μm), L is the length of the cantilever (180 μm), and δs is the differential stress on the cantilever.

In summary, our study has shown that a microcantilever modified by HRP containing multilayer responded specifically and quantitatively to hydrogen peroxide, which could be potentially used for bioprocess monitoring. This work opened a new window for developing microcantilever sensors by using layer-by-layer approach. A controllable multilayer modification method could be used to detect many other chemical and biological species when different enzymes or receptors are embedded in the multilayer.

2. Develped sensors for H_2O_2 in Air

Experiments were performed for the PDMS/Phenol film modified cantilevers. The cantilever bent after exposure to H_2O_2 as expected. It is observed that the cantilever bent upward immediately after hydrogen peroxide is added to the cell. The cantilever displays a steady upward exponential bending response until it starts to stabilize after approximately 54 min (Figure 5). The cantilever bending return to its orignal position three hours after the H_2O_2 was replaced by air.

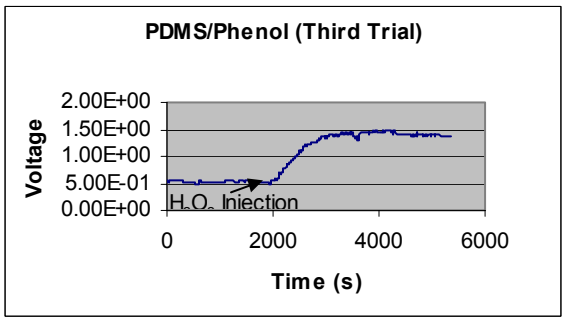

Figure 5: The bending response of PDMS/phenol modified micro-cantilever upon exposure to H_2O_2

The substantial difference in the bending response of the cantilever towards the control solution and towards the PDMS/Phenol implies that the microcantilever is quite chemically selective to the specific substrates on the surface. In the presence of phenol in the PDMS layer, the cantilever probably bent upward in response to phenol oxidation by hydrogen peroxide.

3. Developed a pattern that may be used for visiable measurement of H_2O_2.

We have built rectangular cantilever array with SiO_2 Figure 6). In this process, the SiO_2 were released by ICP iteching. We selectively modified some cantilevers in order to read the a pattern by naked eyes once the array panel is exposed to H_2O_2. A slight shadow change was observed as expected. The only draw back is that the cantilever bending is significantly big to be readily distinguished from the noise. We plan to build such a system by using PMMA, a polymer with smaller young's module than SiO_2. It is expected that the cantilever bending will give a readily eye-recognizable pattern that can be used for power-free H_2O_2 Detector.

PROJECT TITLE: Development of Novel Low-Cost Power-Free Hydrogen Peroxide Microcantilever Detector (Cont.)

FY03 ACCOMPLISHMENTS (Cont.):

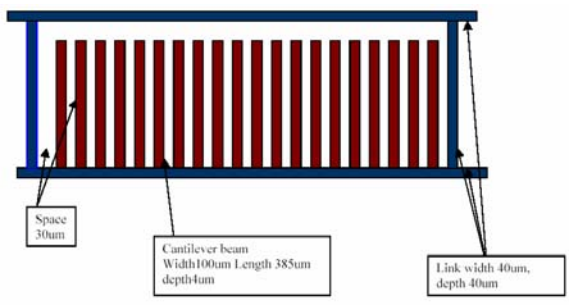

Figure 6: Patten design of a microcantilever array for power-free detection of H_2O_2

Publications and Patents

1. X. Yan, K. Shail, H.-F. Ji, W. Cyr "Modification of Microcantilevers Using Layer-By-Layer Self-Assembly Film for H_2O_2 monitoring" To be submitted
2. M. Upali, H.-F. Ji, " Phenol Doped PDMS Covered Microcantilever for H_2O_2 Sensing" in preparation.

Planned Future Work

Since NASA no longer uses H_2O_2 propellant, we are not going to pursue to perfect the system for final product. However, we plan to develop the same type of device for A) gases detection, such as H_2, benzene, CO, CO_2 etc, which would be critical for traveling to Mars, and (B) biomedical application of the technology could be used for NASA.

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FY03
Earth Science Applications Directorate
CDDF Projects

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PROJECT TITLE: Application of Phytoplankton Photosynthetic Efficiency to the Development of Coastal Ocean-Color Algorithms and Harmful Algal Bloom Research

INVESTIGATORS: Callie Hall/MA10
Carlos Del Castillo/MA10
Bruce Spiering/HA30

INITIATION YEAR: FY 2003

FUNDING AUTHORIZED FOR FY03: $36.95K

ACTUAL EXPENDITURES OF FY03 OR EARLIER YEAR FUNDING:

- In-house: $3,650
- Contracts: $33,300
- Grants: $0

STATUS OF INVESTIGATION AT END OF FY03: To be continued in FY04 with funds remaining from FY03

EXPECTED COMPLETION DATE: August, 2004

PURPOSE:

The purpose of this project is twofold: 1) to evaluate the utility of a phase fluorometer for improving *in situ* measurements of phytoplankton photosynthetic efficiency, thereby improving satellite chlorophyll algorithms and developing regional satellite algorithms for primary productivity, and 2) to characterize the chlorophyll fluorescence lifetime of *Karenia brevis*, responsible for Gulf of Mexico harmful algal bloom events.

BACKGROUND AND APPROACH:

Profiling and bench-top phase fluorometers developed under NASA SBIR grants to Ciencia, Inc., were used to determine the chlorophyll fluorescence lifetime of cultured phytoplankton and mixed populations of phytoplankton within the northern Gulf of Mexico. Because the processes of fluorescence and photosynthesis are assumed to be inversely related (Ciencia, 1999), measured fluorescence lifetime can be used to estimate photosynthetic efficiency. The basic principle underlying this approach is that fluorescence quantum yield (ϕ_f) is directly related to measured fluorescence lifetime (τ):

$$\tau/\tau_0 = k_f/(k_f + k_p + k_d + k_t) = \phi_f,$$

where τ_0 is the intrinsic, or natural, lifetime and k_f, k_p, k_d, and k_t are the rate constants for fluorescence, photochemistry, heat dissipation, and transfer of energy to another species, respectively (Lavorel and Etienne, 1977; Samuellson and Oquist, 1977). Thus, the quantum yield of fluorescence can be expressed as the ratio between the rate of fluorescence, or the measured lifetime of chlorophyll *a* fluorescence, and the total rate of de-excitation, or the natural (intrinsic) lifetime of chlorophyll *a* fluorescence. Furthermore, the ratio of measured lifetime to natural lifetime is directly related to the ratio of variable fluorescence to maximum fluorescence (F_v/F_m):

$$\tau/\tau_0 = (F_m - F_0)/F_m = F_v/F_m.$$

The ratio of F_v/F_m is correlated with the maximum quantum efficiency of photochemistry in photosystem II, where the primary photochemical reactions occur (Falkowski and Raven, 1997). The phase fluorometer measures the phase difference between sinusoidally modulated optical excitation and the resulting fluorescence. The fluorescence lifetime is then calculated from the phase difference and the modulation frequency (Ciencia, 1999).

The bench-top phase fluorometer was used in the laboratory to measure the fluorescence lifetime and photosynthetic efficiency of several cultured phytoplankton species representative of northern Gulf of Mexico populations. The

PROJECT TITLE: Application of Phytoplankton Photosynthetic Efficiency to the Development of Coastal Ocean-Color Algorithms and Harmful Algal Bloom Research (Cont.)

BACKGROUND AND APPROACH (Cont.):

fluorescence lifetime and photosynthetic efficiency of mixed phytoplankton populations were measured during three cruises occurring within northern Gulf of Mexico coastal waters in July – September, 2003. Ancillary measurements of the underwater and surface light fields, reflectance, turbidity, and the concentration of dissolved organic matter were also performed.

FY03 ACCOMPLISHMENTS:

The profiling phase fluorometer experienced technical difficulties throughout the project duration. Although this instrument was unavailable for significant laboratory and field testing, testing with the benchtop phase fluorometer provided valuable insight into the stability and robustness of fluorescence lifetime measurements.

Tests of the stability of the benchtop phase fluorometer were performed with a rose bengal-methanol solution, as this solution has a known fluorescence lifetime of 600 ± 40 ps. Over twenty rose bengal tests were run within the phase fluorometer, and the average fluorescence lifetime was 632 ± 0.012 ps.

The lifetime signatures of two coastal phytoplankton species in culture were determined. A coastal diatom (*Chaetoceros gracilis*) and a chlorophyte (*Dunaliella tertiolecta*) were used in laboratory testing of the benchtop phase fluorometer (Figs. 1 – 4). *D. tertiolecta* displayed a higher chlorophyll fluorescence lifetime (2.04 ± 0.254 ps) than *C. gracilis* (1.11 ± 0.105 ps), but photosynthetic efficiency and fluorescence quantum yields were not significantly different between the two species ($p \leq 0.05$). Variable fluorescence normalized to maximum fluorescence (F_v/F_m) was 0.151 ± 0.108 for *C. gracilis* and 0.143 ± 0.100 for *D. tertiolecta*. Fluorescence quantum yield was 0.843 ± 0.106 for *C. gracilis* and 0.851 ± 0.104 for *D. tertiolecta*.

The benchtop phase fluorometer was used on several cruises within the northern Gulf of Mexico. Photosynthetic efficiency (F_v/F_m) was calculated for chlorophyll fluorescence lifetimes of mixed phytoplankton populations within the Mississippi River plume and adjacent shelf region (Fig. 5). In waters within the Mississippi River plume, photosynthetic efficiency was high (F_v/F_m = 0.5 – 0.6; theoretical maximum of F_v/F_m = 0.65). Photosynthetic efficiency was lower within offshore waters ($F_v/F_m \approx 0.30$).

PROJECT TITLE: Application of Phytoplankton Photosynthetic Efficiency to the Development of Coastal Ocean-Color Algorithms and Harmful Algal Bloom Research (Cont.)

FY03 ACCOMPLISHMENTS (Cont.):

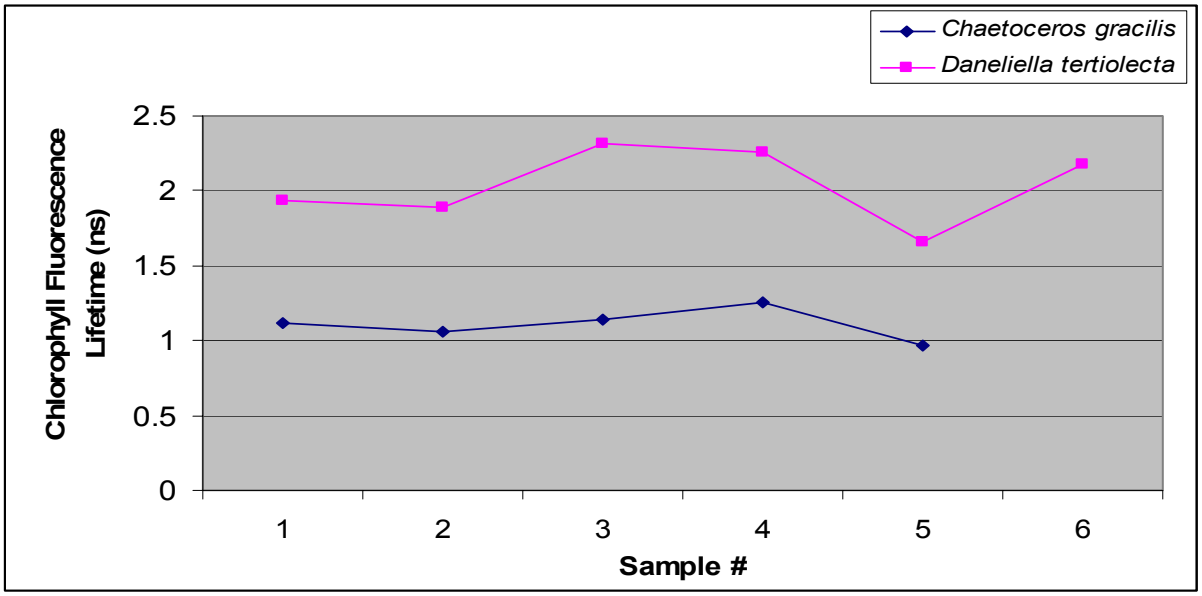

Figure 1. Chlorophyll fluorescence lifetime (measured in nanoseconds) of a diatom, *Chaetoceros gracilis*, and a chlorophyte, *Dunaliella tertiolecta*.

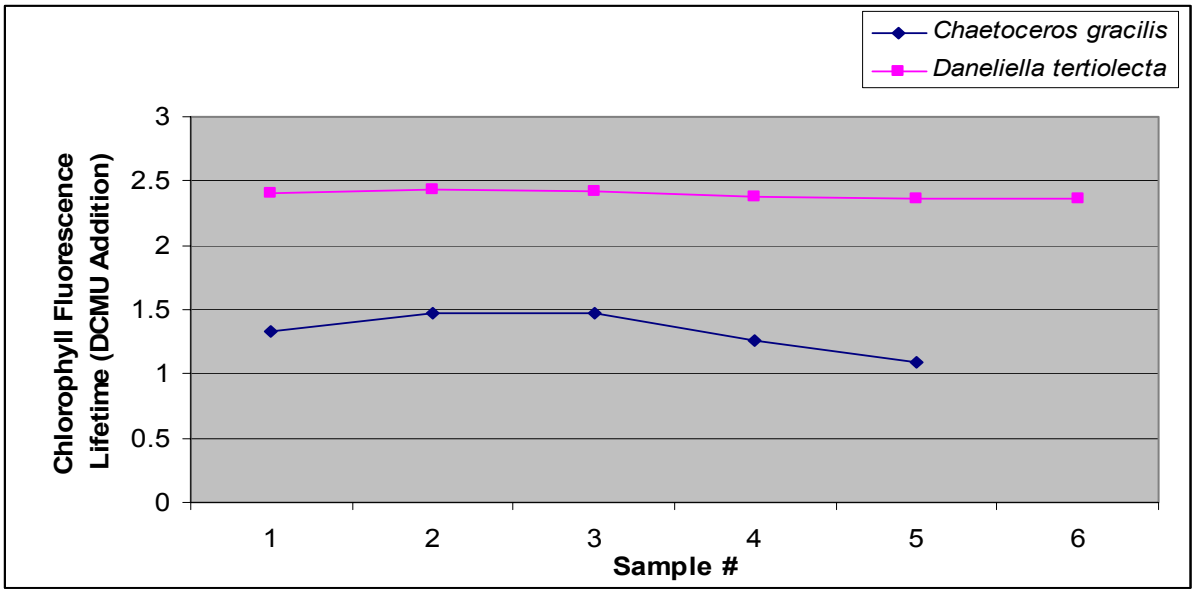

Figure 2. Chlorophyll fluorescence lifetime of phytoplankton cells after addition of DCMU (an herbicide). DCMU blocks electron transport within the chloroplast and "closes" the cell for photosynthesis. Fluorescence is at a maximum when DCMU is added.

PROJECT TITLE: Application of Phytoplankton Photosynthetic Efficiency to the Development of Coastal Ocean-Color Algorithms and Harmful Algal Bloom Research (Cont.)

FY03 ACCOMPLISHMENTS (Cont.):

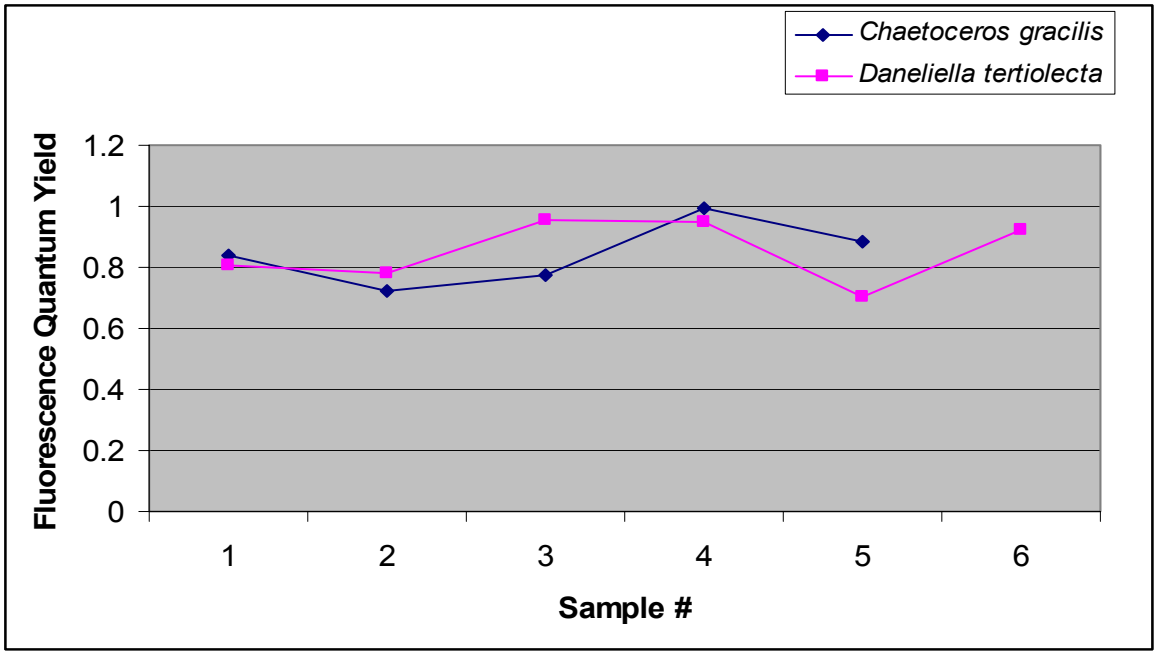

Figure 3. Fluorescence quantum yield for *C. gracilis* and *D. tertiolecta*. Quantum yield exhibits the same pattern over 5 sample measurements for each culture.

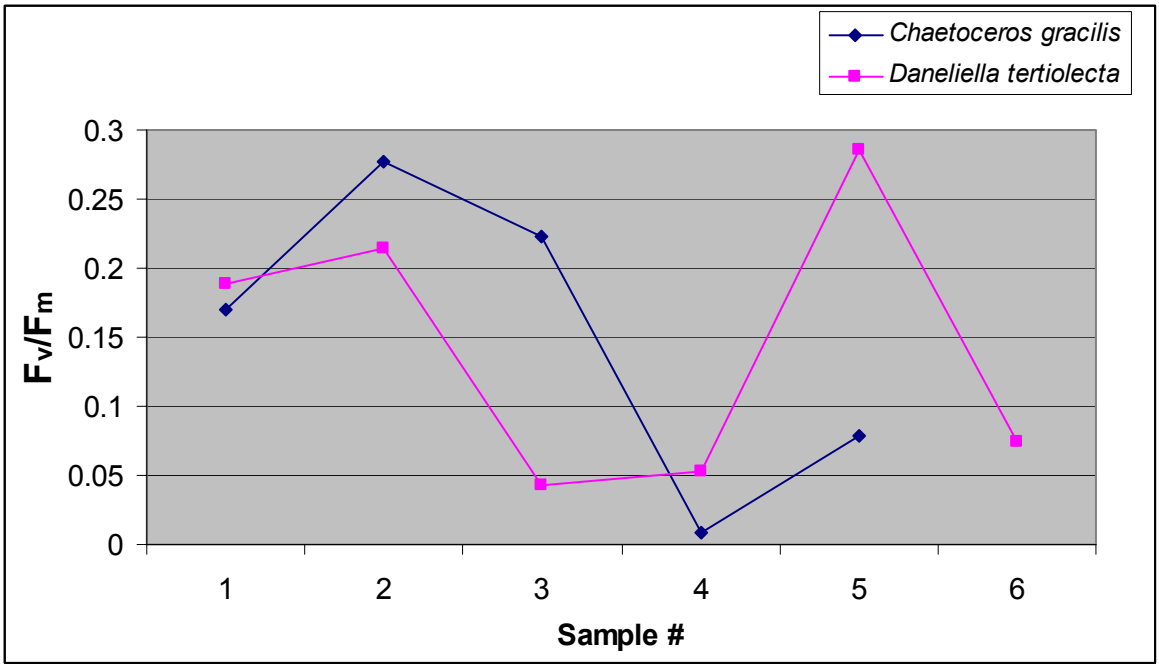

Figure 4. Photosynthetic efficiency (F_v/F_m) for *C. gracilis* and *D. tertiolecta* over 5 – 6 sample measurements. Although the photosynthetic efficiency of each sample differs for each culture, F_v/F_m displays a similar pattern for each sample over 5 subsequent measurements.

PROJECT TITLE: Application of Phytoplankton Photosynthetic Efficiency to the Development of Coastal Ocean-Color Algorithms and Harmful Algal Bloom Research (Cont.)

FY03 ACCOMPLISHMENTS (Cont.):

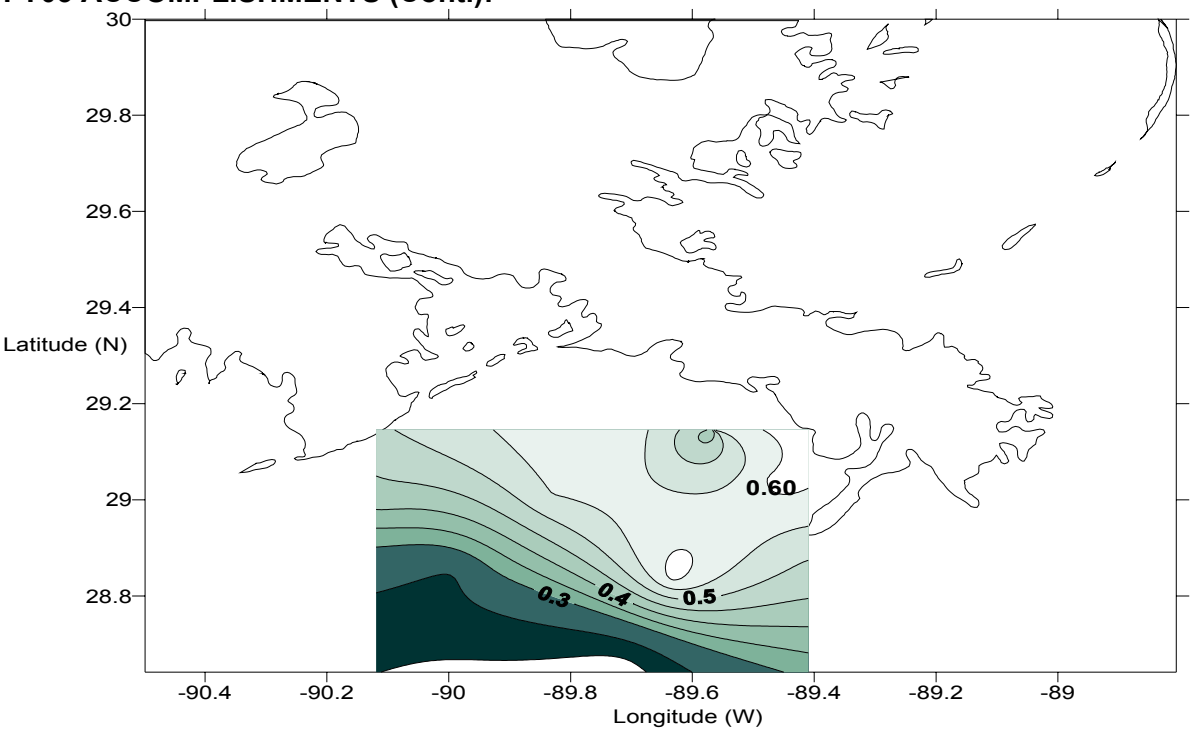

Figure 5: Photosynthetic efficiency (F_v/F_m) of mixed phytoplankton populations sampled within the Mississippi River plume and adjacent Gulf of Mexico shelf. F_v/F_m is higher near the mouth of the Mississippi River and decreases offshore.

PUBLICATIONS/PATENTS:

A manuscript will be submitted to a peer-reviewed journal when experiments and cruises are complete and results are analyzed fully. Manuscript submission is expected by October 2004.

PLANNED FUTURE WORK:

Future work for this project involves field testing of a profiling phase fluorometer within the northern Gulf of Mexico and characterization of the fluorescence lifetime and photosynthetic efficiency of *Karenia brevis* in culture.

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PROJECT TITLE: Automated Mosquito Monitoring: A Prototype Sensor for Vector Borne Disease Tracking and Response

INVESTIGATORS: Timi Vann/MA10
Dr. Jane Andrews/LMSO
Dane Howell/LMSO
Dr. Robert Ryan/LMSO
Dr. Dawn Wesson/Department of Tropical Medicine and Parasitology, Tulane Medical Center

INITIATION YEAR: FY 2003

FUNDING AUTHORIZED FOR FY03: $50K

ACTUAL EXPENDITURES OF FUNDING FROM EARLIER YEARS:

- In-house: $50,000
- Contracts: $0
- Grants: $0

STATUS OF INVESTIGATION AT END OF FY03: To be continued in FY04 with funds remaining from FY03

EXPECTED COMPLETION DATE: March 2004

PURPOSE:

Proof of concept to determine if a sensor could be developed to detect and identify flying insects based on wing beat frequency.

BACKGROUND AND APPROACH:

Overview

This report describes the results of a sensor technology project designed to automatically detect and discriminate flying insects based on optical waveform patterns that result in specific wingbeat signatures (WBSs). Preliminary data indicate that our configuration is capable of detecting and differentiating the WBSs of a number of butterfly, moth, and skipper species (Order: Lepidoptera), one fruit fly species (Order: Diptera), and two mosquito species (Order: Diptera). This effort supports the hypothesis that an automated insect monitoring device can be used to improve the availability of digitized insect information. The results presented in this report could ultimately lead to the development of powerful new active surveillance tools. A provisional patent has been submitted on this approach.

NASA Interests

One of the National Application programs sponsored by NASA's Earth Science Enterprise and supported by the Earth Science Applications Directorate at Stennis Space Center is the Public Health Applications of Earth Science (PHASES) program. NASA's interest in public health is directly related to the Earth Science Enterprise primary mission to understand the Earth system and to apply Earth system science to improve the prediction of climate, weather, and natural hazards (National Aeronautics and Space Administration, 2003). Although links between climate and disease are not always direct, it has been shown that the incidence and distribution of pathogens and their vectors are a function of specific environmental conditions, such as temperature, precipitation, and humidity (National Research Council, 2001; U.S. Global Change Research Program, 2000). Climate models predict substantial increases in average global temperatures and precipitation over the next century, increasing the likelihood of emergent, resurgent, and redistributed vector-borne diseases (Epstein, 2002; Githeko et al., 2000). Arthropods, in particular, are highly sensitive to climate and weather changes

PROJECT TITLE: Automated Mosquito Monitoring: A Prototype Sensor for Vector Borne Disease Tracking and Response

BACKGROUND AND APPROACH (Cont.):

(Epstein, et al., 1998). Species distribution is related to climate while population density is influenced by weather. As reviewed by Epstein (2002), a growing body of research links shifts in insect range to climate changes, suggesting that insects may be useful indicators of ecological change. Characterizing demographic shifts in insect populations and displacement patterns as part of a regional, national, or multinational monitoring regime would serve as an important data component for substantiating climate change. The value of insect monitoring from both a public health and a climate change science perspective is compelling, yet no efficient tools or methods are currently available for coordinating or systematically monitoring insect populations. The AFIDS system was designed for efficient and systematic insect monitoring to serve the public health and climate change communities.

Disease Surveillance

Disease surveillance systems quantify disease activity at a given time, predict the probable future course of the disease cycle, and indicate when control should be started to prevent epizootic or epidemic transmission (Moore et al., 1993). However, vector-borne infectious disease surveillance is limited, due in part to the dynamics of disease transmission between primary hosts (e.g., birds) and primary vectors (e.g., mosquitoes). Disease surveillance is also dependent on passive and active reporting.

Passive surveillance relies on standardized reporting systems in which physicians report clinical cases of specific diseases. This type of surveillance is typically good for monitoring long-term disease trends but is not effective for detecting disease with minimal delay.

Active surveillance relies on a standardized data collection methodology and rapid lab-based verification and validation. Commonly used active surveillance techniques for monitoring insect-born diseases include the use of various insect traps, such as the New Jersey light trap, CO_2 baited traps, Center for Disease Control and Prevention (CDC) light traps, and Gravid traps. Both the New Jersey and CDC light traps rely on medium-wattage light bulbs to attract mosquitoes and a fan to capture specimens. The CO_2 baited traps lure mosquitoes by emulating CO_2, a natural mosquito attractant found in the breath of living animals. In contrast, the Gravid trap uses stagnant water to simulate natural mosquito breeding grounds to attract female mosquitoes. Regardless of the mosquitoes attracted, all mosquito specimens must be manually collected from the traps for species count, identification, and lab-based analyses for disease. Another method for assessing mosquito population density includes counting the number of insects that land on an individual in the field during a specific period. Techniques for establishing the presence or absence of disease include the analysis of blood from sentinel chicken flocks that have been bitten by mosquitoes. When used in combination, these active surveillance technologies are capable of generating data for a gross estimation of changes in vector population density and are effectively used to collect samples for lab-based detection of disease. However, these surveillance methods are labor intensive and often require daily trap inspection. In addition, lab results may take many days or weeks to obtain.

Factors that currently influence the accuracy and fidelity of insect density estimates and the development of meaningful insect control action thresholds include variations in sampling strategies, error, and precision (Bidlingmayer, 1967; Armed Forces Pest Management Board Technical Guide 43). These factors make it extremely difficult to fully interpret insect surveillance data for rapid response and mitigation of target sites. Although surveillance methods continue to improve, the timeliness of species collection, identification, and data interpretation is insufficient for rapid response. Significant improvements could be made through automated, computerized surveillance; however, efforts are hampered by the lack of digitized insect information. Digital insect data are required for the development of computer-generated tools that could be used to improve vector control, to understand complex insect population dynamics, and to enhance the accuracy of disease modeling.

PROJECT TITLE: Automated Mosquito Monitoring: A Prototype Sensor for Vector Borne Disease Tracking and Response

BACKGROUND AND APPROACH (Cont.):

Related Work

The laws of physics put extreme constraints on insect flight mechanics and wing range of motion. These limitations result in specific wingbeat patterns that are unique for individual flying insect species and possibly even for males and females within species. Many types of insects have wings that beat at near-constant rates. Previous reports suggest that this characteristic results in acoustic and optical temporal signatures that are species specific (Richards, 1955; Moore et al., 1986; Campbell, 1996). In addition, Moore (1991) used a neural networking software system to differentiate male mosquitoes from female mosquitoes based on characteristic light patterns that were produced when the mosquitoes flew through a light field. Joint studies between the U.S. Army and the Worcester Polytechnic Institute showed that wingbeat sound harmonics were sufficiently distinct to identify five species of mosquitoes (Campbell, 1996). Although studies such as these are interesting, the resulting technologies have not been integrated into fully automated systems. Recent developments in insect attractants and in identification of digital flying insect signatures present new opportunities for developing advanced automated systems.

The work presented here builds on previous work in the field of automated insect detection using wingbeat frequency (Moore and Miller, 2002; Engel and Wyttenbach, 2001; Moore et al., 1986; Schaefer and Bent, 1984; Eaton, 1980; Unwin and Ellington, 1979). This work is differentiated from that of others by a unique hardware design that uses custom illumination to improve discrimination and to simplify data processing. The custom illumination provides a uniform light field that enables the photodiode to repeatedly detect light energy scattered by the insect's beating wings regardless of the insect's location or flight orientation. This refinement is a significant advancement because other configurations are considerably more aspect dependent. Scattered light data are collected in a discrete time series and subsequently Fourier transformed to identify characteristic frequencies and spectra.

FY03 ACCOMPLISHMENTS:

Enclosure Engineering and Design

Enclosure Design

The AFIDS sensor was designed based on the following assumptions:

1. It is possible to repeatedly detect a flying insect from modulated scattered light reflected from the insect's wing surface in a diffuse field.
2. Variations in frequency spectrum signals between different insects are sufficient for species discrimination.

To test these conjectures, a first enclosure design was built using a cylindrical plastic container configured with two 12 V, 55/65 Watt Super Blue Halogen lamps (3700 K color temperature) that were placed between the container top and a baffle to provide illumination (Figure 1).

The Hamamatsu (Si S2592 series) photodiode was selected based on a number of design requirements, including operating temperature sensitive power and spectral range. This photodiode has a spectral response range between 190 and 1100 nm with a peak at 960 nm to match closely the color temperature of the bulb. An operational amplifier of 124 was selected for its low voltage noise (Burr Brown Corporation, 1993; Noise Precision Difet [http://focus.ti.com/lit/ds/symlink/opa124.pdf]) which was required to achieve the desired feedback values and low input current noise. Design considerations centered on the optimization of the signal to noise ratio, which resulted in custom circuitry for the detection of small changes in light intensity and frequency. A photodiode-amplifier with DC restoration to reject low frequency background light signals was built based on a design described by Stitt and Meinel (1993 Burr-Brown AB-061). This DC restored transimpedance amplifier enabled approximately two orders of magnitude greater AC gain than conventional designs, which resulted in improved signal to noise ratios.

PROJECT TITLE: Automated Mosquito Monitoring: A Prototype Sensor for Vector Borne Disease Tracking and Response

FY03 ACCOMPLISHMENTS (Cont.):

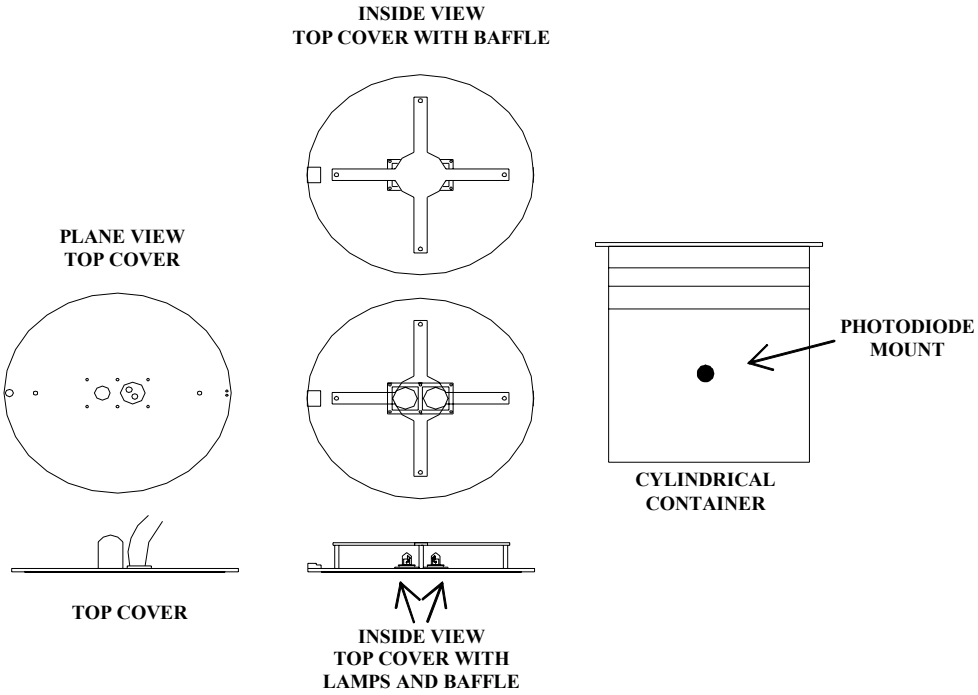


Figure 1: First Enclosure Design

Light Source

The first enclosure (Figure 1) light source, a halogen lamp, was replaced with one green and one white light emitting diode (LED) for the prototype design. New high-intensity LEDs can now be used as alternative light sources (Craford et al., 2001; Herman et al., 2001; http://www.lumileds.com/luxeon/products/products_index.html, Luxeon, 2004; The LEDlight.com, 2000 http://www.theledlight.com/technical1.html). LEDs are highly monochromatic, emit in a narrow frequency range, and are available in numerous wavelengths. They can be used alone or arranged in LED arrays to increase total light output or spectral content. Some devices emit in excess of 100 mw for less than 1 w input, have a lifespan of 100,000 hours, and are encapsulated in a crystal-clear solid resin, making them extremely rugged. In addition, LEDs are relatively inexpensive, costing $20–95 each (http://www.industrialtechnology.co.uk/2000/ledtronics.html, Industrial Technologies). Therefore, the replacement of less stable or unreliable light sources with high-output LEDs or LED arrays significantly lower design costs, reduce input power, enhance durability, and advance technology accessibility.

Both LEDs were driven with a typical forward voltage of 6.84 V and a forward current of 700 mA. The LED custom circuitry shown in Figure 2 was designed to drive the LEDs and to eliminate noise at 60 Hz.

PROJECT TITLE: Automated Mosquito Monitoring: A Prototype Sensor for Vector Borne Disease Tracking and Response (Cont.)

FY03 ACCOMPLISHMENTS (Cont.):

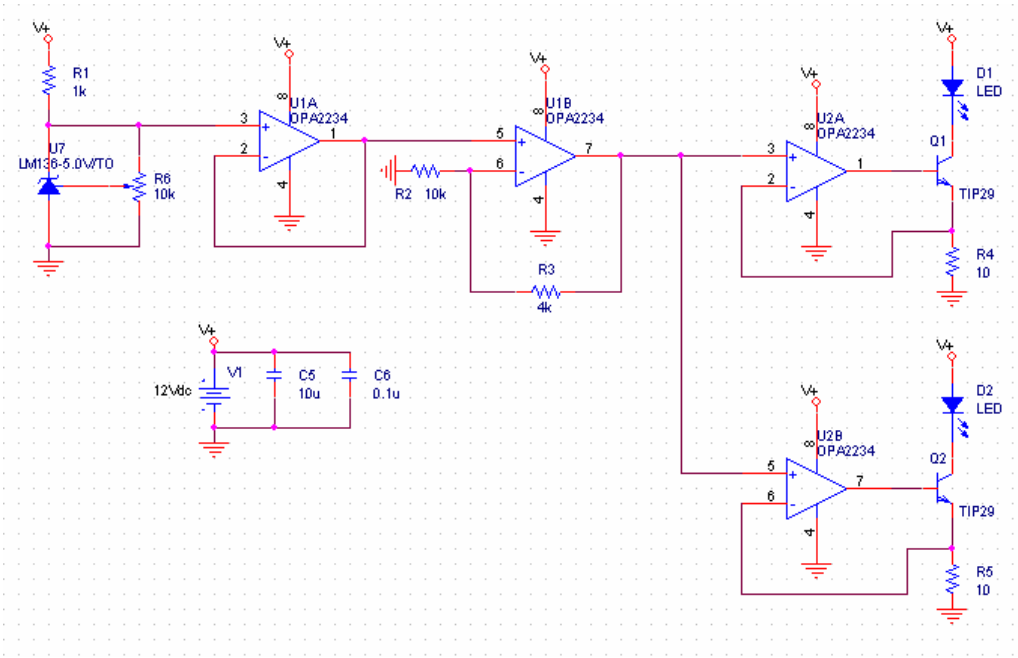


Figure 2. Light Emitting Diode Driver Circuit.

Data Acquisition

The data acquisition system included a portable laptop computer with a National 12-bit DAC card. A breakout box served as the standard data communication interface between the photodetector circuit and the computer. The data acquisition system was configured to measure single-ended voltage signals acquired by the photodetector circuit during insect flight passage. A graphical user interface for data acquisition, signal analysis, report generation, and file input/output was designed for use with LabVIEW software.

Integrating Sphere Prototype Design

The prototype design (used for all fruit fly and mosquito experiments) consisted of an integrating sphere in which Luxeon V Star LEDs were used as the light source and custom circuitry was used to facilitate LED operation. The sphere was also equipped with a removable vial that was used to culture and transfer *Drosophila* (Figure 3).

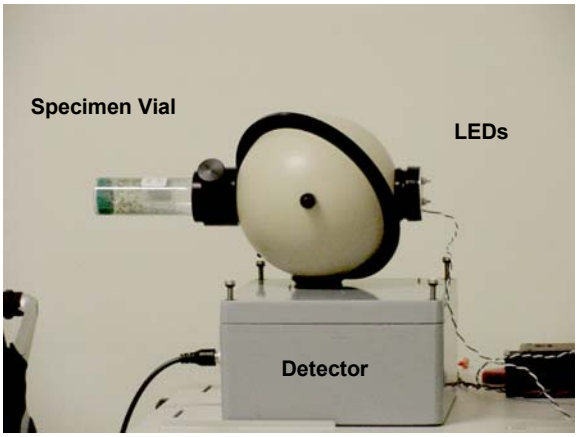


Figure 3: Integrating Sphere Prototype Design

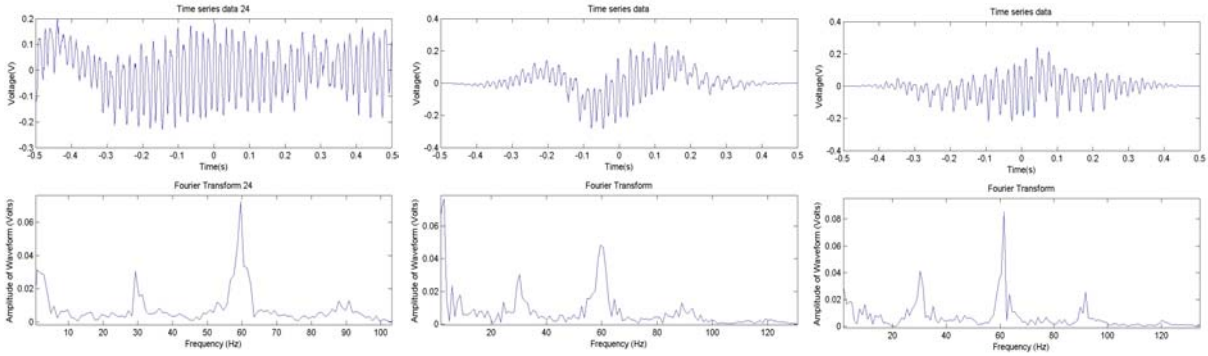
PROJECT TITLE: Automated Mosquito Monitoring: A Prototype Sensor for Vector Borne Disease Tracking and Response (Cont.)

FY03 ACCOMPLISHMENTS (Cont.):

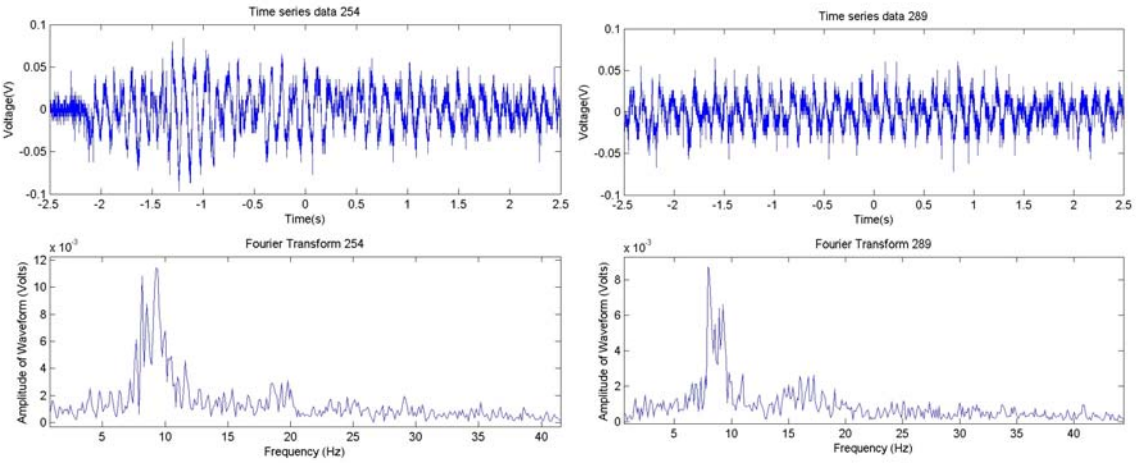
Experiments:

Series I: **Order: Lepidoptera (moths, butterflies, and skippers)**

Materials and Methods: Three species of moths, butterflies, or skippers, all in the family *Lepidoptera,* were collected at random with a black light insect trap. They were then individually introduced into a uniform light field (Figure 1 First Enclosure Design) to determine whether light scattered from their wings during flight could be measured. It was thought that the relatively large wing area of Lepidoptera relative to smaller winged insects would result in greater light scatter signal and thus make them ideal for initial testing. Four preliminary tests on Lepidoptera were conducted. Time series data were sampled at a rate of 1000 Hz with varying time intervals (1–5 seconds) and were Fourier transformed to create frequency spectral signatures. Frequencies between 10 and 66 Hz were recorded. Examples of the resulting WBSs are shown in Figures 4 to 6.



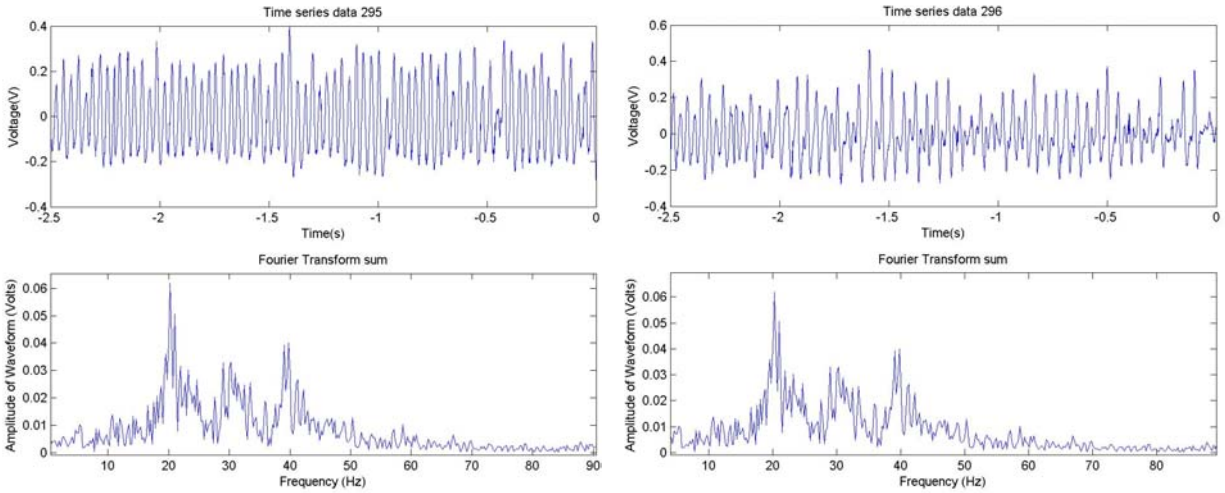
(A) Specimen ID 071403; Fs=1000Hz; 1s interval; Frequencies recorded at 60 Hz



(B) Specimen ID 080103; Fs=1000Hz; 5s interval; Frequencies recorded at approximately 10 Hz.

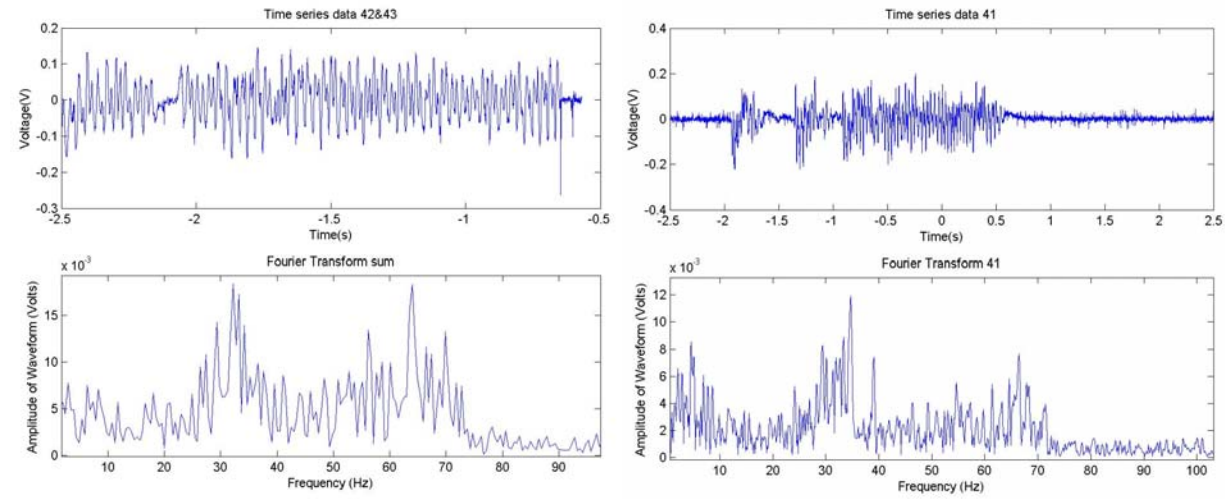
Figure 4. Moth Wingbeat Signatures (Order: Lepidoptera; Family: Arctiidae).

FY03 ACCOMPLISHMENTS (Cont.):



Specimen ID 072103; Fs=1000Hz; 5s interval; Frequencies recorded at 20, 30, and 40 Hz

Figure 5. Moth Wingbeat Signatures (Order: Lepidoptera; Family: Notodontidae).



Specimen ID 07202203; Fs=1000Hz; 5s interval; Frequencies recorded at 33 and 66 Hz

Figure 6. Skipper Wingbeat Signatures (Order: Lepidoptera; Family: Hesperiidae).

PROJECT TITLE: Automated Mosquito Monitoring: A Prototype Sensor for Vector Borne Disease Tracking and Response (Cont.)

FY03 ACCOMPLISHMENTS (Cont.):

Results: These results indicate it is possible to detect wingbeat signatures using uniform illumination. Sensor design improvements were made based on lessons learned from the first enclosure design and initial experiments. A prototype AFIDS sensor was developed for use with smaller flying insects; i.e., fruit flies and mosquitoes.

Series II: **Order: Diptera; Family: Drosophilidae; Genus Species: *Drosophila melanogaster* (Fruit Fly):**

Experimental protocols were developed to test the feasibility of using the AFIDS sensor to distinguish male from female *Drosophila* (fruit flies). Fruit flies were selected because they are well studied and physically smaller than mosquitoes (Knospe, 1998). Size was an important consideration. If the sensor could detect fruit flies, it was theorized the WBSs for the target species, mosquitoes, could be easily obtained.

Materials and Methods: A *Drosophila melanogaster* colony was maintained as described by Demerec and Kaufmann (1996). Fruit flies were immobilized by cooling them to -4ºC for 12 minutes and subsequently placed either in sampling vials (for Experiment I) or in 35 mm polystyrene petri dishes for sex determination (Experiment II). Once in the petri dishes, the flies were re-anesthetized by covering the dish with a funnel containing ether vapor (Demerec and Kaufmann, 1996). The dish was then immediately placed on the stage of a dissecting microscope where females and males were identified and sorted into separate vials.

Individual flies were then placed in the integrating sphere and observed for 5 minutes, and all WBSs occurring within that period were recorded. A total of 5–8 males and 5–8 females were selected for each replicate experiment, with a total of 4 replicates being performed on separate days. The resulting fruit fly data are shown in Figures 7-9.

Data Analysis:

For these experiments, data sampling rate adjustments were made to the detector so that fundamental frequencies and harmonics could be captured. The optimal sampling rate was found to be 6000 Hz with 2-second time intervals. The flight mechanics of the fruit fly resulted in increased signal noise compared to earlier tests with Lepidoptera, but this noise could be lowered to acceptable levels with the use of a band-pass filter.

Drosophila Experiment I (multiple fruit fly evaluation): The repeatability of WBS detection was subjectively evaluated following Fourier transformation.

Drosophila Experiment II (sex determination): These data were analyzed for normality using the Lilliefors test. Differences between male and female WBSs were tested ($p = .05$) using the Wilcoxon rank sum test.

Results: *Drosophila Experiment I:* Examples of multiple fruit fly WBSs are shown in Figure 7 (A–C). Preliminary data were encouraging. These data demonstrated that although Drosophila signatures were noisier than Lepidoptera, repeatable values could be obtained.

PROJECT TITLE: Automated Mosquito Monitoring: A Prototype Sensor for Vector Borne Disease Tracking and Response (Cont.)

FY03 ACCOMPLISHMENTS (Cont.):

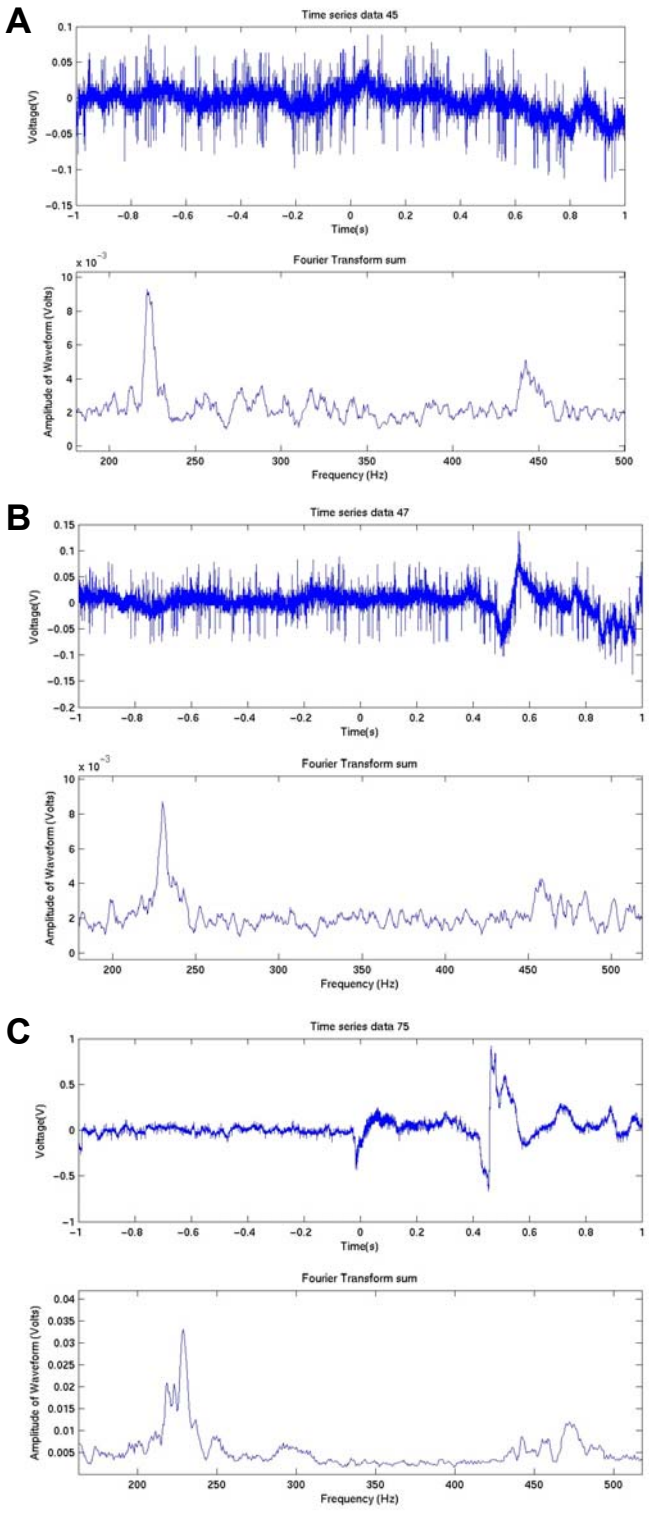


Figure 7. Examples of Wingbeat Signatures for *Drosophila melanogaster.* [a,b,c]

a. Fs=6kHz; 2s intervals.
b. Frequency spikes are centered at 222, 228, and 230 Hz.
c. The 1st harmonic was also detected for each time series.

Figure 8. Wingbeat Distributions for Male and Female *Drosophila melanogaster*

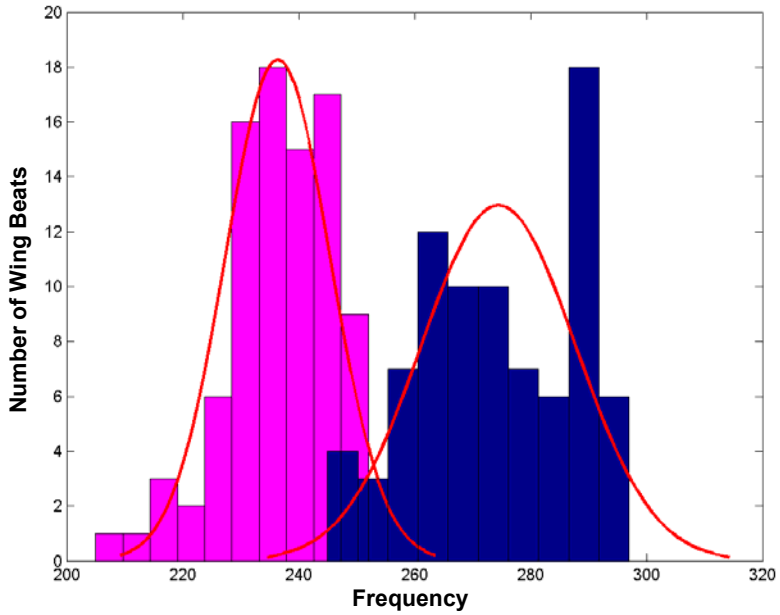
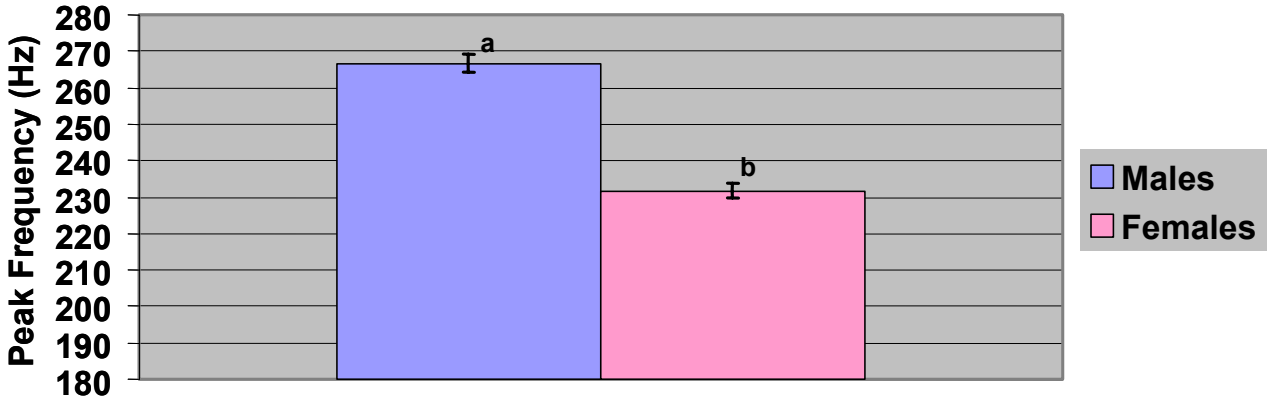


Figure 9. Wingbeat Frequencies Differ Between Male and Female *Drosophila*. [a,b,c]



[a] Data are presented as the mean and standard error for 20 and 25 wing beat signatures from 10 males and 9 females respectively, from two replicate experiments.

[b, c] Histograms with different superscripts are significantly different.

PROJECT TITLE: Automated Mosquito Monitoring: A Prototype Sensor for Vector Borne Disease Tracking and Response *(*Cont.*)*

FY03 ACCOMPLISHMENTS (Cont.):

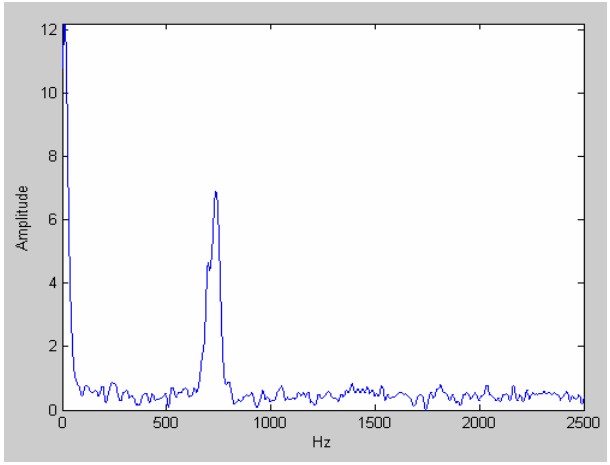
Drosophila Experiment II (Sex determination): As shown in Figure 8, the wingbeat frequencies are normally distributed for females but not for males, the reason for which remains obscure. Alternatively, data presented in Figure 9 show a significant difference between male and female WBSs (P=0.05) and that AFIDS can detect these differences.

Series III: **Order: Diptera; Family: Culicidae (Mosquitoes):**

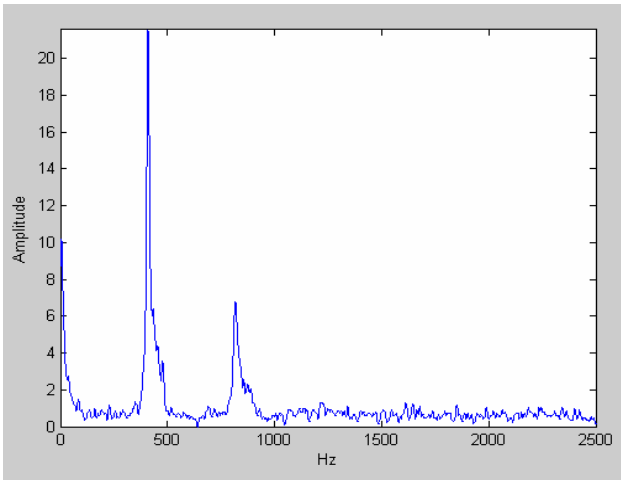
Materials and Methods: These experiments were conducted in collaboration with Dr. Dawn Wesson, Department of Tropical Medicine and Parasitology, Tulane Medical Center.

One- to three-day-old male and female mosquitoes of two species were tested (Aedes aegypti and Aedes albopictus). Mosquitoes were grouped by sex and introduced into the integrating sphere. Time series data were sampled at a rate of 6 KHz. The resulting data were Fourier transformed to create WBSs.

Results: Examples of the resulting WBSs for male verses female Aedes Albopictus are presented in Figure 10 (A and B). As shown in Table 1, frequency differences exist between male and females within species. Smaller cross species differences within females and within males are also indicated, but additional experiments must be conducted to determine statistical significance.



(A) Three females, Aedes albopictus; NOLA (409 Hz)



(B) Three males, Aedes albopictus; NOLA (737 Hz)

Figure 10: Mosquito Wingbeat Signatures

PROJECT TITLE: Automated Mosquito Monitoring: A Prototype Sensor for Vector Borne Disease Tracking and Response *(Cont)*

PUBLICATIONS/PATENTS:

Publications

Advances in Optically Sensed Detection of Flying Insects Using Wingbeat Waveforms: Preliminary Results from Research Funded by the National Aeronautics and Space Administration. Timi Vann, Jane Andrews, Robert Ryan, and Dane Howell. NASA Technical Memorandum (In preparation).

Provisional Patent

Provisional Patent Filed by NASA on 12/17/03; Number 00/60,530,330

PLANNED FUTURE WORK:

We propose to further develop this proof of concept device to a fully deployable automated system that could be used to support public health decisions, agriculture insect control and perform insect research. This prototype device will include all the features necessary for unattended remote operation and will be referred to as the Automated Flying Insect Detection System (AFIDS). Once fully developed, public health and agricultural organizations will be able to monitor the number and type of insects in specific geographical areas. When insect thresholds are reached, decision-makers will be quickly notified and able to take immediate action to respond to the insect threat. This rapid response will reduce inefficiencies associated with labor intensive field collections and lab analysis, and costs associated with ineffective insecticide spray applications and adverse human health and crop impacts.

CDDF PROJECTS

INITIATED IN FY2002

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FY02
Propulsion Test Directorate
CDDF Projects

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PROJECT TITLE: Hydrogen Peroxide Sensor System

INVESTIGATORS: Dr. W. St. Cyr/HA30
Harvey S. Smith/LMSO

INITIATION YEAR: FY 2002

AGGREGATE AMOUNT OF FUNDING FROM EARLIER YEARS: $35K

FUNDING AUTHORIZED FOR FY03: $0K

ACTUAL EXPENDITURES OF FY02 OR EARLIER YEAR FUNDING:

- In-house: $15,173
- Contracts: $0
- Grants: $0

STATUS OF INVESTIGATION AT END OF FY03: To be continued in FY04 with funds remaining from FY02

EXPECTED COMPLETION DATE: March, 2004

PURPOSE:

To develop a Hydrogen Peroxide Sensor System utilizing state-of-the-art technology, that will be capable of warning personnel when hazardous conditions exists around the storage facility.

BACKGROUND AND APPROACH:

Hydrogen peroxide has many uses in industry. It is increasingly being used as a rocket fuel, and especially so at SSC. Hydrogen peroxide is very corrosive and a strong oxidizer. Any leakage is very dangerous to most materials and especially so to organic materials. Transportation and storage is very critical and can only be handled with specialized equipment and by certified personnel.

Presently, there are no means to determine and indicate immediate hazard conditions at the existing storage and handling infrastructure at SSC. Thus, the requirement for a hydrogen peroxide leak detection system is paramount.

A hydrogen peroxide leak detection system will provide early detection of potential or imminent hazardous conditions and would reduce delays in pinpointing problems. Also, the capability to monitor this product and appropriately handle it in emergency situations will contribute to reduce risks and allows for more efficiency in dealing with safety issues.

The approach for this project is that it will be multi-year and be performed in two phases. The first phase would see to the acquisition and evaluation of existing sensors, necessary equipment, and develop a proof-of concept prototype. Also, any suitable existing commercial-off-the-shelf (COTS) systems are to be acquired and evaluated. It would be advantageous to acquire a COTS system as minimal development time and costs would be incurred. Thus, the focus is to see whether a COTS system exists and if not to develop a proof-of-concept prototype to meet SSC requirements.

The second stage would see the deployment of a fully functional and capable sensor system. The system would consist of one or more sensors positioned within the perimeter of the storage facility to provide total area coverage for leaks. The system would be rugged, hazard proof and simple to operate and be maintained.

FY03 ACCOMPLISHMENTS:

The COTS sensor was subjected further to vapor, under free flowing conditions.

The results show that the response under freely flowing vapor conditions, was dramatically reduced. The results are shown in Table 1.

PROJECT TITLE: Hydrogen Peroxide Sensor System (Cont)

FY03 ACCOMPLISHMENTS (Cont.):

Table 1: Mil-Ram H_2O_2 Sensor Response under Freely Flowing Vapor Conditions

Mil Ram Sensor - Total Exposure Time, 15 Minutes		
H_2O_2 %	**Time Elapsed for Sensor Response**	**Reading (ppm)**
30	5 seconds	0
30	1 Minute	0
30	5 Minutes	0.1
30	10 Minutes	0.1
30	15 Minutes	0.1
50	25 Seconds	0.1
50	1 Minute	0.1
50	5 Minutes	0.1
50	10 Minutes	0.2
50	15 Minutes	0.2
70	25 seconds	0.1
70	1 Minute	0.1
70	3 Minutes	0.2
70	10 Minutes	0.2
70	15 Minutes	0.2
97	9 Seconds	0.1
97	1 Minute	0.2
97	5 Minutes	0.3
97	10 Minutes	0.3
97	15 Minutes	0.3

A second COTS sensor system was acquired.

Figure 1 shows a photograph of the COTS unit.

Lab and field evaluations were performed on both sensors simultaneously. The systems were subjected to different concentrations of hydrogen peroxide at a set distance of six inches from source to sensor. Table 2 shows the results from the laboratory tests.

Figure 1: The PortaSens II H_2O_2 Sensor

PROJECT TITLE: Hydrogen Peroxide Sensor System (Cont.)

FY03 ACCOMPLISHMENTS (Cont.):

Table 2: PortaSens II H_2O_2 Sensor Response under Normal (free flow) Operating Conditions

PortaSens II Sensor - Total Exposure Time, 15 Minutes		
H_2O_2%	**Time Elapsed for Sensor Response**	**Reading (ppm)**
30	5 seconds	1.5
30	1 Minute	7.5
30	5 Minutes	10.7
30	10 Minutes	11.6
30	15 Minutes	11.3
50	9 Seconds	6.1
50	1 Minute	22.5
50	5 Minutes	23.2
50	10 Minutes	35.2
50	15 Minutes	42.3
70	5 Seconds	1.09
70	1 Minute	35.1
70	5 Minutes	49.5
70	10 Minutes	56.7
70	15 Minutes	50.0
97	5 Seconds	> 50
97	1 Minute	116
97	5 Minutes	120.3
97	10 Minutes	120.3
97	15 Minutes	120.3

Table 2 shows the data for the PortaSens II sensor operating simultaneously with the Mil-Ram sensor (Table 1). The results were dramatic in comparison. The Port-Sens II sensor was much more responsive at all H_2O_2 concentrations.

Field Tests

The field evaluations of the Mil-Ram H_2O_2 Sensor and PortaSens II H_2O_2 meter (ECN 2155921) were conducted at the Outside Test & Storage Facility adjacent to Bldg. 8110 on March 26, 2003. The field evaluation is a follow on effort to the lab tests that were performed on January 27, 2003. The temperature at the time of the field tests was approximately 75 *deg F* under partly cloudy skies. The wind was out of the northwest at 5 *MPH*. The relative humidity was 65%, with a barometric pressure of 29.97 *in* and falling. The test configuration is depicted in Figure 2.

100 ml of H_2O_2 was placed in a 6 *in* x 6 *in* stainless steel witness plate. The sensor was exposed to a fluid surface area of 36 in^2 at a distance of 8 *in* above the witness plate. The peroxide was placed directly in the sunlight to provide a sustained vapor area from decomposition. Results of the tests are shown in Tables 3, 4, and 5.

Figure 2: H_2O_2 Sensor Field Test Setup (1 *Witness Plate w/ H_2O_2*. 2 *PortaSens II H_2O_2 Sensor,* 3 Mil-*Ram Electronics & LCD Readou*t, 4 Mil -*Ram H_2O_2 Sensor,* 5 DC *Power Supply,* 6 Empty *Witness Plate used as a Counter Weight for the Base of the Stand*)

PROJECT TITLE: Hydrogen Peroxide Sensor System (Cont.)

FY03 ACCOMPLISHMENTS (Cont.):

Table 3: Instrument Readings for 50% H_2O_2– 10 Minute Duration

Instrument Readings for 50% H_2O_2 10 Minute Duration	
PortaSens II (ppm)	Mil-Ram (ppm)
3.8	0
3.8	0
8.1	0

Table 4: Instrument Readings for 70% H_2O_2- 10 Minute Duration

Instrument Readings for 70% H_2O_2 10 Minute Duration	
PortaSens II (ppm)	Mil-Ram (ppm)
3.7	0
0.5	0
1	0
6.2	0

Table 5: Instrument Readings for 98.6 % H_2O_2 - 25 Minute Duration

Instrument Readings for 98.6 % H_2O_2 25 Minute Duration	
PortaSens II (ppm)	Mil-Ram (ppm)
14	0
2.7	0
3.0	0
13.2	0
30.1	0
3.4	0
14.3	0
8.1	0
13.4	0

CONCLUSION

Both lab tests and field tests indicate the PortSens II H_2O_2 Sensor provided superior detection capabilities than the Mil-Ram H_2O_2 sensor. The lab test using 97% H_2O_2 indicate the PortSens II is approximately 400 times more sensitive than the Mil-Ram sensor evaluated in this study. The PortaSens II uses a positive flow for both calibration and for monitoring which enable rapid indication of the presence of hydrogen peroxide.

PLANNED FUTURE WORK:

The next phase of this project is to develop a working system. Adding a pump to the Mil-ram system may be effective, but untried. The initial lab tests showed that it works well if there is a flow over the sensor. Assembling a leak detection system build around the PortaSens II sensor or its variants appears to be the best choice as its detection capabilities have been proven and documented.

PROJECT TITLE: Field Test Methods for Hydrogen Peroxide Stability Margin

INVESTIGATORS: Robert Ross/VA14
Dr. William Anderson/Purdue University
Tabrez Ali/Purdue University

INITIATION YEAR: FY 2002

FUNDING AUTHORIZED FOR FY03: $50K

ACTUAL EXPENDITURES OF FY03 OR EARLIER YEAR FUNDING:

- In-house: $0K
- Contracts: $50
- Grants: $0

STATUS OF INVESTIGATION AT END OF FY03: Completed in July 2003

PURPOSE:

The purpose of this research was to determine the stability margin of propellant grade hydrogen peroxide (HTP) stored in run tanks at test facilities. The research developed the stability margins by accelerating the decomposition in small samples of HTP over metal coupons, thus simulating the tank.

BACKGROUND AND APPROACH:

Stability of stored Hydrogen Peroxide is a concern in propulsion applications. Even though highly pure hydrogen peroxide stored in a thoroughly clean vessel made of a non-catalytic material is stable over long periods of time, maintaining such levels of purity and material compatibility in field applications can be difficult. Propellant grade peroxide (HTP) stored in metal run tanks decomposes slowly but continuously over time due to heterogeneous catalytic action caused by the tank surface resulting in a loss of concentration. There is no direct method to measure the *'stability margin'* of hydrogen peroxide which can be defined as the time taken for stabilizer inhibition.

In its pure form hydrogen peroxide is a relatively stable compound. However decomposition can be initiated and further accelerated by several factors such as rise in temperature, impurities which might catalyze the decomposition reaction, high pH value, ineffectiveness of stabilizers and radiation.

Many elements and their compounds are known to cause liquid or vaporized hydrogen peroxide to decompose.

Normally the hydrogen peroxide decomposition can be said to be either of homogeneous or heterogeneous nature.

Homogeneous Decomposition in Liquid Phase

Homogeneous decomposition occurs when the catalyst is present in the same phase as the reacting molecule, i.e., when pure hydrogen peroxide gets contaminated by certain metallic salts present in true molecular solution, and decomposes. Homogeneous decomposition can occur even at extremely low levels of contamination due to salts of various metals like those of iron, copper, chromium, vanadium, tungsten, molybdenum and platinum.

Heterogeneous Decomposition

Though not as well understood as the homogeneous catalysis, this results when hydrogen peroxide comes into direct contact with insoluble materials. The rate of decomposition depends on the nature of the material in contact, the surface area to volume ratio etc.

As the hydrogen peroxide molecule approaches the active site on the surface it begins to feel the attractive Van der Waal forces.

PROJECT TITLE: Field Test Methods for Hydrogen Peroxide Stability Margin (Cont.)

BACKGROUND AND APPROACH (Cont.):

Variables Effecting Decomposition Rate

Although the decomposition rates for highly purified hydrogen peroxide are known to be very low, certain physio-chemical factors are responsible for affecting the rate of the reaction, temperature and pH being the primary ones. Other factors might include radiation, surface area to volume ratio, surface finishes etc. The reaction variables have an effect on the catalytic activity, thus affecting the reaction kinetics.

In general, decomposition rates of pure, unstabilized hydrogen peroxide solutions at temperatures varying from 50 to 70°C have shown to increase by a factor of 2.2± 0.1 for a 10°C rise in temperature.

Low decomposition rates have been observed for pure hydrogen peroxide when mixed with pure sulfuric acid or sodium hydroxide, in the vicinity of ph 4.5 to 5.0.

Though not much data is available, some studies carried out with pyrex glass have shown that the decomposition rate is roughly linearly proportional to the ration of surface area to volume over a considerable range though at lower ratios the curve on the 'surface to volume ration vs decomposition' plot tends to flatten out. For example, a cubic inch of hydrogen peroxide in contact with 1 square inch of surface will decompose at about half the rate shown by a cubic inch of peroxide in contact with 2 inches of surface. The variation can be thought to represent the summation of three distinct mechanisms: (1) heterogeneous decomposition of the liquid on the walls of container; (2) heterogeneous decomposition of the vapor, also in contact with the walls; and (3) homogeneous decomposition in the liquid. Heterogeneous decomposition, of course, being the dominating factor of the three. Surface roughness can be an important factor, and should be taken into account while interpreting the results.

Studies have shown that both photochemical and radiochemical radiation can have significant effect on the decomposition and stability of hydrogen peroxide. In dilute to moderate and even to some extent for higher concentrations and at moderate intensities of absorbed radiation the rate of decomposition is directly proportional to the concentration of hydrogen peroxide and to the square root of the intensity.

Hydrogen peroxide is not affected by exposure to light having a wavelength greater than 3800 A° though it has absorption bands in these frequencies. Also the data on the effect of wavelength in the ultraviolet region on decomposition is inconclusive. Decomposition in case of ionization radiation is more difficult to interpret due to the fact that not only are ionized particles involved in addition to those found in photochemical radiation, but free radicals are also produced along the tracks of fast particles which might cause them to be distributed non-uniformly throughout the solution. The decomposition rate in this case, as before, has been found to be proportional to the concentration of hydrogen peroxide and to the square root of the intensity, though at lower concentration this isn't true.

Stability of Hydrogen Peroxide

Stability of peroxide can be defined as the loss in concentration with time. Stability is usually expressed as concentration loss per unit time, which could be as low as 0.001% per hr for highly pure hydrogen peroxide at room temperature.

Techniques used to Measure the Decomposition Rates

Refractive Index

The refractive index indirectly measures the density of H202. A decrease in the refractive index indicates that the decomposition of H2O2 has increased. Lab refractometers can detect refractive indexes up to 0.0001 and the general variation in refractive index value for 1% change in concentration (near 90%) conc.) is of the order of 0.0008. Thus concentration can be measured accurately up to 0.08%. For every 1% change in concentration by weight of hydrogen peroxide, 0.475% oxygen by weight is liberated.

Permanganate Titration

Potassium Permanganate titration has been and is the most common method of accurately measuring the concentration of hydrogen peroxide.

PROJECT TITLE: Field Test Methods for Hydrogen Peroxide Stability Margin (Cont.)

BACKGROUND AND APPROACH (Cont.):

Need for Stability Margin

To evaluate stability margin, the decomposition processes occurring in the run tank have to be simulated and accelerated over metal coupons made of similar material as the tank and one or more decomposition reaction indicators, such as rise in temperature, loss in concentration or active oxygen, which essentially are inter-dependent needs to be measured. In this research small peroxide samples were periodically withdrawn from a stainless steel run tank into a petri dish containing a stainless steel coupon, and the formation and growth of bubbles over the coupon surface is used as a tool to calculate the stability margin of hydrogen peroxide. Inhibition of stabilizers with time in the tank causes an increase in rate of bubble formation over the metal coupon due to higher decomposition rates. The rationale for choosing the rate of oxygen bubble formation and its growth as the reaction indicator is because of the underlying facts:

- Oxygen bubble formation is one of the predominant heterogeneous decomposition reaction indicator.
- It is the first direct step occurring besides the infinitesimal temperature rise due to the decomposition reaction, and can broadly reflect on the general state of peroxide at the very periphery between the solid-liquid phase.
- Significant bubbles are formed even with low decomposition reaction rates.
- It can be done fairly quickly, giving us a qualitative ideal of the propellant state.
- Localized surface effects, if any, can be detected.

Heterogeneous Nucleation on the Surface

Bubbles formed at the surface (walls of container and similar in homogeneities), rather than in the bulk of the solution, are said to be nucleated heterogeneously. In case of liquid hydrogen peroxide, in contact with the metal surface, the nucleation results due to the evolution of oxygen as a result of the decomposition process which desorpes into non- wettable air pockets (surface rugosities and micropores) with significant oxygen gas concentration. The degree of nucleation depends on the contact angle and the geometry of the nucleation site or void. As the contact angle increases from zero, it becomes easier for the bubbles to be formed.

Growth of oxygen bubbles and growth law

The catalytic decomposition of hydrogen peroxide causes the oxygen to be desorbed into the surrounding bulk fluid. Concentration gradients then come into play and oxygen is transported to the nucleation sites, which already have gaseous oxygen, trapped in macro and micro pores. Initially, the growth depends very strongly on inertia effects, viscosity and surface tension of the surrounding fluid. But soon the growth is limited by the rate at which dissolved oxygen can diffuse to the bubble surface. The 'Fickian' diffusion controlled growth of the oxygen bubble is governed by the diffusional mass transport equations.

Figure 1 shows the typical bubble growth for 90% hydrogen peroxide kept at room temperature over SS-304 coupon. The bubble was observed under a microscope (50x) coupled with a CCD camera and measurements were made w.r.t. to its size during the growth period by analyzing successive frames.

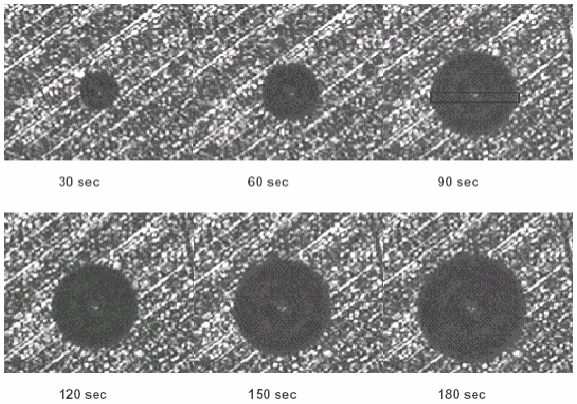

Figure 1: Typical oxygen bubble growth over a coupon immersed in 90% peroxide at room temperature.

PROJECT TITLE: Field Test Methods for Hydrogen Peroxide Stability Margin (Cont.)

FY03 ACCOMPLISHMENTS:

The experiment involved the storage of hydrogen peroxide in bulk over a period of three weeks during which small samples (10 cc) were periodically withdrawn and introduced into a passivated petri dish containing stainless steel (SS 304) coupons, thus simulating the run tank. This resulted in accelerated decomposition and stabilizer inhibition due to significantly high 'surface-to-volume (S/V) ratio', over the coupons. The samples were withdrawn every 12 Hrs initially and every 24 Hrs thereafter. The reason S/V ratio was chosen as the accelerating variable was because the other reaction variables, namely temperature and pH, are fairly constant in the run tank over the duration of a test, so the effect of keeping the peroxide in a run tank can be simulated in a short duration only by increasing the exposure of the peroxide to the tank surface resulting in a higher contribution of catalytic surface area, leading to faster decomposition rates and inhibition of stabilizers. The S/V ratio for each coupon experiment was 7.22 $inch^{-1}$, compared to the S/V ration of approximately 0.70 $inch^{-1}$ for the run tank. This provided a scaling factor of approximately 10.

Experimental run tank set up

A 2.5-gallon stainless steel (SS 304) sampling cylinder was used as the simulated run tank for the experiment at the Aerospace Sciences Lab at Purdue University. The tank was cleaned, passivated with 70% nitric acid (H N O3) and subsequently conditioned with 30% peroxide for 48 Hrs in accordance with FMC guidelines. After passivation, 2.25 gallons of 90% HTP supplied by FMC corporation was added to the tank. The tank was then instrumented with a thermocouple and closely monitored.

Coupons used for the experiment

Three stainless steel '304-SS' coupons were used during the experiment. Each coupon was 2 inches long, 0.75 inches wide and 0.0175 inches thick. They came from the same metal sheet stock and hence had similar surface roughness and other physical/chemical properties.

CCD camera

A Kodak Megaplus model ES 1.0 CCD camera was used for the image acquisition. It has an interline transfer sensor which has a pixel array of 1008 x 1018 with progressive scan readout. Each pixel measures nine square microns with a 60% fill factor using a microlens. The output is an 8 bit digital image with 1024 levels of gray.

Accelerated decomposition

Small peroxide samples (10 cc) of HTP were withdrawn periodically from the run tank in a passivated and conditioned glass petridish containing the stainless steel coupon. Soon after the peroxide was poured over the coupon, it was observed under a CCD camera for oxygen bubble formation over the surface for a period of 25 mins (Figure 2). Frames were captured every 120 secs until significant bubble detachment was observed.

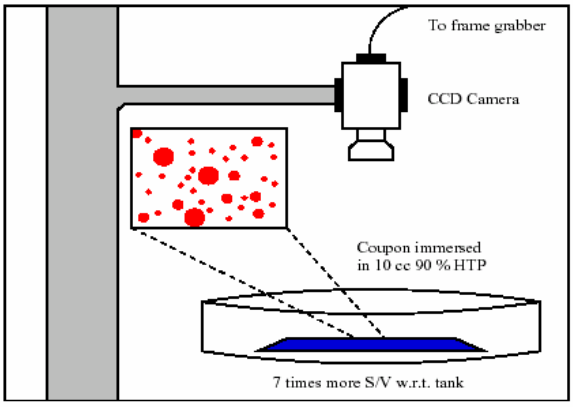

Figure 2: The camera setup for capturing bubble data

Figure 3 shows the typical oxygen bubble formation over the coupon at a given instant of time. The frame was analyzed and filtered to obtain a binary image highlighting the bubbles over the coupon. The binary image was then used to get the percentage area covered by the bubbles. Each frame gave a distinct % area value and this growth in area over the 25 min duration is plotted in Figure 4. This analysis was done on every sample withdrawn from the run tank over the duration of experiment and each time the same coupon was used in the same petri-dish.

PROJECT TITLE: Field Test Methods for Hydrogen Peroxide Stability Margin (Cont.)

FY03 ACCOMPLISHMENTS (Cont.):

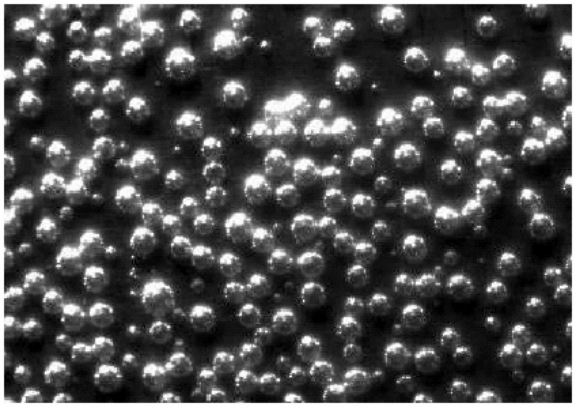

Figure 3: Typical Oxygen bubble formation over the Stainless Steel coupon

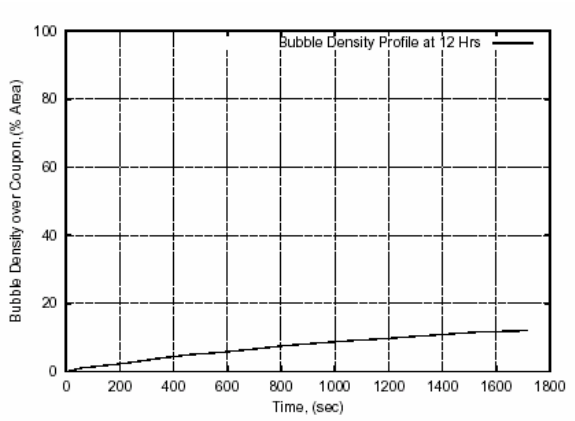

Figure 4: Typical bubble density variation over the coupon surface for a withdrawn sample

Results

A total of three coupons were used each time a sample of peroxide was withdrawn, and over 1000 frames were captured and analyzed during the duration of the experiment. The concentration in the run tank was periodically measured using potassium permanganate titration and the rate of decomposition is shown in Fig. 4. The run tank was kept at a constant bulk temperature of 25°C and the change in concentration was linear, approximately 2.5% over the 450 Hr duration or about 0.13% per day. The test was concluded after 18 days, which was far beyond initial project interest, as the peroxide concentration became less than that of interest.

Figure 5 shows the bubble density at a particular instant for various samples withdrawn during the experiment. It is evident from the figures that the bubble density profile has a linear relationship with time as well as with the 'aging of peroxide'. This is attributed to the fact that with time the stabilizers in the tank are slowly inhibited by the catalytic species produced, causing an increase in the bubble formation and growth rate. There may also be a small possibility of auto-catalysis where certain intermediate species formed during the decomposition reaction might act as a catalyst and might also be responsible for stabilizer inhibition.

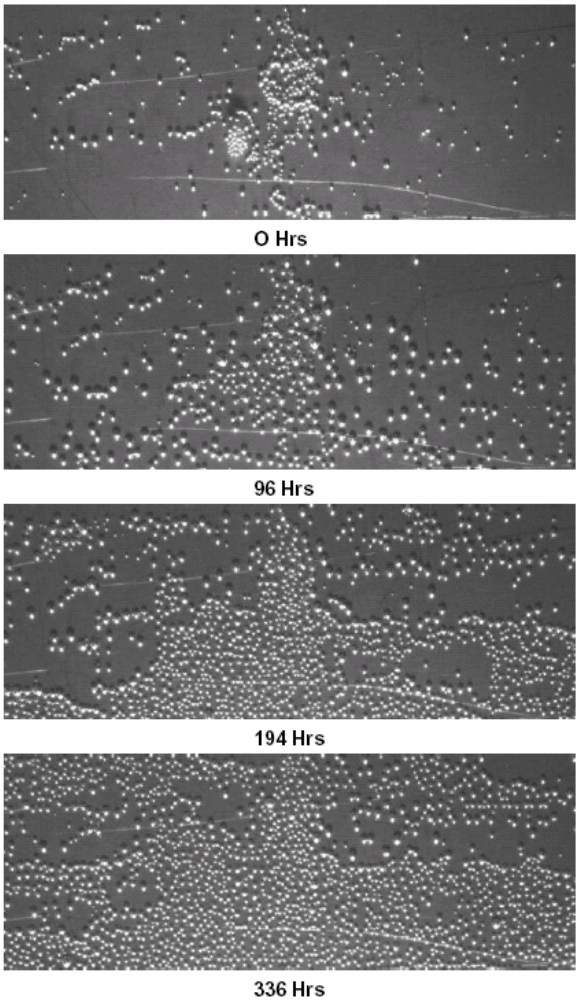

Figure 5: Typical bubble densities at a particular instant for samples withdrawn during peroxide aging

FY03 ACCOMPLISHMENTS (Cont.):

Figures 6 to 9 show the filtered bubble density trend at different time periods during the aging of peroxide. This trend is linear and directly proportional to the aging of peroxide. This is caused by the inhibition of stabilizers, which results in a higher decomposition rate, which subsequently leads to a higher bubble formation and growth rate.

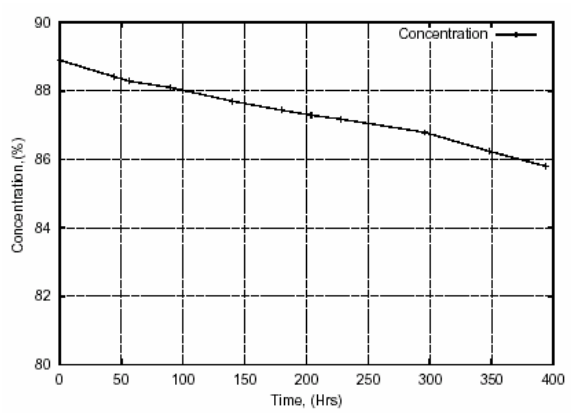

Figure 6: Change in concentration as observed in the run tank

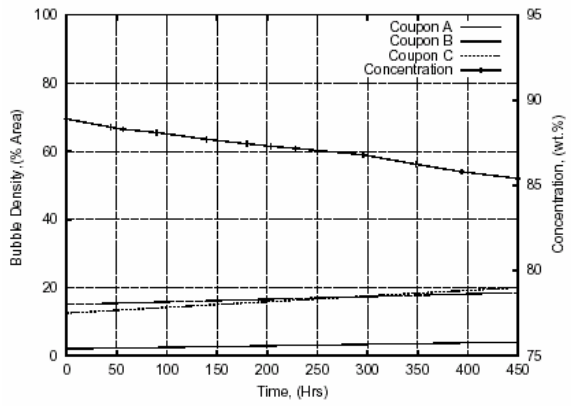

Figure 7: Bubble density variation with peroxide aging (@200 secs)

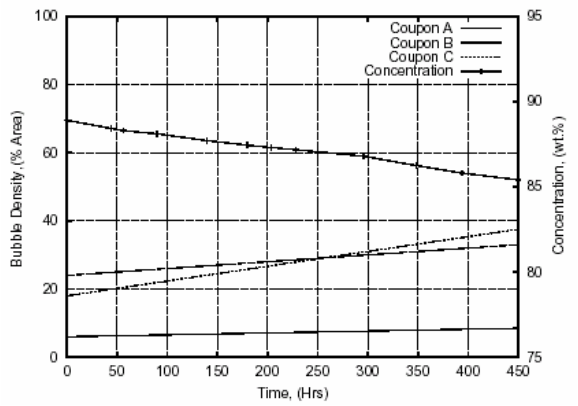

Figure 8: Bubble density variation with peroxide aging (@400 secs)

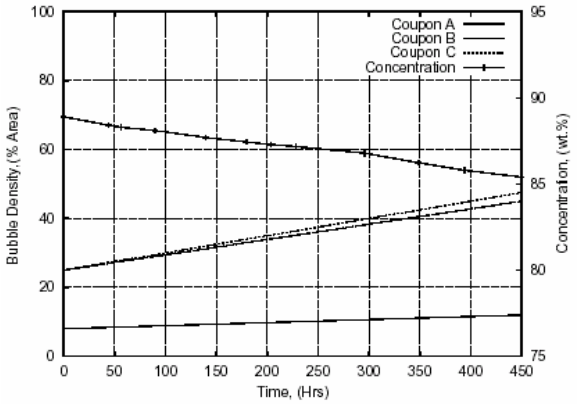

Figure 9: Bubble density variation with peroxide aging (@600 secs)

Conclusions and Recommendations:

Conclusions

Results are presented for the mass transfer controlled bubble growth over stainless steel coupons immersed in hydrogen peroxide and data have been compared to the measured decomposition rate of peroxide in the run tank. The conclusions can be summarized as follows:

1. During the test duration the stability of propellant grade HTP was observed to decrease linearly.
2. Bubble density measurement over coupons can provide valuable information in regard to the general state of peroxide and has the potential to be a practical field test method. Bubble densities obtained from samples

PROJECT TITLE: Field Test Methods for Hydrogen Peroxide Stability Margin (Cont.)

Conclusions and Recommendations (Cont.):

withdrawn at different times can be compared to give a qualitative idea on the general state of peroxide.

3. All the oxygen bubbles, which form on the coupon surface, tend to be perfectly spherical and hence it has been inferred that the surface is highly hydrophilic. This also prevents any screening effect by the bubbles, and the net surface area available for the heterogeneous reaction remains constant.
4. 90% HTP can be safely stored in stainless steel tanks (SS 304) for more than a week.

Recommendations

Bubble density over coupons may be used as a field test method to determine the peroxide stability margin and a typical test would include the following steps:

- As soon as the peroxide is introduced in the run tank (0Hrs), a small sample (approx 10cc) should be withdrawn in a passivated petri dish containing the coupon.
- The bubble formation over the coupon should be qualitatively observed for a fixed time period (b/w 5 – 10 mins). A photograph taken at the end by a digital cameral would be helpful.
- Thereafter, samples may be withdrawn whenever the state of the bulk peroxide in the run tank is to be known and analyzed in a similar fashion for the same time period.
- The two photographs should be qualitatively compared to give an idea about the behavior of peroxide.
- If the bubble density pattern is similar (even though scaled) then the stabilizers are being inhibited linearly and linear decomposition behavior can be expected for some time. If significant new bubble locations are observed then the peroxide decomposition will not be linear.

This method is sensitive to physio-chemical characteristics of the coupon and certain precautions should be taken.

1. Each time the same coupon should be used and care should be taken to prevent any contamination of the coupon surface during successive use.
2. Even though the analysis is done at room temperature care should be taken to avoid significant temperature variation.
3. If the peroxide is withdrawn from the tank using a valve, then care should be taken to discard the initial amount of HTP so that the peroxide used for analysis comes from the bulk tank and not from the valve or other plumbing components involved. A better approach would be to use a pipette to withdraw the sample directly from the tank itself.

Other Possible Methods

Prediction of stability margin requires continuous monitoring of concentration of the peroxide under accelerated decomposition study. The usual methods like refractive index and permanganate titration may not be practical for this purpose. Active oxygen loss (AOL) can be used but it tells nothing about the way the decomposition occurs (i.e. decomposition could be local) and hence the bubble density measurement might be a good tool but this too has certain limitations:

- It is difficult to obtain the exact bubble density unless the image is processed which can be time consuming.
- Sampling of peroxide from the tank could be a problem (Certain areas of the tank might result in a higher local decomposition)

And due to these reasons, it would be better if some sort of non-destructive evaluation can be done on the peroxide stored in the run tanks. A possible tool can be an acoustic emission sensor attached to the tank, which detects the evolution of oxygen from hydrogen peroxide. Oxygen bubbles formation results in an acoustic emission, which can be detected. The rate of liberation of oxygen is determined by the change in activity of the acoustic emission.

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PROJECT TITLE: Development of Low-Cost High-Sensitivity Polymer Tunneling Accelerometers

INVESTIGATORS: Dr. Tianhong Cui/Louisiana Tech University
Dr. Kody Varahramyan/Louisiana Tech University

INITIATION YEAR: FY 2002

AGGREGATE AMOUNT OF FUNDING FROM EARLIER YEARS: $40K

FUNDING AUTHORIZED FOR FY03: $0K

ACTUAL EXPENDITURES OF FUNDING FROM EARLIER YEARS:

- In-house: $0
- Contracts: $40,000
- Grants: $0

STATUS OF INVESTIGATION AT END OF FY03: Completed in FY03

PURPOSE:

To design and develop an ultra high-sensitivity polymer tunneling accelerometer based on novel hot embossing and ICP techniques.

BACKGROUND AND APPROACH:

This project will develop a novel design and fabrication for an ultra high-sensitivity polymer tunneling accelerometer based on novel hot embossing and ICP techniques. This kind of polymer tunneling sensor is very sensitive, more functional, and has higher sensitivity while it is very small, light, and inexpensive. This type of accelerometer can be used to measure vibration in high accuracy and quick response. The accelerometer is needed to support the ground testing of the rocket and its surrounding vibration at NASA-SSC. It will deliver accelerometer prototypes with nominal vibration sensitivity higher than 25 mV/g, frequency range from 2 Hz to 3 KHz, with an output impedance of less than 100 ohms to perform and survive in the harsh environments. Analytical models will be developed to optimize the design of the accelerometer to meet the required design conditions. Drawings and fabrication processes for the developed design will be documented and provided at the completion of the project. In addition, to develop the design the accelerometer prototype will be fabricated and tested.

FY03 ACCOMPLISHMENTS:

The grant was completed in October of FY03. Our tasks are focused on design, simulation, fabrication and characterization of the novel ultrasensitive polymer-based tunneling sensor platform for acceleration sensing.

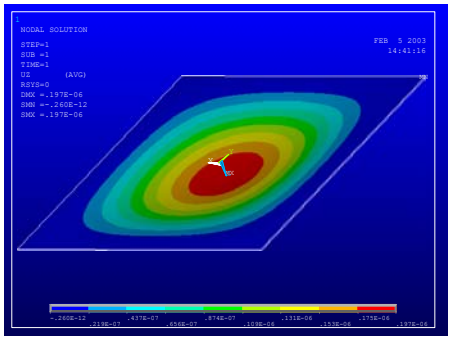

Fig.1 Displacement of the membrane

1. ANSYS Simulation of Polymeric Tunneling Sensor Platform

Simulation work has been implemented to discuss some important issues. ANSYS is used for mechanical-level analysis. PMMA is used as the mechanical material instead of silicon. Based on ANSYS simulation, it is proved that PMMA has several advantages over silicon: high sensitivity, simple fabrication process, and the requirements for dimension are not so strict. For a simple membrane structure with dimension of 4 mm × 4 mm × 20 μm, a high sensitivity of 47 nm/g and a high resolution of 1.17 mg/√Hz can be achieved. Several factors such as spring constant, natural frequency, and electrostatic force of the structure can be obtained from the simulation results, which can be used in higher

PROJECT TITLE: Development of Low-cost High-Sensitivity Polymer Tunneling Accelerometers (Cont.)

FY03 ACCOMPLISHMENTS (Cont.):

level simulation. As shown in Fig. 1, the maximum displacement of the structure is about 0.2 μm, and the corresponding spring constant *k* is approximately equal to 80 N/m.

2. Modeling and Control System Synthesis by MatLab Simulation

Simulation work has been implemented to establish the function model of the tunneling sensor by MatLab Simulink. MATLAB is used for the system-level analysis. A simple but effective mathematical model is described. Each function block of the model are discussed and analyzed. Based on small signal variation of the sensor, the model is linearized. Transfer function of the system is derived by Laplace transformation. Simulation results about root locus, step response, bandwidth, and damping effect are described and discussed. Fig. 2 shows the root locus and all the poles of the accelerometer.

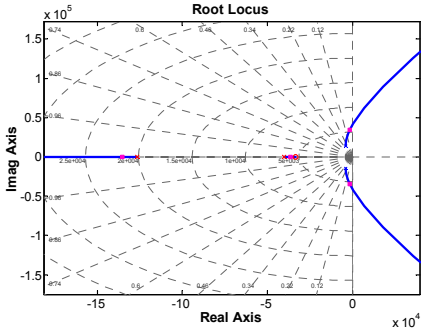

Fig. 2. Root locus of the accelerometer system.

3. Fabrication of Tunneling Sensors

The polymeric tunneling sensor platform will be fabricated by advanced polymeric MEMS fabrication technology. The sensor fabrication will be mainly based on the hot embossing technique, in conjunction with using an ICP (Inductive Coupled Plasma) Etcher, which are advanced tools. The basic idea is to use ICP etching and wet bulk micromanufacturing to build the mold insert for the hot embossing tool. This will allow one to batch produce the microsensors with the advanced hot embossing tool. The electrostatic microactuator is to control the tunneling gap at 1 nm after releasing the movable parts. These and other tools at the Institute for Micromanufacturing (IFM) at Louisiana Tech University provide a unique and valuable set of fabrication capabilities for the realization of leading-edge MEMS and microelectronics products (both silicon and non-silicon-based). Fig. 3 shows the PMMA tip of a vertical tunneling accelerometer. Fig. 4 illustrates the PMMA lateral tunneling sensor.

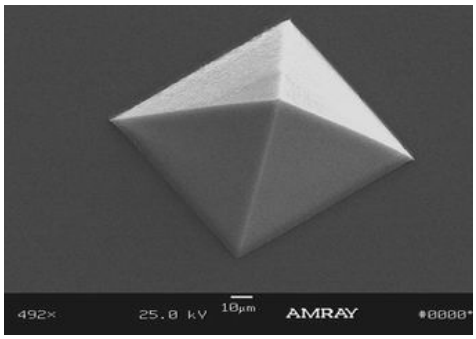

Fig. 3 The tip of vertical tunneling sensor

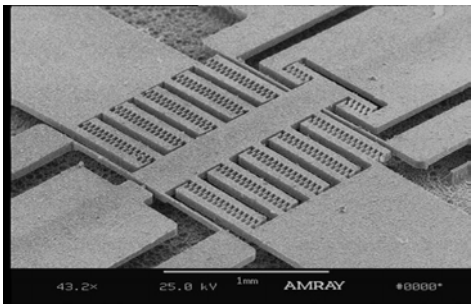

Fig. 4 The lateral tunneling sensor

PUBLICATIONS/PATENTS:

(1) Invited Presentation: Tianhong Cui, Kody Varahramyan, Yongjun Zhao, and Jing Wang, "Simulation and Fabrication of Novel Polymeric Tunneling Sensor by Hot Embossing Technique", ASME International Mechanical Engineering Congress & Explosition, New Orleans, November 17-22, 2002.

(2) Jing Wang, Yongjun Zhao, and Tianhong Cui, and Kody Varahramyan, "MatLab Simulink Modeling and Controller Synthesis in Tunneling Accelerometers", Journal of Micromechnics and Microengineering, Vol.12, No.6, 2002: pp.730-735.

PROJECT TITLE: Development of Low-cost High-Sensitivity Polymer Tunneling Accelerometers (Cont.)

PUBLICATIONS/PATENTS (Cont.):

(3) Jing Wang, Wei Xue, and Tianhong Cui, "A Combinative Technique to Fabricate Hot Embossing Master for PMMA Tunneling Sensors", accepted by journal of Microsystem Technologies. (in press)

(4) Yongjun Zhao and Tianhong Cui, "Fabrication of High-aspect-ratio Polymer-based Electrostatic Comb Drives by Hot Embossing", Journal of Micromechnics and Microengineering, Vol.13, No.3, 2003: 430-435.

(5) Jing Wang, Tianhong Cui, and Kody Varahramyan, "Synthesis and Fabrication of PMMA Tunneling Accelerometer", the fifth Texas MEMS Workshop, Texas, May 6, 2003.

(6) Yongjun Zhao and Tianhong Cui, "High-aspect-ratio Polymer-based Electrostatic Comb Drive by Hot Embossing Process", the fifth Texas MEMS Workshop, Texas, May 6, 2003.

(7) Tianhong Cui, Jing Wang, and Yongjun Zhao, "Polymer Based Tunneling Sensor", Patent Application Serial No. 10/648,927 (filed on August 27th, 2003)

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PROJECT TITLE: Concentration Ratio Measurement of N_2 and O_2 in a Liquid Oxygen Feed Line

INVESTIGATORS: Dr. Jagdish. P. Singh/Mississippi State University
Fang-Yu Yueh/Mississippi State University

INITIATION YEAR: FY 2002

AGGREGATE AMOUNT OF FUNDING FROM EARLIER YEARS: $67.5K

FUNDING AUTHORIZED FOR FY03: $0K

ACTUAL EXPENDITURES OF FUNDING FROM EARLIER YEARS:

- In-house: $0
- Contracts: $67,500
- Grants: $0

STATUS OF INVESTIGATION AT END OF FY03: Completed in FY03

PURPOSE:

The purpose of this project was to evaluate a Raman system for monitoring the quality of liquid oxygen (LOX) in the delivery line during the testing of a rocket engine.

BACKGROUND AND APPROACH:

NASA/SSC needs a sensor which can monitor the quality of liquid oxygen in the delivery line during the testing of rocket engine. Spontaneous Raman scattering (SRS) has been known for years as a relatively simple analytical method. It can be used to identify various molecules in the samples by means of their vibrational spectra and then use the intensity of the desired molecule bands to determine the concentration of that molecule. It has the potential to be developed to a sensor to measure the concentration ratio of nitrogen and oxygen in a liquid oxygen feed line.

In this project, a system for detecting the oxygen and nitrogen ratio in cryogenic propellants has been designed based on a CW laser Raman system. This system is an optical fiber based system so that the laser, the spectrometer, and detection electronics can be kept at a distance from the test cell. A high pressure cell for recording Raman spectra of liquid air or liquid N_2 has been designed and used to evaluate the design of the CW Raman system. The N_2 and O_2 Raman data recorded at various liquid pressures will help to extrapolate the laboratory results with actual rocket engine test condition. Finally, the performance of the developed SRS system will be demonstrated at NASA/SSC.

FY03 ACCOMPLISHMENTS:

A Spontaneous Raman Spectrometer (SRS) optical fiber sensor is developed in the lab for NASA/SSC long-term detection and monitoring of the quality of liquid oxygen in the delivery line during the testing of rocket engine. This SRS setup uses a frequency doubled 532 nm continuous Nd:YAG laser as the excitation light source, with maximum output power at 330 mW. In the process of critically improving the performance of our sensor, we employed three configurations for test measurement and optimization, using acetone as a first sample. Once reaching to the optimum level with each configuration, experiments were then extended first to the liquid nitrogen and then to the concentration ratio measurement of N_2 and O_2 in a high pressure gas phase environment for further improving the performance characteristics in order to approach towards the final aim of the concentration ratio measurement of N_2 and O_2 in liquid oxygen feed line.

In the proposed SRS system, the optical fiber is used to deliver the exciting light source to the sample and collect the SRS signal from the sample. It is important that this system can keep a distance from the sample and still obtain good signal-to-noise ratio data. To this end, three fiber configurations were tested. The experimental set-up of these fiber configurations are show in

PROJECT TITLE: Concentration Ratio Measurement of N_2 and O_2 in a Liquid Oxygen Feed Line (Cont.)

FY03 ACCOMPLISHMENTS (Cont.):

Figures 1-3. In the first configuration, the laser, reflected with two dichroic mirrors, was focused onto the sample cell using single optical fiber and a suitable launching/collimating optics. The emitted Raman signal was then received (through the same optical fiber in the backward direction with suitable exciting/coupling (E/C) optics), filtered, and fed to the spectrometer through another optical fiber bundle. It was noticed that the Raman signal collected with this configuration has an additional peak approximately at 663 nm, though relatively small, which could be due to the laser induced fluorescence or could be due to some nonlinear effects in optical fiber. We found that this configuration is limited with very weak response efficiency. In order to improve the response efficiency and filtering of the additional peak from the sensor response, we employed Ocean Optics Reflection/Backscattering probe (R200-REF) in the second design configuration. This probe consists of seven optical fibers, each having 200 μm core diameters with one launching fiber and six surrounding collecting fibers having an additional fiber to monitor the illumination source, which we thought would be useful for the experiment to monitor the spectral noise of the source as well. Thus, unlike the previous case, here the Raman signal in the backward direction was collected by six optical fibers; and then filtered and fed to the spectrometer through another optical fiber bundle. The launching optics remained the same, whereas the E/C optics at seven-fiber bundle end of the Y-shaped probe was modified. The spectra recorded with this configuration show that the additional peak approximately at 663 nm has been successfully suppressed with much improved response as compared to the single fiber Raman probe. Also the response characteristics of the sensor system improved by more than a factor of 2.5 with the modified E/C optics. In order to critically improve the optical fiber Raman sensor response with suppressing the background noise, in the third design configuration, we employed InPhotonics state-of-the-art miniaturized Raman probe. It is a coaxial, two fiber probe with one fiber, used for the excitation, whereas, the other is for the signal collection. The Raman probe optimizes optical throughput while completely removing fiber background. As can be observed from the response, due to the efficient filtering before and after the sample, the background noise has been greatly suppressed from the quartz fiber optics for the spectra measured with Raman probe. In addition, the response of the sensor improved ~ 8 times as compared to the Y-shape reflection/backscattering probe with the modified optics.

After these characterizations, the experiments were extended to monitor liquid nitrogen and then the concentration ratio measurement of N_2 and O_2 in a high pressure gas phase environment to further investigate the performance. The recorded data of liquid nitrogen from Y-shaped reflection/backscattering probe and In-Photonics fiber optic Raman probe are plotted and shown in Fig. 4 and 5 respectively. As clearly shown in these figures, the response of the sensor system, employing In-Photonics fiber optic state-of-the-art miniaturized Raman probe is tremendously improved (~13 times) as compared to the Y-shaped reflection/backscattering Raman sensor system.

PROJECT TITLE: Concentration Ratio Measurement of N_2 and O_2 in a Liquid Oxygen Feed Line (Cont.)

FY03 ACCOMPLISHMENTS (Cont.):

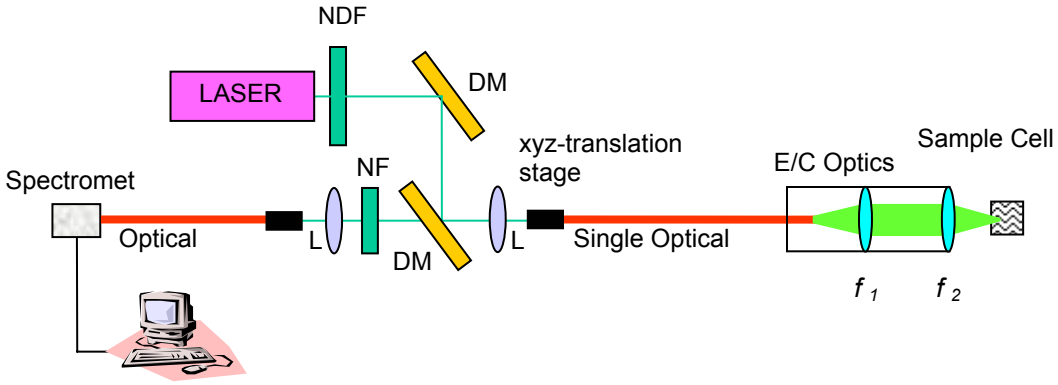

Fig. 1 *Experimental set-up with Ocean Optics spectrometer employing single optical fiber, used as a light guiding, as well as signal collecting channel*

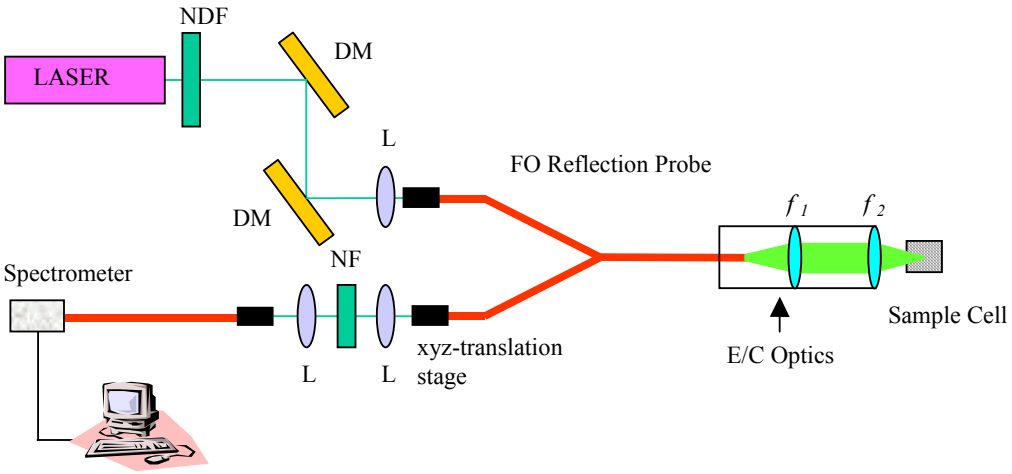

Fig. 2 *Experimental set-up using Ocean Optics Reflection/Backscattering probe (R200-REF).*

As a final step, we extended our experiments with the three developed SRS sensor design configurations for the concentration measurement of N_2 and O_2 in a high pressure gas phase environment to further investigate the sensor performance. The high pressure cell was designed at DIAL and was compatible for a gas pressure as high as 1000 psi. The concentration ratio measurements of N_2 and O_2 were carried out at various individual gas pressures in a gas mixture with constant total pressure in the cell at 900psi.

PROJECT TITLE: Concentration Ratio Measurement of N_2 AND O_2 in a Liquid Oxygen Feed Line (Cont.)

FY03 ACCOMPLISHMENTS (Cont.):

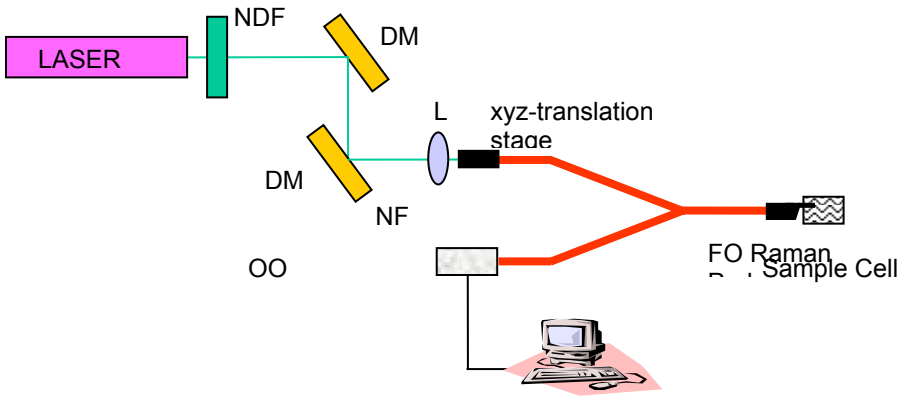

Fig. 3 *Experimental set-up using In Photonics Fiber Optic Raman probe.*

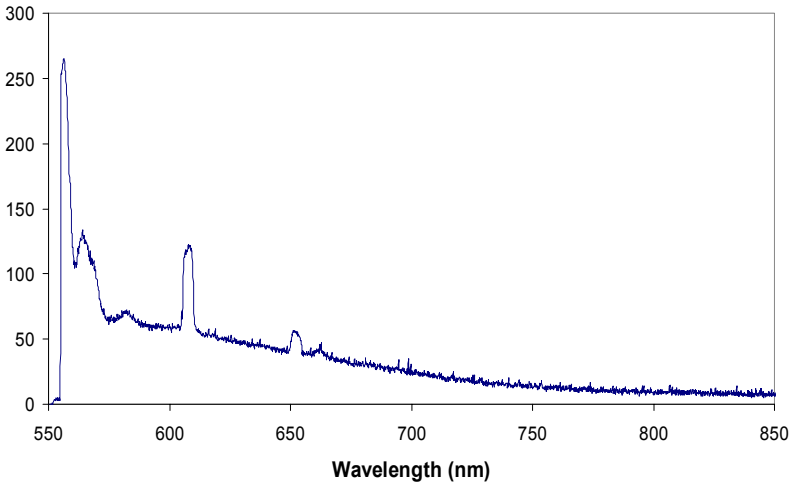

Fig. 4 *Experimental result for liquid nitrogen with full laser power and modified E/C optics, using Ocean Optics spectrometer, along with Ocean Optics Reflection/Backscattering probe (R200-REF).*

PROJECT TITLE: Concentration Ratio Measurement of N_2 AND O_2 in a Liquid Oxygen Feed Line (Cont.)

FY03 ACCOMPLISHMENTS (Cont.):

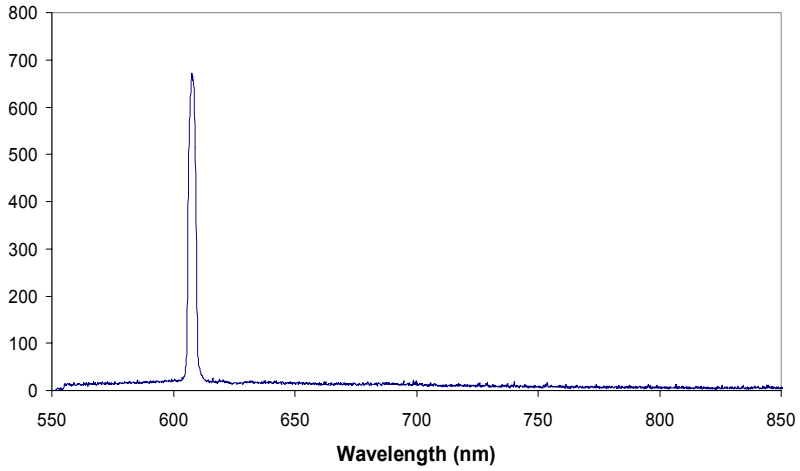

Fig. 5 *Experimental result for LN_2 with full laser power using In-Photonics fiber optic Raman probe.*

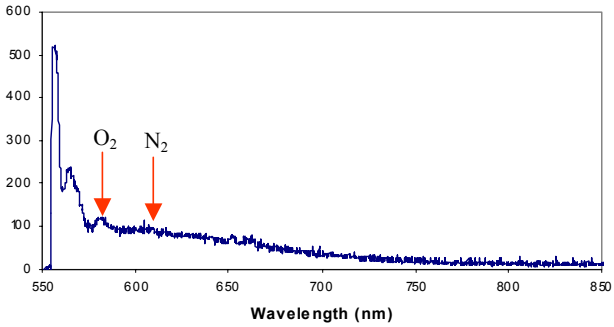

Fig. 6: *Experimental result for N_2 (450 psi) and O_2 (450 psi) in a gas mixture with full laser power and modified E/C optics, using Ocean Optics spectrometer, along with Ocean Optics Reflection/Backscattering probe (R200-REF).*

The recorded data, with same NDF and laser power, from Ocean Optics spectrometer employing Y-shaped reflection/backscattering probe is shown in Fig. 6. The following conclusions can be drawn from the observed data. First, the sensor system is capable to sense successfully N_2 and O_2 in a gas mixture. Second, the response of the sensor is very weak. In order to investigate further with this design configuration, we employed Princeton high resolution ICCD spectrometer and varied the individual gas pressure within the pressure cell maintaining a total pressure constant at 900 psi. Fig. 7 shows the response of the sensor for nitrogen and oxygen at an identical gas pressure of 450 psi, whereas as can be observed, the sensor was well capable to resolve the two gases and successfully sensed their

PROJECT TITLE: Concentration Ratio Measurement of N_2 AND O_2 in a Liquid Oxygen Feed Line (Cont.)

FY03 ACCOMPLISHMENTS (Cont.):

concentration ratios. Comparing all the data, we concluded that there is a trade off between the sensitivity of the spectrometer and the gas pressure! Either an extremely sensitive spectrometer has to be employed to work at such a low gas pressure, or one has to go to the higher gas pressure. In our case, the working gas pressure was limited to the cell, which was designed for 1000 psi only.

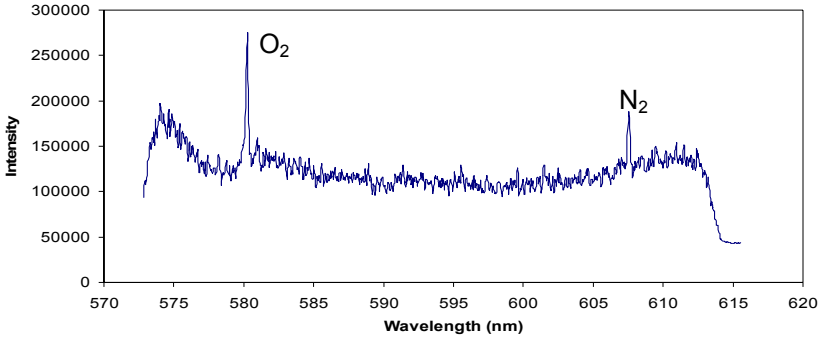

Fig. 7 *Experimental result for N_2 (450 psi) and O_2 (450 psi) in a gas mixture with full laser power and modified E/C optics, using JY spectrometer, along with Ocean Optics Reflection/Backscattering probe (R200-REF).*

Finally, Fig. 8 shows the data for nitrogen and oxygen in a gas mixture at 900 psi, recorded with the third sensor design configuration employing InPhotonics Raman probe. As can be observed, the response of optical fiber reflection probe is comparable to the InPhotonics, though the later exhibited an improved response over the first. The main highlight of this response is again the need to realize a pressure cell which can afford a gas mixture at an extremely high pressure. At the same time, the optical fiber reflection probe has a wide room to be improved in terms of light collection efficiency by optimizing various fiber parameters in order to realize a more compatible probe towards Raman signal parameters.

PROJECT TITLE: Concentration Ratio Measurement of N_2 AND O_2 in a Liquid Oxygen Feed Line (Cont.)

FY03 ACCOMPLISHMENTS (Cont.):

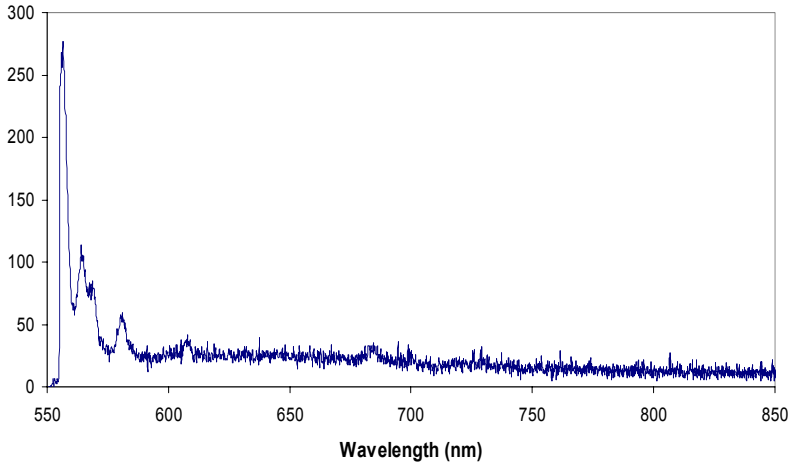

Fig. 8: *Experimental result for (450 psi) and O_2 (450 psi) in a gas mixture with full laser power using In-photonics fiber optic Raman probe.*

In conclusion, we have carried out a detailed and exhaustive experimental study for the development of Raman sensor system towards realizing the final objective of this project. As indicated by the results reported here, we have made significant improvements towards the process of critically improving the performance of the sensor system, and have reached to the optimum characteristics level. At present, we are extending our experimental study towards recording the Raman signal in a gas mixture of nitrogen and oxygen in a high pressure cell, which is again a further step towards the realization of the goal of this project.

PUBLICATIONS/PATENTS:

1. **S. K. Khijwania**, A. Kumar, Fang-Yu Yueh and J. P. Singh, "Raman Sensor to monitor the nitrate and nitrite in the nuclear waste tank", *SPIE*, vol. 5268, pp 47-52, 2003.
2. **S. K. Khijwania**, A. Kumar, Fang-Yu Yueh and J. P. Singh, "Raman Sensor to monitor the nitrate and nitrite in the nuclear waste tank", *Photonic East*, Rhode Island USA, 27-30 Oct. 2003.

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CDDF PROJECTS

INITIATED IN FY2001

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PROJECT TITLE: Transmitters with R-Shunt Capability

INVESTIGATORS: Mark Hughes/VA30E
Randy Holland/VA30E
Steven Sorgenfrei/Sverdrup
Terrence Burrel/LMSO
Robert Drackett/LMSO

INITIATION YEAR: FY 2001

AGGREGATE AMOUNT OF FUNDING FROM EARLIER YEARS: $50K

FUNDING AUTHORIZED FOR FY03: $0K

ACTUAL EXPENDITURES OF FUNDING FROM EARLIER YEARS:

- In-house: $12,349
- Contracts: $24,629
- Grants: $0

STATUS OF INVESTIGATION AT END OF FY03: Completed in FY03

PURPOSE:

The purpose of this project is to identify and evaluate a COTS transmitter(s) with an internal shunt capability to provide end-to-end system checks and span error corrections.

BACKGROUND AND APPROACH:

TRANSDUCERS (0-30mV output)

Transducer technology provides the ability to initiate voltage shunt calibrations that verify the end-to-end system setup and compensate for span “gain” errors using a R-shunt resistor. This R-shunt resistor electrically simulates an applied pressure providing very useful information on sensor/system health and compensation for system span errors.

Transducers are linear and follow the equation y=mx+b. C1, the coeficient of x at the 80% shunt calibration point, and the constant C0 are derived below.

y=C1x+C0 Where: C1=slope, C0=constant (y-axis crosspoint when x=0)

C1=PSI/Cnt

C1=Kn/(CntHi-CntLo)

C0=-(Kn*CntLo)/(CntHi-CntLo)

Kn=KeyNumber, Cnt=Counts,

The KeyNumber is provided by the calibration laboratory where the sensors are calibrated against NIST standards. This information is stored in the data acquisition system. End-to-end system checks (R-Shunt Calibrations) give the engineer the ability to see how close the R-shunt calibration approaches the calibration lab result. This procedure is done in counts where 32,768 is the maximum possible resolution. Procedures dictate that variations greater than 20 counts (.00061 volts) be flagged as out of tolerance.

TRANSMITTERS (4-20 mA output)

Transmitter technology provides good process control, noise reduction “current loop”, and uses a smaller number of conductors while not needing any signal conditioning. Transmitters are not normally calibrated but a voltage insertion method can be used on the data acquisition front end prior to test to simulate the process. However, this method does not correct for span errors and may not detect bridge anomalies. This project investigates a hybrid approach that utilizes the positive features of both technologies and provides for a way to calibrate transmitters similar to transducers.

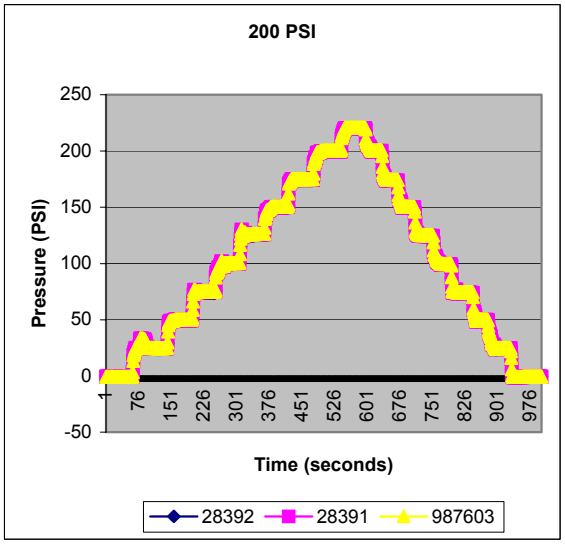
PROJECT TITLE: Transmitters with R-Shunt Capability (Cont.)

FY03 ACCOMPLISHMENTS:

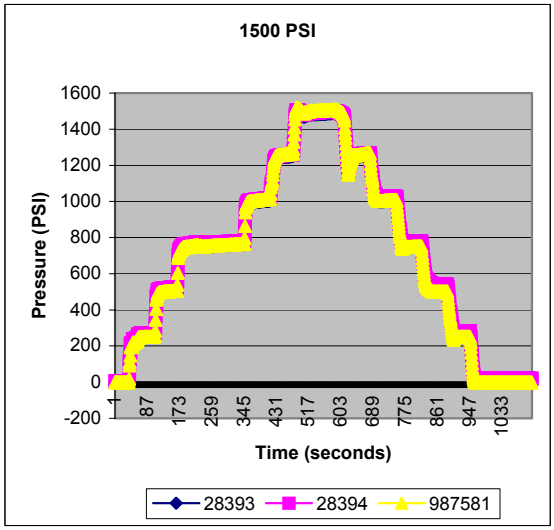
In FY02, prototypes were procured from a single manufacturer after evaluation of the proposals. After receiving the transmitter protoypes, a Stennis Work Request was written to calibrate, evaluate, clean and install the prototypes transmitters and the control transducers with internal shunt capability. Exact sensors, against which the prototypes would be compared, were not available in every case. A reasonably similar device was chosen instead.

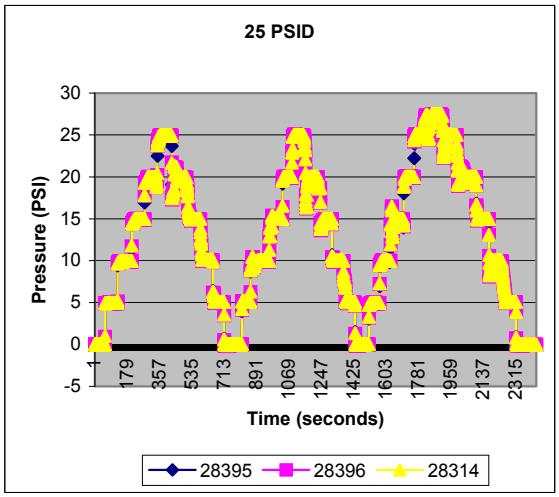
The protoypes were submitted for calibration by the calibration lab in the summer of FY02 but they were not ready until early FY03. Test facilities were also not available during this time period so they could not be tested.

The protoypes were calibrated and returned in early FY03. Prior to installation for testing, the prototypes were checked for compatibility and adaptation to the existing data systems in the DACS Lab. Data was taken to prove the installation technique was correct. After installation, testing occurred at the E3 Test Facility during mid to late FY03 when a window of opportunity opened following a test program. Below is a quick look at the data taken.



It is significant to note that the 25 PSID Transmitters were compared against a 50 PSID transducer. More detailed data revealed little loss of resolution by the 50 PSID transducer versus the 25 PSID transmitters.



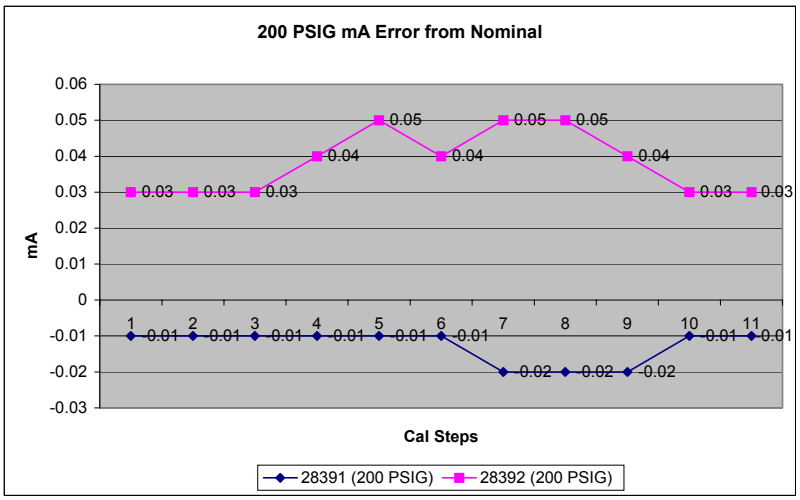


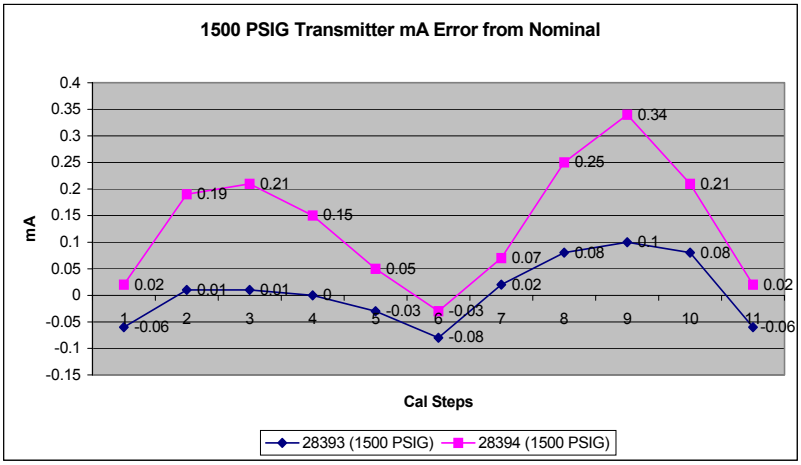
Final Analysis

In general, the data taken by the prototypes tracked the control transducers well. Closer scrutiny does reveal some minor differences in anticipated values throughout the tests for one of the 1500 PSIG transmitters transducers. This may be attributed to a minor manufacturing defect. The 200 PSIG and the 25 PSID prototype transmitters tracked much better.

PROJECT TITLE: Transmitters with R-Shunt Capability (Cont.)

FY03 ACCOMPLISHMENTS (Cont.):





The 1500 PSIG transmitters were out of calibration tolerances according to the calibration lab which used secondary standards calibrated by the National Institute of Standards and Technology. Even after adjustment, S/N 28394 of the 1500 PSIG transmitter prototypes could not be adjusted to stay within calibration tolerance levels of .20 mA as seen in the graph above.

In general, the transmitter prototypes' unique architecture bridged the differences between transmitters and transducers. They did not require signal conditioning like transducers, can drive a control input directly, can be calibrated like a transducer for circuit health just prior to test, can make minor span corrections like a transducer, are normally immune to noise like a transmitter, and require less wiring than a transducer.

PUBLICATIONS/PATENTS:

An article is planned for submission to NASA Tech Briefs.

PLANNED FUTURE WORK:

The transmitters have been placed in storage and are available for use on a test program. If removed for recalibration, the calibration data will be compared to existing data for corraboration. No further work is planned for this project.

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PROJECT TITLE: Geospatial Education Pilot Study for the Gulf of Mexico Accord

INVESTIGATORS: Dr. Ramona Travis/IA20
Dr. David Powe (Education/workforce development)/NASA
Dr. Merrill Johnson (Geospatial research)/University of New Orleans
Dr. David Clawson (Latin Am. Ag. Appl.)/University of New Orleans
Ms. Liesel Ritchie (Ed. eval. and assess.)/Mississippi State University
Mr. Glenn Vanderbeek (Distance learning tech.)/ SSC/MSS/IDI
Prof. Augustin Ceballos (Cart. lab/ag. appl.)/Univ. of Veracruz
Prof. Juan Perez (Atmos. sci./satellite comm.)/Univ. of Veracruz

INITIATION YEAR: FY 2001

AGGREGATE AMOUNT OF FUNDING FROM EARLIER YEARS: $40K

FUNDING AUTHORIZED FOR FY03: $0K

ACTUAL EXPENDITURES OF FUNDING FROM EARLIER YEARS:

- In-house: $10,000
- Contracts: $30,000 (delivery orders to UNO and MSU)
- Grants: $0

STATUS OF INVESTIGATION AT END OF FY03: Completed in FY03

PURPOSE:

To develop and implement innovative geospatial training and research techniques utilizing cutting edge remote sensing and distance learning and electronic information/ communication methodologies.

BACKGROUND AND APPROACH:

The Gulf of Mexico Accord involves eleven states bordering the Gulf of Mexico (five in the U.S. and six in Mexico) and evolved under the auspices of the North American Free Trade Agreement. Under the accord, these states will establish collaboration to mutually benefit economic development of the region with the six focal areas of collaboration being: 1) Investment; 2) Communication and Transportation; 3) Health; 4) Education and Culture; 5) Agriculture, Fisheries, and Forestry; and 6) Tourism. Leads in these areas include Mississippi in Education (with the now previous NASA/SSC Education Director as the lead) and Veracruz in Agriculture, Fisheries, and Forestry (with the Univ. of Veracruz having primary responsibility for oversight).

In order for new technologies to be adopted into the economic infrastructure of a region and economic growth expanded, members trading goods and services of that region must have both knowledge of and some capability to utilize these new technologies. The eleven states bordering the Gulf of Mexico have a population of more than 50 million people and the potential to support a dynamic economic base and shared future focused on common environmental issues and applications utilizing geospatial technologies. Remote sensing and GIS (Geographic Information Systems) are geospatial technologies relevant to NASA's interests within the context of the Accord and the Earth Science Enterprise Applications Program objectives at SSC. Additionally, Dr. David Powe, previous NASA/SSC Education Director and project co-investigator, served as the State of Mississippi lead for the Accord's Education focal area.

In general, this project conducted a pilot study intended to increase the knowledge base and demonstrate the utility of geospatial technologies for one of the focal Accord issue areas, agriculture, in the Mexican state of Veracruz by employing innovative educational technologies and methodologies. The approach

PROJECT TITLE: Geospatial Education Pilot Study for the Gulf of Mexico Accord (Cont.)

BACKGROUND AND APPROACH (Cont.):

embraced not just background training in geospatial technologies and applications, but engaged more specific utility by conducting and incorporating small agricultural research application(s)/studies in that training to make the training have immediate and local impact. Collaborations involved NASA and selected universities in the U.S. Gulf States (the Univ. of New Orleans – UNO, and Mississippi State Univ. - MSU). NASA funds were only used for US universities. The Mexican university, the University of Veracruz in Xalapa, Veracruz, provided its own funding base.

FY03 ACCOMPLISHMENTS:

A site visit was made in very early FY2003 by UNO team members to conduct the training activity with the geospatial training modules and related materials.

MSU team members developed evaluation instruments for the training and testing phases of the program in FY2002 and then implemented their use at those geospatial training sessions in early FY2003 and findings were later reported.

A video was also developed about the project, for use by the various partners in the project; it illustrated the training activities and impacts.

The Clawson classification scheme was further refined and applied to data from the region for multiple dates. Figure 1 identifies the general location of the study area in Veracruz, Mexico. Figures 2a and 2b illustrate multi-temporal analyses using ISODATA and a Clawson Typology hybrid classification for two of the years analyzed.

Final reports for the project were submitted by: 1) the University of New Orleans entitled " Using Satellite Imagery to Analyze Agricultural Land-Use Changes Near Veracruz; and 2) Mississippi State University entitled "Evaluation Findings of the Remote Sensing Workshop".

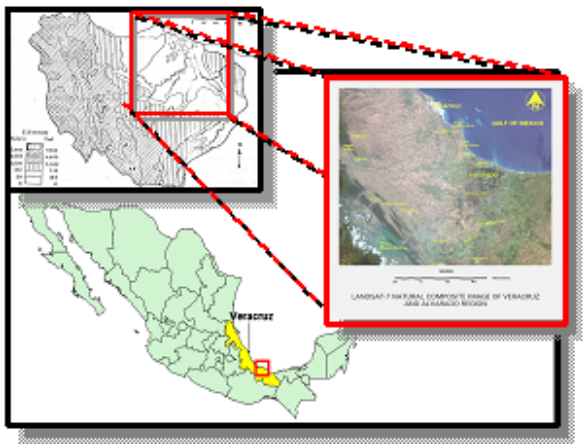

Figure 1: General Location of Study Areas in the state of Veracruz, Mexico

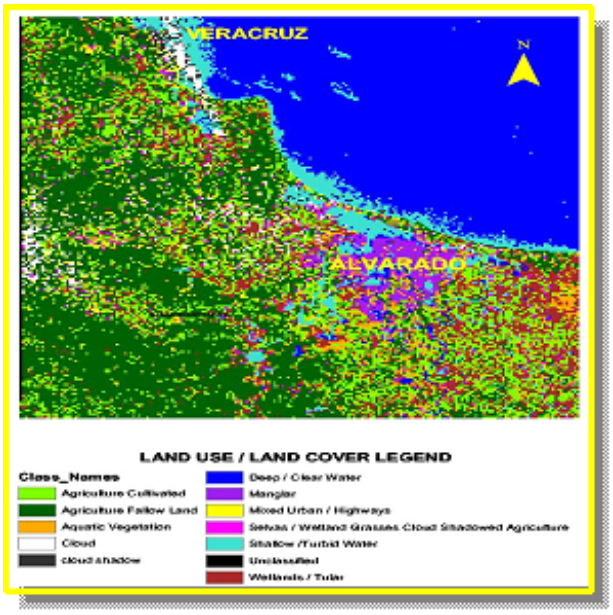

Figure 2a: Multi-temporal analysis using ISODATA and a Clawson Typology hybrid classification – 1990

PROJECT TITLE: Geospatial Education Pilot Study for the Gulf of Mexico Accord (Cont.)

FY03 ACCOMPLISHMENTS (Cont.):

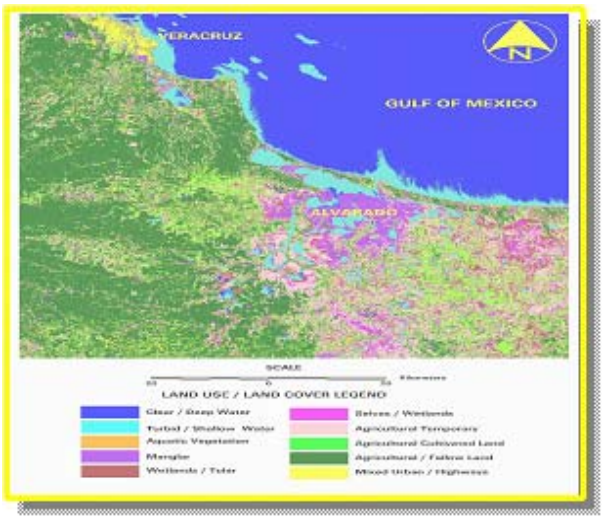

Figure 2b: Multi-temporal analysis using ISODATA and a Clawson Typology hybrid classification – 2000

OVERALL ACCOMPLISHMENTS OF THE PROJECT:

Most of the original objectives of the project were achieved except, that due to international telecommunication issues; distance learning activities from the University of New Orleans to the University of Veracruz were not accomplished. Instead, the training modules were delivered directly utilizing on-campus telecommunication and geospatial computer technologies for the training activities.

Small research projects involving classification of some of the local agricultural region were conducted. A significant result was a new classification typology, based on a USGS acknowledged classification scheme in part, but better adapted to the considerable variability that exists in an agricultural landscape with mixed lowland and highland tropical environments and also accounts for centuries of regional agricultural practices and related impacts on the environment. These projects are expected to be continued and expanded upon by the Veracruz investigators, utilizing the training that they received.

Project products include: two peer-reviewed journal articles in preparation; a conference paper presented; geospatial training modules developed and delivered on CDs; and a project video.

An evaluation study of the training activities indicate that the technology will be gradually incorporated into the courses offered in agricultural and geography departments at universities, utilizing the modules.

Due to this project, NASA/SSC has developed a closer tie with the University of New Orleans in the area of Latin American earth science applications. As a result, NASA/SSC is supporting a continuation of some efforts started with this CDDF project with a Graduate Student Researchers Program (GSRP) grant award to further some of the research aspects of this project.

Partly related to this project and the geospatial technologies that it engaged, the University of New Orleans has expanded its research in Latin America, especially with the University of Veracruz, one of the stronger research institutions in the region.

PUBLICATIONS/PATENTS:

A paper entitled “Testing for the Effects of Resolution on Land Use Interpretation in a Tropical Setting” is being drafted to discuss testing for the effects of remotely sensed data resolution from the older MSS and TM and the newer high resolution ASTER on land-use interpretation in tropical settings. Potential journals being considered for submission are: the *International Journal of Remote Sensing; Remote Sensing of the Environment;* and *GEOCARTO International*.

A second journal article entitled “Toward an Updated System of Integrated Land-Use/Land-Cover Classification in Tropical Settings” is also being drafted for submittal to the *Journal of Geography.* This paper will discuss an updated system of integrated land-use/land-cover

PROJECT TITLE: Geospatial Education Pilot Study for the Gulf of Mexico Accord (Cont.):

PUBLICATIONS/PATENTS (Cont.):

classifications for tropical settings using the new Clawson typology. If application of geospatial technologies for classifying and monitoring land use and change is to become a common practice in the tropics for land management concerns, it is important to have a classification system that is appropriate to the situation and needs of the local users. This outcome of the project may be a very significant advancement stemming from the research that was not previously anticipated.

The Geospatial training modules developed earlier in the project were improved upon later in the project and have been distributed to project partners for use via CDs. They will not be officially published and disseminated otherwise.

Similarly, a video was developed in both English and Spanish versions about the project and was distributed to all project partners to further enable collaborations among the partners. The video is not intended to be officially published or disseminated .

DUAL USE COOPERATIVE AGREEMENTS

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NASA SSC Dual Use Projects for FY03

Project Title/ Commercial Partner	Project Year	NASA Funding ($K)	Company Contribution ($K)	Project Status	Expected Date of Completion (Month/Year)
FY03 Projects					
Disaster Mitigation Decision Support System Using Lidar in Support of Flood Inundation Mapping *NVision Solutions, Inc.*	2003	75	75	Completed 9/30/2003	--
A Polychromatic Field Sensor for the Determination of Particulate and Dissolved Organic Matter (DOM) in Fresh and Sea Water - UltraPath-2. *World Precision Instruments, Inc. (WPI)*	2003	69.9	69.9	Open	September 2004
Valve Design Optimization with Sculptor's CFD Shape Optimization Tools *Optimal Solutions, Inc.*	2003	70	70	Open	January 2004
Cryogenic Resistance Temperature Detector (RTD) *RdF Corporation*	2003	63	63	Open	August 2004
FY02 Projects					
Cryogenic Transfer Triplex Pumping System *ACD*	2002	62.95	62.95	Completed 1/20/2003	--
Low Cost Servo Valves for High Performance Valve Actuation Systems *BAFCO*	2002	35	53	Completed 9/30/2003	--
Integration of Shape Optimization Tools *Optimal Solutions, Inc.*	2002	50	55	Completed 12/28/2002	--
Commercially Competitive Soft-Seating Relief Valve *Marotta Controls, Inc.*	2002	70	157	Open	December 2003
FY01 Projects					
Low Cost Methods to Enhance Oxygen Compatible Stainless Steel for High Pressure Oxygen Control Valves *Dresser*	2001	42.5	42.5	Completed 12/20/2002	--

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DUAL USE PROJECTS

INITIATED IN FY2003

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PROJECT TITLE: Disaster Mitigation Decision Support System Using Lidar in Support of Flood Inundation Mapping

PARTICIPATING PARTNER (COMPANY): NVision Solutions, Inc.

TECHNICAL MONITOR: Tom Stanley

INITIATION YEAR: FY 2003

COOPERATIVE AGREEMENT: NCC13-03002

NASA FUNDING: FY03 - $75,000

FUNDING SOURCE: Innovative Technology Transfer Program (ITTP)

COMPANY CONTRIBUTION: $75,000

COMPLETION DATE: September 30, 2003

PURPOSE:

The purpose of this project was to develop a decision support system (DSS) that would provide timely flood inundation warning for Emergency Operation Managers. The specific objective is to provide a DSS that can provide a web-based early warning system for flood inundation in St. Tammany Parish that uses a flood inundation model which is integrated with a legacy 911 system to provide early public warning.

BACKGROUND AND APPROACH:

St. Tammany Parish is characterized by huge areas of densely populated low lying areas. The potential for inundation comes from the sources such as torrential or enduring precipitation that overwhelms existing drainage controls, drainages that exceed their maximum capacity, and slosh effects from Lake Pontchartrain. The problem is further exasperated by the fact that all three of these potential threats routinely coincide.

Once inundation occurs, it is likely that health and human services concerns become the highest priority. Other concerns include the impacts and attention to septic systems, waste treatment systems, school district transportation, hospital access, and emergency evacuation routes.

As a result, emergency planning is a critical component of flood inundation preparedness and mitigation. Well conceived plans can significantly reduce the impact of severe and catastrophic events on property, infrastructure, and life.

This project is intended to develop a Decision Support System (DSS) to monitor the environment and predict flood inundation to provide early warning of inundation. The DSS will include the creation of a Geo-Spatial data warehouse for St. Tammany Parish, a Geo-Spatial Web Portal, a flood inundation model, real-time data synchronization, and an EOP manager's interface to the system. The DSS will integrate inundation model input with a legacy 911 system to provide a comprehensive public warning system that can be activated at the push of a button.

FY03 ACCOMPLISHMENTS:

The Emergency Management System for Tammany Parish was completed with the first version in place. The flood inundation model utilizes Lidar elevation data, local demographic information and data from the USGS gaging stations. The model was built on ESRI's ArcGIS platform and using COTS software for the development foundation. The Geospatial data warehouse and web portal were created and implemented as part of the System. The DSS was created and integrates the inundation model with GIS and remotely sensed data to produce products desired by the Emergency Operation Center (EOC) managers to help them make critical, timely decisions using the real-time data

input from the field. The system integrates existing real-time data sources of USGS, LDNR, NOAA, Lake Ponchartrain Institute, and the Causeway Foundation. With this information input available to the model, a comprehensive interface is provided that helps the EOC be more effective during times of crisis.

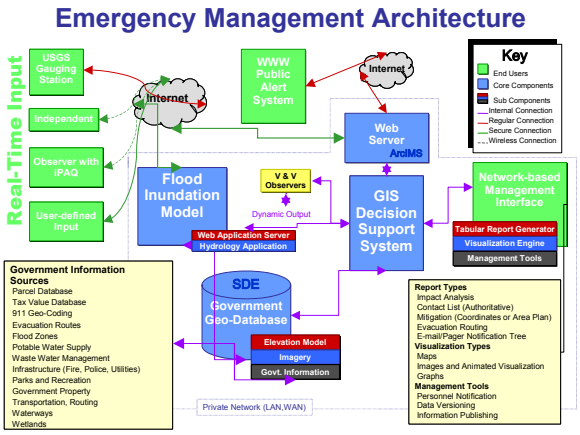

Figure 1.1: St. Tammany Parish Emergency Management Architecture

PROJECT TITLE: A Polychromatic Field Sensor for the Determination of Particulate and Dissolved Organic Matter in Fresh and Sea Water - UltraPath-2.

PARTICIPATING PARTNER (COMPANY): World Precision Instruments, Inc. (WPI)

TECHNICAL MONITOR: Bruce Spiering

INITIATION YEAR: FY 2003

COOPERATIVE AGREEMENT: NCC13-03003

NASA FUNDING: FY03 - $69,900

FUNDING SOURCE: Innovative Technology Transfer Program (ITTP)

COMPANY CONTRIBUTION: $69,900

STATUS OF PROJECT AT END OF FY03: The GFF filter pad folder was designed and the fabrication and assembly of the prototype was initiated.

EXPECTED COMPLETION DATE: September 15, 2004

PURPOSE:

The purpose of the project is to develop an UltraPath-2 instrument that will provide in-situ measurements for particulate matter as well as dissolved organic matter to provide cost effective and timely ground truth data for Earth Science verification of remotely sensed data.

BACKGROUND AND APPROACH:

The currently accepted standard method of measuring particulate matter filters a known amount of water sample through glass fiber filters (GFF) of 0.47 μm pore size. The GFF disk is wetted with the filtrate of the water sample and placed in the optical path of bench top spectrophotometer and spectrometers between various treatments to measure the particulate matter. This requires the collection, preservation in liquid nitrogen, and transportation of the sample to the appropriate laboratory with the necessary apparatus and expertise.

This project will design a multiple pathlength sample cell (called the UltraPath-2) that will allow the direct measurement of dissolved and particulate matter by measuring and subtracting backscattered light for the front scattered portion to determine the total particulate absorption.

The UltraPath-2 will eliminate the work intensive method of preserving and transportation of sample. It will allow in-situ measurements and will increase the number of samples that can be analyzed in a given coastal water. The inclusion of this capability in addition to the ability to make in-situ DOM measurements will provide a cost effective and efficient instrument that will result in significant cost savings and allow more and improved research results.

FY03 ACCOMPLISHMENTS:

The GFF filter pad folder was designed and the fabrication and assembly of the prototype was initiated.

PLANNED FUTURE WORK:

The prototype will be fabricated and assembled, then assessed and evaluated for necessary modifications before the deliverable prototype is fabricated and delivered.

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PROJECT TITLE: Valve Design Optimization with Sculptor's CFD Shape Optimization Tools

PARTICIPATING PARTNER (COMPANY): Optimal Solutions, Inc.

TECHNICAL MONITOR: Peter Sulyma

INITIATION YEAR: FY 2003

COOPERATIVE AGREEMENT: NCC13-03004

NASA FUNDING: FY03 - $70K

FUNDING SOURCE: Innovative Technology Transfer Program (ITTP)

COMPANY CONTRIBUTION: $70K

STATUS OF PROJECT AT END OF FY03: Most of the software has been developed and is undergoing testing.

EXPECTED COMPLETION DATE: January 15, 2004

PURPOSE:

The purpose of this project is to create a powerful CDF design tool, specifically for optimization of valve designs, that can be applied as a "plug-in" module to the Sculptor Shape Optimization software.

BACKGROUND AND APPROACH:

Sculptor is software package that allows the user to interactively perform shape deformation and shape optimizations in computational fluid dynamics (CFD) applications. This package is based on the shape deformation capabilities of Arbitrary Shape Deformation (ASD) that was also developed by Optimal Solutions.

During the previous Dual Use project to adapt Sculptor for use with the SSC CFD package, Fluent, there were some issues discovered in modeling the internal shape of valves. This project is an attempt to resolve these issues.

The technical approach divides the work into three areas, ASD volume manipulation tools, valve optimization tools, and grid quality measurement tools. The volume manipulation tools facilitates the deformation and control of the ASD volume that deforms the embedded CFD grid. These tools will guarantee that the valve trim components will be deformed identically in different CFD grids.

The valve optimization tools allows the user to input a set of grid files for a valve and to concurrently deform and analyze them. The user will also be able to input a flow characteristic curve and set the optimization problem to shape the plug to match a given curve with respect to the full operational range.

The grid quality measurement tools monitor the grid quality to insure accurate CFD results from the generated grid.

The final task will be the implementation of the tools in conjunction with a significant current valve design problems at SSC.

FY03 ACCOMPLISHMENTS:

The work had progressed on schedule with expected completion on the due date. Most of the tools had been completed and are in the process of testing and checkout to insure proper functionality.

PLANNED FUTURE WORK:

Testing of the various tools will be completed and necessary modifications made before the completions date. The valve optimization tool suite is expected to be delivered to SSC on schedule in January 2004.

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PROJECT TITLE: Cryogenic Resistance Temperature Detector (RTD)

PARTICIPATING PARTNER (COMPANY): RdF Corporation

TECHNICAL MONITOR: Mark Hughes

INITIATION YEAR: FY 2003

COOPERATIVE AGREEMENT: NCC13-03006

NASA FUNDING: FY03 - $63K

FUNDING SOURCE: Innovative Technology Transfer Program (ITTP)

COMPANY CONTRIBUTION: $63K

STATUS OF PROJECT AT END OF FY03: Materials procured and testing in progress.

EXPECTED COMPLETION DATE: August 11, 2004

PURPOSE:

The purpose of this project is to develop high performance cryogenic resistance temperature detectors (RTD) that meet or exceed the harsh rocket engine and component test operational requirements of the NASA test facility, and advance the technology of RTD sensors to provide a more cost effective RTD with more timely delivery to meet the testing schedule at SSC while meeting the performance requirements.

BACKGROUND AND APPROACH:

One of the prime objectives of the Rocket Engine Testing at Stennis Space Center (SSC) is to provide accurate, reliable data that allows the characterization of the test article performance. One of the key types of data are temperature measurements. Due to the harsh environment of the rocket engine testing, there is a need for the temperature measurement devices that will provide the temperature data from that environment at the data rates required for monitoring the test article and test facility performance.

Two design candidates will be pursued for potential development of an RTD. The prime candidate is a modified version of an existing Space Shuttle sensor design. A hermetically sealed platinum element assembly used in this sensor design has a proven record when used in difficult applications. The design demonstrates stability over the required operating range and has the durability to withstand the environmental requirements.

The RdF Hollow Annulus element design will be used because it allows equal pressure inside and outside the element and eliminates collapse as a failure mode. The design construction will be optimized for speed of response by decreasing the outer sheath, increasing the mandrel ID and reducing the active element winding length. The thermal coupling of the outer sheath to the element winding, such as using a thermal transfer compound, will be evaluated

A second candidate is an exposed element construction. This approach has a greater technical challenge due to the high flow rates and pressures. It would provide a faster response time which is one of the requirements. Since the element is exposed, additional consideration must be given to sealing the sensor.

FY03 ACCOMPLISHMENTS:

The materials for the fabrication and evaluation of the candidate designs were procured and the test designs prepared and testing. The results will be evaluated and recommendations prepared for the Preliminary Design Review (PDR) in February 2004.

PLANNED FUTURE WORK:

The design selection will be made at the PDR and the selected RTD will be fabricated and tested at RdF with final testing at SSC. The expected completion date will be in August 2004.

DUAL USE PROJECTS

INITIATED IN FY2002

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PROJECT TITLE: Cryogenic Transfer Triplex Pumping System

PARTICIPATING PARTNER (COMPANY): ACD

TECHNICAL MONITOR: Nick Raines

INITIATION YEAR: FY 2002

COOPERATIVE AGREEMENT: NCC13-02004

NASA FUNDING: FY02 - $62,950

FUNDING SOURCE: Innovative Technology Transfer Program (ITTP)

COMPANY CONTRIBUTION: $62,950

COMPLETION DATE: January 30, 2003

PURPOSE:

The purpose of this project was the development of improvements to the cold end of the Triplex pumping system to improve system efficiency and eliminate operational problems.

BACKGROUND AND APPROACH:

ACD is a manufacturer of cryogenic pumping and turboexpander systems. The high-pressure cryogenic transfer pumping system used at Stennis Space Center and other NASA Centers was manufactured by ACD. These pumping systems have experienced some operational problems and loss of efficiency during operation. This project was intended to address these problems and produce a more reliable and efficient system for use at Stennis.

The first issue to be addressed was modification of the existing cold end assembly which currently uses a "V" band clamp design by replacing it with a flanged and bolted connection.

The second issue was modification of the existing vacuum jacketed manifold, which uses a "V" clamp design for the bayonet type of connection to mate up to the suction adapter of the cold end. The solution will incorporate a flange and bolted connection which will allows better and even compression across the mating flanges and eliminate potential leaks.

These modifications were leak tested to insure they meet the seal requirements. The final modifications will be installed on one of the current SSC transfer pumping systems.

FY03 ACCOMPLISHMENTS:

ACD completed the engineering drawings for the modifications to the cold end system, procured the necessary materials, and manufactured the modified components. The modified system was assembled and shipped to SSC for installation in the E test area.

Figure 1-1: Modified cold ends

The installation and checkout of the modified pumping system was completed in the E1 test area at SSC. Installation occurred in the test area in late July and August of 2003. The newly modified system has not leaked and appears to provide a successful improvement to the earlier cold ends.

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PROJECT TITLE: Low Cost Servo Valves for High Performance Valve Actuation Systems.

PARTICIPATING PARTNER (COMPANY): BAFCO

TECHNICAL MONITOR: Nickey Raines

INITIATION YEAR: FY 2002

COOPERATIVE AGREEMENT: NCC13-02005

NASA FUNDING: FY02 - $35,262

FUNDING SOURCE: Innovative Technology Transfer Program (ITTP)

COMPANY CONTRIBUTION: $52,893

COMPLETION DATE: September 30, 2003

PURPOSE:

The purpose of this project was to develop a family of servo-valves that use combined best technologies (CBT) to meet the performance requirements for use in the SSC propulsion test facility.

BACKGROUND AND APPROACH:

The current Commercial Off the Shelf (COTS) electro/hydraulic servo-valves used in the test area are expensive and require a significant lead-time. There are fewer COTS servo-valves available that meet the test area requirements.

This project will develop a family of electro/hydraulic servo-valves as an alternative to these COTS servo-valves. This family of servo-valves will utilize the combined best technology (CBT) of the existing COTS valves. The new family of servo-valves will be designed to meet the performance and will have shorter lead times to manufacture at lower costs.

FY03 ACCOMPLISHMENTS:

During FY02, the requirements for the CBT servo-valves were identified and specific COTS servo-valves were procured. These valves were the MOOG Model G761-3003 and Model 207-103, the Sargent JP10-102, and the HR Textrom 27C20F.

These valves were tested on a BAFCO high performance actuator in the BAFCO laboratory. The results of the testing indicated that it was not favorable for development of a CBT valve. The final results were that there is no servo-valve currently available that meets the performance as well as the cost and schedule performance criteria. Development of a CBT would be outside the scope of this project and might not be able to meet the commercial requirement for cost and schedule.

The work was completed and the final report was submitted on September 30, 2003.

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PROJECT TITLE: Integration of Shape Optimization Tools

PARTICIPATING PARTNER (COMPANY): Optimal Solutions, Inc.

TECHNICAL MONITOR: Peter Sulyma

INITIATION YEAR: FY 2002

COOPERATIVE AGREEMENT: NCC13-02006

NASA FUNDING: FY02 - $50K

FUNDING SOURCE: Innovative Technology Transfer Program (ITTP)

COMPANY CONTRIBUTION: $55K

COMPLETION DATE: December 28, 2002

PURPOSE:

The purpose of this project is to integrate the shape optimization software, Sculptor, with the SSC CFD codes to provide an enhanced design capability at SSC.

BACKGROUND AND APPROACH:

Optimal Solutions, Inc. developed a commercial quality software package, Sculptor, which allows the user to interactively perform shape deformation and shape optimization in computational fluid dynamics (CFD) applications. Sculptor is based on the shape deformation capabilities of Arbitrary Shape Deformation (ASD) developed by Optimal Solutions. Sculptor's user interface links ASD with optimal search algorithms and the CFD code to provide a unique and innovative CFD design tool.

Prior to this project, Sculptor had only been linked to the Fluent commercial CFD code. The purpose of this project is to integrate the Sculptor capabilities with the CFD codes used at SSC. This will provide SSC with an innovative and significantly enhanced design capability to examine and optimize the design of unique shapes. This improved tool should improve the designs with reduced costs.

The project will develop the integration links between Sculptor and the SSC CFD codes. Once the appropriate interfaces have been developed and the tools are in place, the Sculptor shape optimization capabilities will be applied to a current problem of interest at SSC.

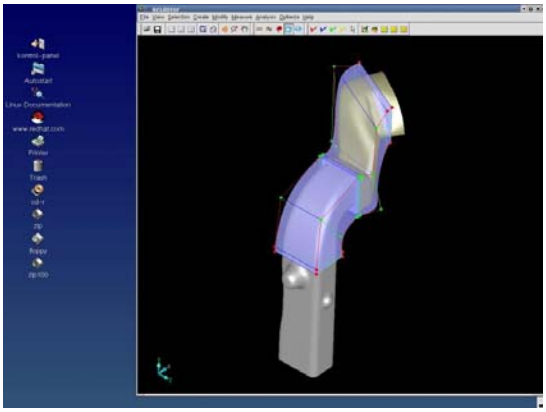

Figure 3-1: Normally Designed Duct

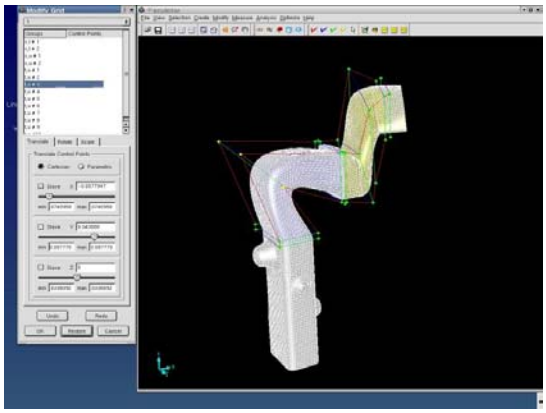

Figure 3-2: Shape Optimized Duct

FY03 ACCOMPLISHMENTS:

Three Sculptor licenses and the new Sculptor interfaces developed for integration with the SSC CFD code and the latest version of Sculptor were delivered to the Technology Development group at SSC along with tutorials for the use of Sculptor. The interface to read Plot3D files and the ability to handle Big and Little Endian files were created. Training for the use of Sculptor was provided to SSC CFD personnel.

Work on the design problem discovered that additional enhancements were required to handle the moving grids that occur within the internal shapes of valves. It was suggested that another project be negotiated to develop the tools needed to accommodate these additional design requirements.

PROJECT TITLE: Commercially Competitive Soft-Seating Relief Valve

PARTICIPATING PARTNER (COMPANY): Marotta Scientific Controls, Inc.

TECHNICAL MONITOR: Nickey Raines

INITIATION YEAR: FY 2002

COOPERATIVE AGREEMENT: NCC13-02007

NASA FUNDING: FY02 - $70K

FUNDING SOURCE: Innovative Technology Transfer Program (ITTP)

COMPANY CONTRIBUTION: $157,395

STATUS OF PROJECT AT END OF FY02: The preliminary valve design has been completed and the valves fabricated for the ASME Section VIII certification testing.

EXPECTED COMPLETION DATE: December 15, 2003

PURPOSE:

The purpose of this project was the development of a commercially viable version of the PRV95 series soft seating relief valve that is certified according to the ASTM Section VIII standards.

BACKGROUND AND APPROACH:

Under a prior SBIR contract with SSC, Marotta developed a non-impact, no-oscillation relief valve that has been designated the PRV95 series. While the valve was technically accepted, it was not considered to be commercially feasible without meeting the ASME Section VIII certifications.

Under this project, Marotta will design a low impact relief valve that is adaptable to different fluid types. This design will entail significant design modifications to optimize the manufacturability and ensure material compatibility with highly volatile line fluids at high pressure.

Marotta will undergo an ASME Quality Audit to ensure that the manufacturing and fabrication facilities comply with ASME Section VIII standards. At that point, a series of the newly designed valves will be evaluated at an ASME certified lab to obtain an ASME Section VIII certification of these valves prior to delivery to SSC.

FY03 ACCOMPLISHMENTS:

The designs of the new set of relief valves have been completed and the valves have been fabricated and tested. Due to problems associated with the valve performance during testing, an extension was requested to December 15, 2003. This was granted with an associated $5K reduction in the NASA funding.

PLANNED FUTURE WORK:

The ASME Quality Audit will be performed and the valves will be tested for conformance with the ASME standards before delivery of the valves to SSC.

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DUAL USE PROJECTS

INITIATED IN FY2001

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PROJECT TITLE: Low Cost Methods to Enhance Oxygen Compatible Stainless Steel for High Pressure Oxygen Control Valves

PARTICIPATING PARTNER (COMPANY): Dresser

TECHNICAL MONITOR: Larry DeQuay

INITIATION YEAR: FY 2001

COOPERATIVE AGREEMENT: NCC13-01005

NASA FUNDING: FY01 - $42,500

FUNDING SOURCE: Innovative Technology Transfer Program (ITTP)

COMPANY CONTRIBUTION: $42,500

COMPLETION DATE: December 20, 2002

PURPOSE:

This project examined several methods of applying a uniform coating of significant thickness that might provide adhesion to the LOX compatible stainless steel required to produce a high pressure oxygen control valve of superior technology.

BACKGROUND AND APPROACH:

There is a need for a low cost method of enhancing oxygen compatible stainless steel for high pressure oxygen control valves due to the extraordinarily large clearances required between plug and guide surfaces for valves using K500 Monel plugs and Tin Bronze bushings to compensate for thermal contraction at cryogenic temperatures. In larger valves, these gaps compromise the longevity of a balancing seal typically used to minimize the size and output thrust of actuators. This can be very costly. Large clearance gaps can also lead to fretting and vibration, especially at higher pressures. Another problem using K500 plugs is the very high tendency towards galling when run against the Tin Bronze bushing.

Stainless steel plug materials are much better choices to minimize these gaps because their physical properties are closer to Tin Bronze for thermal coefficient of expansion. However, Monel is preferred in high-pressure oxygen systems because of its resistance to combustion, especially at throttling, high velocity areas at the valve seat/seat ring/body interface.

Conceptually, applying a uniform coating of significant thickness on these interface areas would yield a valve of superior technology. The ultimate goal would be to find an economical method to effectively apply this coating.

There are a number of methods that could potentially accomplish this goal.

1. Electrochemical of electroless platings using nearly pure nickel or amorphous compounds containing nickel and phosphorous.
2. Plasma transferred arc welding of the parts depositing a metallurgically bonded coating approximately 3 to 4 mm thick for line of sight parts. Monel powders should be the feasible candidate.
3. Laser deposition is a process where an insert of some defined shape is metallurgically fused by the laser to the substrate. The insert would be some Monel alloy.
4. Mat brazing is a process where a mat of material containing a brazing alloy and the desired overlay material is first glued and brazed to the substrate at temperatures in the 1950 F range. The brazing alloy is usually Ni-Cr-B.
5. Electro Spark Deposition (ESD) which is a proprietary method where a coating is deposited using a rod of small diameter to provide a metallurgical bond between the substrate and the coating.

The plan was to use coupons of a base material such as 300 Series Stainless Steel and perform the selected coating methods and test the coupons for thickness, adhesion, metallurgy and hardness.

FY03 ACCOMPLISHMENTS:

Coupons were prepared and coated using the different coating methods. The coupons were tested. The results indicated that the Electro Spark Alloying process is exceedingly expensive and impractical for coating large complicated areas. The electroless nickel plating (ENP) using K500 Monel performed the best overall, but the expense of using monel is excessive although this cost might be mitigated due to increased life and reliability of the valve parts. It was recommended that additional testing be performed to better characterize the performance and limitations of the ENP parts.

SMALL BUSINESS INNOVATION RESEARCH

(SBIR)

CONTRACTS

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NASA Stennis Space Center
Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Contracts Through FY03

Contract Title/ Small Business Partner	SBIR/STTR Program Year	Total Contract Value ($K)	Project Status	Expected Completion Date (Mo/Yr)
SBIR Contracts Initiated in 2002				
Propulsion Test Directorate				
Multi-disciplinary Multiphase Flow Analyzer *Engineering Sciences, Inc.*	2001	600	Open	September 2004
Intelligent Wireless Sensor Communication for Health Monitoring *Intelligent Automation, Inc.*	2001	589	Open	September 2004
Acoustic Prediction/Measurement Tool *AI Signal Research, Inc.*	2000	599	Open	January 2004
Low Cost Engine Test Stand for 500 lb Thrust Class Engines *AJT and Associates, Inc.*	2000	600	Completed June 18, 2003	--
Earth Science Applications Directorate				
Hyperspectral Remote Sensing Processing Incorporating Coremicro IMU and GPS Data *American GNC Corporation*	2001	599	Open	September 2004
Web Based Hurricane Storm Surge and Flood Forecasting Using Optimized IFSAR Bald Earth DEMs *WorldWinds*	2001	600	Open	September 2004
An In Situ, Biogeochemical Sensor Using Excitation-Emission Matrix Fluorometry *WET Labs, Inc.*	2001	600	Open	September 2004
Atmospheric Correction of Remote Imagery Using Ground-based Radiometers *Spectral Sciences, Inc*	2001	600	Open	September 2004
An Integrated Optical System for Synoptic Remote Sensing Validation: The DOLPHIN *WET Labs, Inc*	2000	600	Open	January 2004
Low Cost True 3-D Virtual Reality System for Scientific Data Visualization *Physical Optics Corporation*	2000	600	Open	February 2004
An Advanced Multispectral Imager for Marine and Coastal Remote Sensing *Duncan Technologies, Inc.*	2000	597	Open	January 2004

NASA Stennis Space Center
Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Contracts Through FY03

Contract Title/ Small Business Partner	SBIR/STTR Program Year	Total Contract Value ($K)	Project Status	Expected Completion Date (Mo/Yr)
SBIR Contracts Initiated in 2001				
Propulsion Test Directorate				
Unified Test Stand Design and Environmental Impact Model *Plumetech*	1999	600	Completed July 16, 2003	--
Earth Science Applications Directorate				
Profiling Instrument for Analysis of Key Redox Species, pH & Temperature in Wetlands, Marine, and Planetary Environments *Analytical Instrument Systems, Inc.*	1999	600	Completed May 31, 2003	--
Tunable Bandwidth Filter System for Hyperspectral Sensor Technology *Physical Optics Corporation*	1999	600	Completed May 17, 2003	--
A Novel Volumetric 3D Display for Satellite Data Visualization *Genex Technologies, Inc.*	1999	600	Completed Aug 31, 2003	--
STTR Contracts Initiated in FY02				
Propulsion Test Directorate				
Nanostructured High Temperature Optical Filters for Protection of Spectroscopic Instrumentation *NanoSonic, Inc. with Virginia Tech*	2000	500	Open	May 2004

SBIR PHASE II CONTRACTS

INITIATED IN FY2002

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PROPULSION TEST DIRECTORATE

SBIR PHASE II CONTRACTS

INITIATED IN FY2002

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PROJECT TITLE: Multi-disciplinary Multiphase Flow Analyzer

PARTICIPATING PARTNER (COMPANY): Engineering Sciences, Inc.

TECHNICAL MONITOR: Peter Sulyma

INITIATION YEAR: FY 2002

SBIR CONTRACT: NAS13-02052

FUNDING: $599,998.00

STATUS OF PROJECT AT END OF FY03: Objectives of project met to date.

EXPECTED COMPLETION DATE: September 17, 2004

PURPOSE:

The purpose of this contract is to develop a set of models that simulate various multiphase flow situations and that will provide an analytical tool when evaluating those situations.

BACKGROUND AND APPROACH:

Simulation methods will be used to develop models that describe complex, multiphase, flow phenomena including cavitation, cryogenic fluid management, coolant spray and impinging jets. Accurately described real fluid properties will be employed in an integrated simulation tool that involves thermodynamics and fluid dynamics models to describe local vaporization phenomena in liquid rocket engine propellant delivery systems, propellant tanks, and test facilities. Bubbly flows will be simulated with a homogeneous or heterogeneous mixture model that emphasizes the computational efficiency and modeling effectiveness. Cavitating venturi meter and pump flows, cryogenic propellant tank filling processes and evaporating cooling jets can be analyzed with this methodology. More accurate propellant metering, oscillatory inlet flow characterization and accurate description of the thermodynamics environment of cryogenic fluid systems will be examined in this project.

Other complex flows in propellant delivery systems or coolant flows in test facilities will also be amenable to analysis with the final tool.

FY03 ACCOMPLISHMENTS:

A real fluid property model using lookup tables was developed and tested. Capabilities for solving flow problems at very high altitudes were developed to support the Space Shuttle Columbia investigation effort.

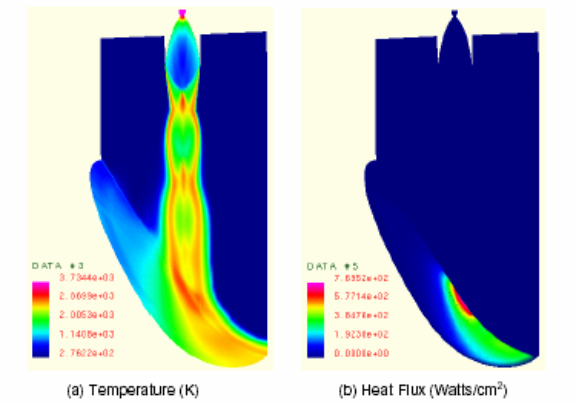

Fig 1.1 Flame bucket flow field solution without cooling water injection.

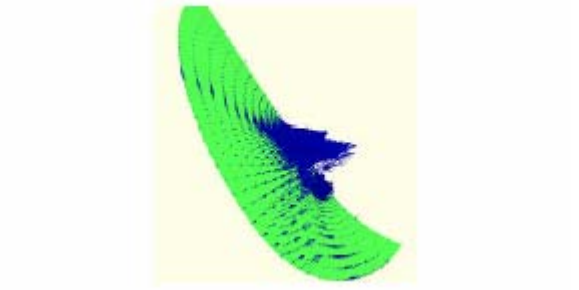

Fig 1.2 Cooling water velocity vectors on the deflector plate.

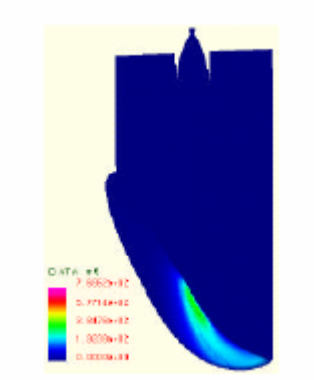

Fig 1.3 Preliminary wall heat flux solution with cooling water.

PLANNED FUTURE WORK:

Continued studies will be done on the LOX tank benchmark data case and pressurization with real fluid model and injection of nitrogen. Computations of water cooling of test stand flame bucket with cooling water injection will be continued. New test cases for the inlet/outlet pressure boundary conditions will be conducted.

PROJECT TITLE: Intelligent Wireless Sensor Communication for Health Monitoring

PARTICIPATING PARTNER (COMPANY): Intelligent Automation, Inc.

TECHNICAL MONITOR: Wanda Solano

INITIATION YEAR: FY 2002

SBIR CONTRACT: NAS13-02053

FUNDING: $589,438

STATUS OF PROJECT AT END OF FY03: Objectives of project met to date.

EXPECTED COMPLETION DATE: September 24, 2004

PURPOSE:

The purpose of this project is to develop a low-cost high data rate wireless sensor network for use in rocket propulsion test facility.

BACKGROUND AND APPROACH:

The objective of this project is the design of a low-cost high data rate wireless sensor network using the Time Modulated Ultra-wideband (TM-UWB) technology for rocket engine test facilities, such as Stennis Space Center's propulsion system test stands. Currently, wired sensors are used for rocket engine tests. The sensor configurations always need to be changed for testing different rocket engines. These changes increase testing cost and time. With wireless sensor networks, this cost will be eliminated and the test can be prepared much quicker than it is now. TM-UWB is the key to implementing wireless sensor networks. At this time, there is no other wireless technology that can achieve the high data rate and high channel capacity required for rocket engine testing.

The proposed wireless sensor network consists of a network controller and many smart sensor nodes. Each smart sensor node is equipped with a TM-UWB transmitter, a narrow band receiver, and a multiplexed data acquisition system. The UWB transmitter is used to transmit the digitized sensor data to the network controller at a data rate of at least 1.25Mbps. The narrow band receiver is used to receive control and configuration commands from the network controller, which will be very infrequent and can be very low data rate. This receiver is very low cost. There are no fundamental technical reasons that the UWB cannot also be used for receiving control and configuration commands. This can be done cost effectively once UWB radios are mass-produced, and the cost comes down. For the prototype, the UWB will only be used for the high bandwidth communication from the sensors to the data storage system.

FY03 ACCOMPLISHMENTS:

Design work was done for a miniaturized ultra-wideband radio, called the "Cube." The Cube radio will support at least a raw rate of 9.6 megabytes per second over a 20-foot distance. An embedded RS232-to-ultra wideband bridge was developed to replace hard wire RS232 or RS485 cables without modifying the smart sensors.

PLANNED FUTURE WORK:

Conduct initial development of the P210 Cube Radio assembly. Develop the Kernel software.

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PROJECT TITLE: Acoustic Prediction/Measurement Tool

PARTICIPATING PARTNER (COMPANY): AI Signal Research, Inc.

TECHNICAL MONITOR: Peter Sulyma

INITIATION YEAR: FY 2002

SBIR CONTRACT: NAS13-02018

FUNDING: $599,060.25

STATUS OF PROJECT AT END OF FY03: The prototype was fabricated and tested.

EXPECTED COMPLETION DATE: January 23, 2004

PURPOSE:

The purpose of this project is to develop an Acoustic Prediction/Measurement Tool (APMT) that will integrate the analytical and experimental techniques when performing a rocket plume investigation.

BACKGROUND AND APPROACH:

The Acoustic Prediction/Measurement Tool (APMT) is an innovative approach to integrate both analytical and experimental techniques when performing a rocket-plume investigation. APMT provides an acoustician access to both experimental data and analytical predictions that are derived from empirical models and a database that includes pertinent extensive Computational Fluid Dynamics (CFD) data. Before, during, or after measurements are recorded, the APMT generates additional acoustic spectra at locations that are not part of the experimental setup. Because the prediction solutions are obtained from a detailed, refined computational model and empirical analysis, the predicted values are very accurate. This accuracy leads to improved quality of the experimental data by disclosing measurement anomalies during data acquisition. The analytical prediction model, once calibrated, can predict acoustic spectra during a static test or launch at various locations on and around the spacecraft, ground support equipment, or support facilities. These predictions can then be used for structural dynamic analysis to evaluate effects of the plume acoustical environment. APMT includes several input parameters that can be varied to simulate or eliminate perturbations in the experiment. This flexibility helps determine the sensitivity of the measured results to various parameters.

FY03 ACCOMPLISHMENTS:

A test version of the measurement subsystem was assembled and tested. It was modified to install a wireless network to control operation of the field stations from the control server. A directional antenna was designed to provide increased signal strength.

PLANNED FUTURE WORK:

This contract will close in January 2004.

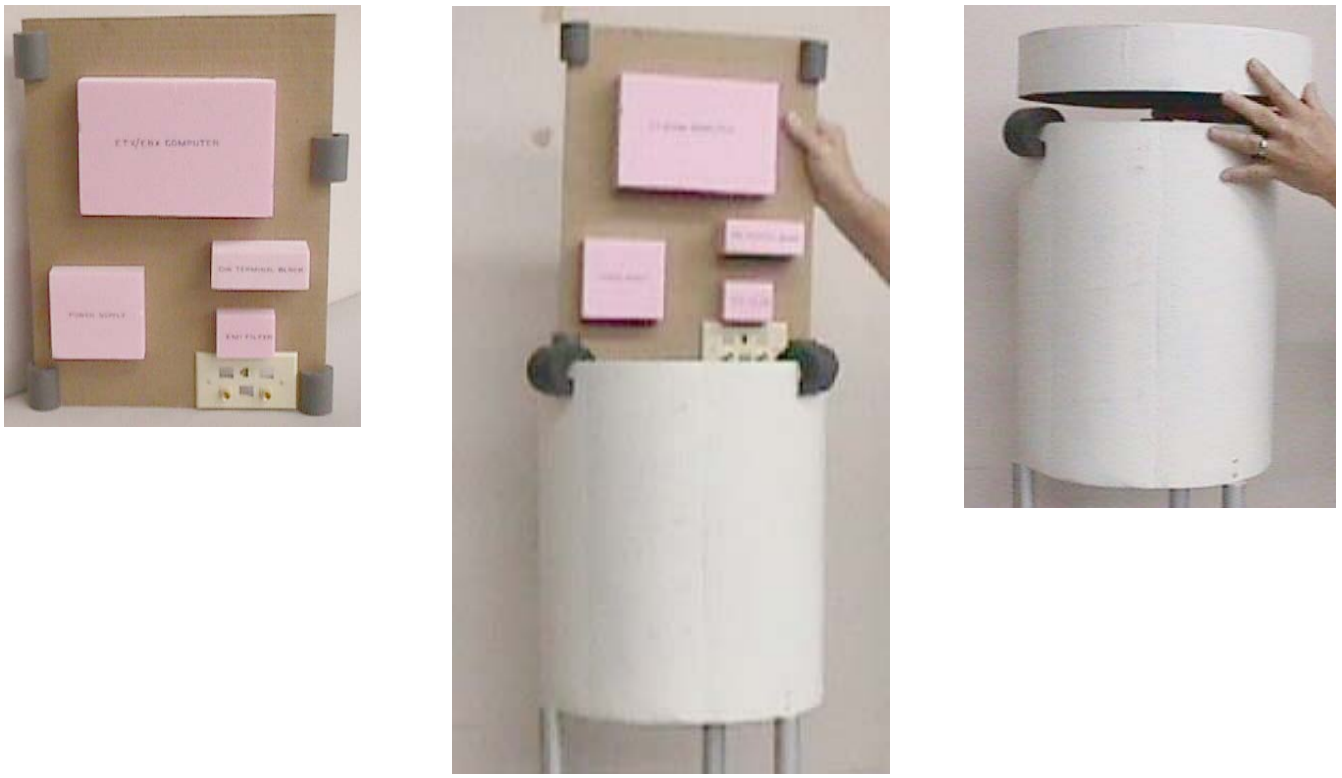

Figure 15-1: Photographic Image Matrix of the APMT Environmental Enclosure Mockup. These views show the arrangement of electronic subassemblies on the mounting panel and the exterior configuration of the enclosure.

PROJECT TITLE: Low Cost Engine Test Stand for 500 lb Thrust Class Engines

PARTICIPATING PARTNER (COMPANY): AJT and Associates, Inc

TECHNICAL MONITOR: Robert Field

INITIATION YEAR: FY 2002

SBIR CONTRACT: NAS13-02021

FUNDING: $599,900.00

COMPLETION DATE: June 18, 2003

PURPOSE:

The purpose of this contract is to design, fabricate and test a low-cost engine test stand with quick transition capability and autonomous operations for testing small thrust engines.

BACKGROUND AND APPROACH:

The operational requirements for the preparation of a test facility for the next test article represents a significant cost to a test program. The project is intended to provide a low-cost engine stand system for small thrust engines that use gaseous, liquid, or cryogenic fluids. This test stand system will incorporate automated propellant transfer, leak testing, and system purge operations. The rocket engine test articles will be mounted onto an instrumented plate that provides the thrust measurement that is then attached to a cart. The cart incorporates four propellant quick disconnects (QD). The test article manufacturers will provide the plumbing interfaces required to mate to the appropriate QD. The cart is designed to be placed on alignment rails and attached to a ground side frame with four QDs that match the cart. The cart will be manually pushed into place and latched. This eliminates the requirement for any reconfiguration of the ground side (test facility) propellant system. A PLC controller will allow the operator to monitor, control and program operational sequences for the propellant system.

This concept will reduce the time and costs typically associated with testing different engines on the same test stand. This concept should be scalable to other, larger engine test facilities.

FY03 ACCOMPLISHMENTS:

AJT & Associates, Inc. successfully designed, fabricated, and tested a prototype small engine test stand capable of testing rocket engines utilizing RP-1 fuel and gaseous oxygen. The test stand has been delivered. With improvements developed with the consultation with Stennis scientists, the apparatus is superior to the original concept from the Phase I SBIR report.

Contract was completed and final report received on June 18, 2003.

Figure 1: Quick Disconnect Small Engine Test Stand

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EARTH SCIENCE APPLICATIONS DIRECTORATE

SBIR PHASE II CONTRACTS

INITIATED IN FY2002

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PROJECT TITLE: Hyperspectral Remote Sensing Processing Incorporating Coremicro IMU and GPS Data

PARTICIPATING PARTNER (COMPANY): American GNC Corporation

TECHNICAL MONITOR: Bruce Spiering

INITIATION YEAR: FY 2002

SBIR CONTRACT: NAS13-02051

FUNDING: $598,936

STATUS OF PROJECT AT END OF FY03: Objectives of project met to date.

EXPECTED COMPLETION DATE: September 26, 2004

PURPOSE:

The purpose of this contract was to develop a coremicro IMU and GPS hyperspectral remote sensing processing system**.**

BACKGROUND AND APPROACH:

The objective of this project is to develop an innovative AGNC-2000 CMIMU coremicro IMU/GPS based hyperspectral remote sensing processing system. This design uses the AGNC-2000 CMIMU (coremicro IMU), AGNC-coremicro-UNCU (Universal Navigation Control Unit) and AGNC-coremicro-UNCUN1 with GPS Chipset to provide highly accurate positioning and attitude determination. A spectral signature is a strong function of the underlying materials present within a pixel subtense, the sensor parameters, atmospheric effects and spatial/temporal events that can vary with the characteristics of the underlying materials. The AGNC-2000 CMIMU spectral radiometer registration techniques provide an efficient way to register the image collected at different times of the day and different seasons, so as to enhance the automated image processing system.

FY03 ACCOMPLISHMENTS:

Work was conducted on the development of a demonstration prototype of an advanced GPS/IMU-based pointing and stabilization system for a hyperspectral remote sensing system, based on the American GNC Coremicro UNCUN1 Universal Navigation and Control Unit with GPS Chipset, American GNC Coremicro PS Pointing and Stabilization Mechanism, and advanced GPS/IMU Integration techniques.

PLANNED FUTURE WORK:

Efforts will continue on the development of a demonstration prototype of the advanced integrated GPS/IMU-based pointing and stabilization system for a hyperspectral remote sensing system. The refinement of GPS attitude determination, which employs American GNC's robust filtering techniques, will be further modeled and tested.

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PROJECT TITLE: Web Based Hurricane Storm Surge and Flood Forecasting Using Optimized IFSAR Bald Earth DEMs

PARTICIPATING PARTNER (COMPANY): WorldWinds

TECHNICAL MONITOR: Tom Stanley

INITIATION YEAR: FY 2002

SBIR CONTRACT: NAS13-02054

FUNDING: **$**599,995.54

STATUS OF PROJECT AT END OF FY03: Objectives of project met to date.

EXPECTED COMPLETION DATE: September 29, 2004

PURPOSE:

The purpose of this contract is to develop a web based hurricane and flood surge models to provide assistance for emergency management and planning.

BACKGROUND AND APPROACH:

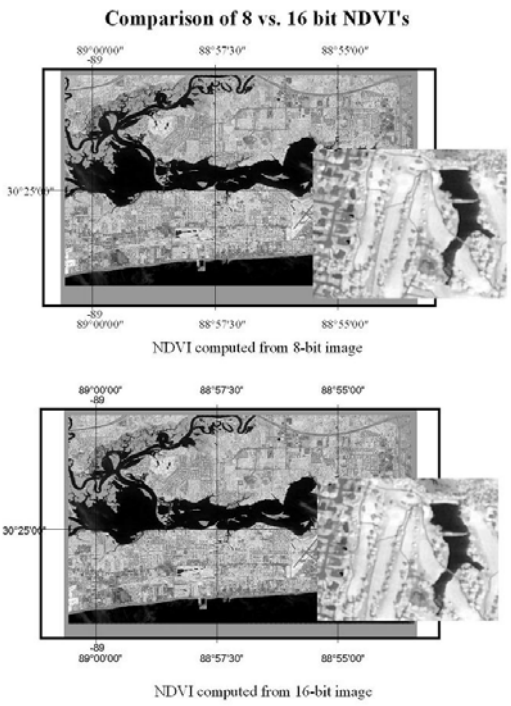
The Gulf Coast shoreline is a region particularly vulnerable to hurricane landfall due to the shallow continental shelf and high tropical cyclone activity. Not only does this present emergency preparedness challenges for state and local officials, development has altered the land morphology which may result in unexpected flooding from heavy rainfall events and hurricane storm surges. As a result of these uncertainties, emergency preparedness procedures tend to be very conservative, requiring widespread evacuations. At least $300,000 per day in business losses are incurred for hurricane preparation costs and lost revenue for every mile of coastline evacuated.

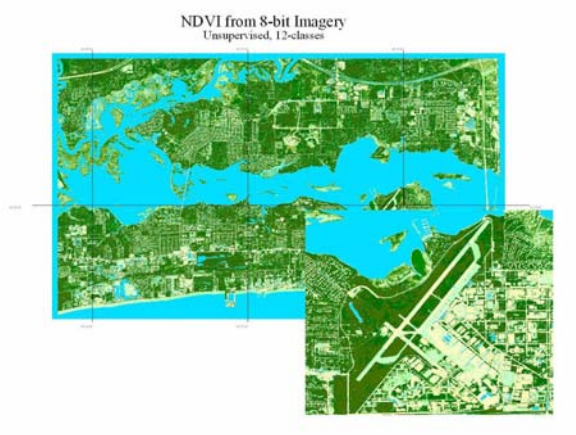
Advances in remote sensing over the past decade have the potential for defining high precision SEMs. One of these techniques uses Interferometric Synthetic Aperture Radar to generate high-resolution topographic maps; when merged with traditional USGS topographic information, an accurate “bald earth” map results. This high-resolution topographic data will give unprecedented accuracy to flooding forecasts, potentially saving many lives.

FY03 ACCOMPLISHMENTS:

The WorldWinds Variational Analysis Code was generally modified to enhance user reliability. New validation sources were used to fine tune the variational analysis software. The pattern recognition scheme to detect and subsequently remove bridges and piers was optimized. Implementation of the flood modeling portion of the project was started. Work on storm surge modeling was also started.

Imagery was acquired for use in development of NDVI's. The data, 11 and 16 bit multi spectral imagery from Digital Globe was processed to produce NDVI's for Biloxi Bay area. The resulting images were compared for similarity and were determined to be nearly identical. The NDVI's were then classified using unsupervised classification techniques. The Classified NDVI's were then exported to a format conducive to statistical analysis. Sample imagery is shown below.





PLANNED FUTURE WORK:

The Phase II contract will continue the work on the variation analysis with validation and verification using additional datasets. The flood mapping and a storm surge atlas will be developed and validated. The web will be developed for access to the flood and storm surge atlases.

PROJECT TITLE: An In Situ, Biogeochemical Sensor Using Excitation-Emission Matrix Fluorometry

PARTICIPATING PARTNER (COMPANY): WET Labs, Inc.

TECHNICAL MONITOR: Richard Miller

INITIATION YEAR: FY 2002

SBIR CONTRACT: NAS13-02055

FUNDING: **$**599,999.13

STATUS OF PROJECT AT END OF FY03: Objectives of project met to date

EXPECTED COMPLETION DATE: September 23, 2004

PURPOSE:

The purpose of this contract is to develop a novel aquatic biogeochemical sensor (XMF) using excitation-emission fluorometry to provide in-situ data and measurements.

BACKGROUND AND APPROACH:

This contract will develop a novel aquatic in-situ biogeochemical sensor, termed the XMF. This sensor will use excitation-emission matrix fluorometry to enable in-situ simultaneous detection and effective analytical separation of individual biogeochemical components present in seawater including humic substances, hydrocarbons, proteins, wastewater/sewage, and other natural and anthropogenic substances. Excitation-emission matrices (EEMs) will be measured at sampling rates on the order of a second. No scanning of the monochromators, in fact, no moving parts whatsoever, will be required. The technology making this possible is Double Dispersion Imaging (DDI). The sensor software will incorporate real-time, automated quantum corrections and 2-D mixing analysis techniques. The design goals will emphasize portability, compactness, ruggedness, and enabling flexible deployment through features such as variable sampling rates and memory storage capabilities. No current sensor for oceanographic deployment has these characteristics.

FY03 ACCOMPLISHMENTS:

A high resolution spectrophotometer, using the scanning source spectrometer electronics developed under this contract, was tested and modified. The scanning source spectrometer was also incorporated into the benchtop model for tests. A new hyperspectral absorption and attenuation meter was developed.

PLANNED FUTURE WORK:

WET Labs will identify and quantify fluorophore components (such as humic acid, fulvic acid, and proteins) in natural samples using EEMs and a 2-D matrix deconvolution technique called PARAFAC.

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PROJECT TITLE: Atmospheric Correction of Remote Imagery Using Ground-based Radiometers

PARTICIPATING PARTNER (COMPANY): Spectral Sciences, Inc

TECHNICAL MONITOR: Bruce Spiering

INITIATION YEAR: FY 2002

SBIR CONTRACT: NAS13-02056

FUNDING: $599,998.89

STATUS OF PROJECT AT END OF FY03: Objectives of project met to date

EXPECTED COMPLETION DATE: September 26, 2004

PURPOSE:

The purpose of this contract is the development of data analysis software tools for ground based radiometers to facilitate improved atmospheric correction of remotely sensed hyperspectral and multispectral imagery of the coastal zone.

BACKGROUND AND APPROACH:

This contract will develop data analysis software tools for ground-based radiometers to facilitate improved atmospheric correction of remotely sensed hyperspectral and multispectral imagery (HSI and MSI) of the coastal zone. The atmospheric variables needed for the correction (water vapor and ozone column amounts, and aerosol optical properties) may be retrieved from a radiometer located in the vicinity of the remotely sensed scene of interest. The radiometer retrieved information will significantly improve atmospheric correction accuracy, most notably by taking the guesswork out of selecting a suitable aerosol model.

During the Phase I contract, MODTRAN based algorithms and tools were developed for analyzing shadow band radiometer measurements and porting the results to the FLAASH atmospheric correction algorithm. There was also demonstration of radiometer data conditioning for continuous daytime retrievals, an aerosol parameterization that extrapolates well into the IR, analysis of radiometer data, and demonstration of complete, end-to-end atmospheric retrieval and correction using simulated radiometer and HSI data.

FY03 ACCOMPLISHMENTS:

Data buffering and calibration tools have been developed for inputting radiometer data from formatted files in a flexible manner. Automated filtering of the radiometer data and data calibration tools has been developed. Software was developed to export the data required for the atmospheric retrieval algorithm.

PLANNED FUTURE WORK:

Spectral Sciences will continue to analyze field data (taken at Davis, CA) using FLAASH and the concurrent USDA Shadow Band Radiometer data. They will use the new MISAR atmospheric data retrieval routine. Spectral Sciences will also begin implementing the interface for inputting the TRAC/MISAR – received atmospheric parameters into the FLAASH atmospheric correction code.

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PROJECT TITLE: An Integrated Optical System for Synoptic Remote Sensing Validation: The DOLPHIN

PARTICIPATING PARTNER (COMPANY): WET (Western Environmental Technology) Labs, Inc.

TECHNICAL MONITOR: Rick Miller

INITIATION YEAR: FY 2002

SBIR CONTRACT: NAS13-02019

FUNDING: $599,999.96

STATUS OF PROJECT AT END OF FY03: A 'bare bones' DOLPHIN system was assembled and field tests were conducted.

EXPECTED COMPLETION DATE: January 28, 2004

PURPOSE:

The purpose of this contract is to develop a compact, towed sensor system to provide rapid optical surveying and hydrographic sensing.

BACKGROUND AND APPROACH:

The Diving Optical Profiler and High Speed Integration Network (DOLPHIN) is a compact, towed body, integrated sensor system designed for rapid optical surveying and real-time realization of advanced data products. The key DOLPHIN system components are a towed optical and hydrographic instrumentation package, a real-time automated data integration, processing and visualization network, and a discrete sampling system designed to continuously pump water from the towed package to the boat for analysis. The goal of the system is to provide optical data sets ideally suited for fulfilling calibration and validation needs for NASA remote sensing application, including aircraft-based and future space-based lidar technologies.

FY03 ACCOMPLISHMENTS:

A second DOLPHIN system was built for delivery to the Stennis Space Center. Improvements were made to the graphical user interface to make it more intuitive to the user. Deployment of the second DOLPHIN system was filmed by Sea Sciences to be shown at the Oceans 2003 meeting in San Diego in September.

PLANNED FUTURE WORK:

This contract will close in January 2004.

Fig. 1.1 – Deploying the DOLPHIN

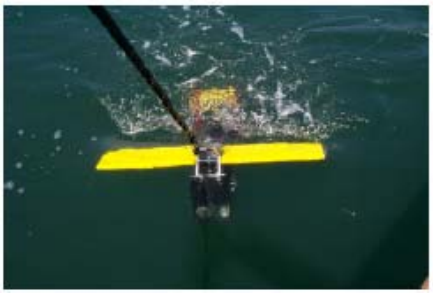

Fig. 1.2: The DOLPHIN vehicle surfacing after deployment

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PROJECT TITLE: Low Cost True 3-D Virtual Reality System for Scientific Data Visualization

PARTICIPATING PARTNER (COMPANY): Physical Optics Corporation

TECHNICAL MONITOR: Vicki Zanzoni

INITIATION YEAR: FY 2002

SBIR CONTRACT: NAS13-02020

FUNDING: $599,989.31

STATUS OF PROJECT AT END OF FY03: Objectives of project met to date

EXPECTED COMPLETION DATE: February 4, 2004

PURPOSE:

The purpose of this contract is to develop a Dynamic Time Multiplexed Holographic (DTMH) System that will provide a low cost 3-D virtual reality system for the visualization of scientific data such as remotely sensed information.

BACKGROUND AND APPROACH:

The Dynamic Time Multiplexed Holographic (DTMH) System is base on new 3-D screens with dynamic time multiplexing and unique playback geometry, uniquely integrated with new multi-channel illuminators. POC has a proprietary holographic screen recording geometry optimized for off-axis image projection, so that the display can be in any geometry from vertical to horizontal. DTMH offers full look-around, with visual channels spatially distributed around the viewer, and high image quality (up to 1600 x 1200 pixels for each visual channel). POC had earlier developed display technology for either horizontal or vertical screen geometry and is now developing a flexible dynamic screen geometry with the preferred position near 45 degrees to visualize objects below the line of sight as well as between the screen and viewer. As a result, high quality 3-D objects float over the screen surface in a geometric form for the viewer (between the screen and viewer in vertical geometry).

FY03 ACCOMPLISHMENTS:

Stability of the fringe stabilization procedure has been refined. Improvements were made to the geometry for the multi-channel holographic screens. A three-node Linux cluster system for real-time, multi-channel rendering was developed. A ray tracing system was developed to predict the pattern of reconstruction of the holographic optical element. True 3-D Virtual Reality System optimization is in progress.

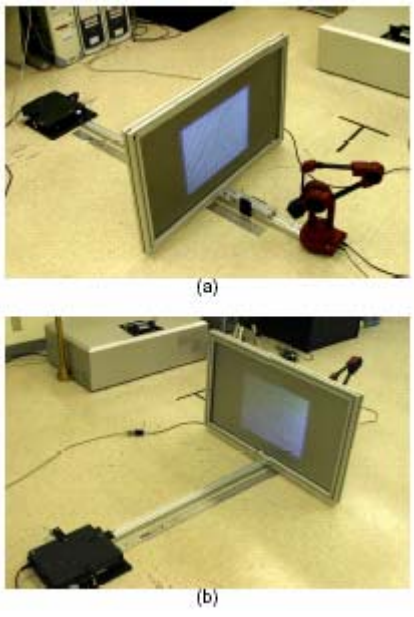
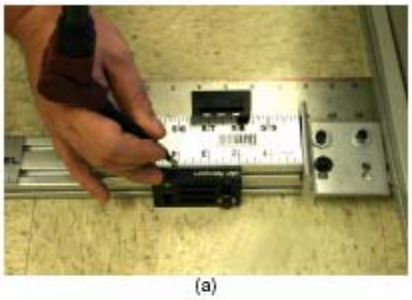
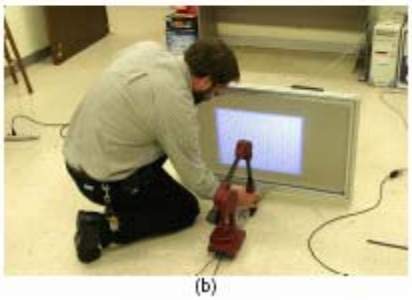


Fig 1.1 - Initial digitizing arm calibration rig (a) Front view (b) Rear view.

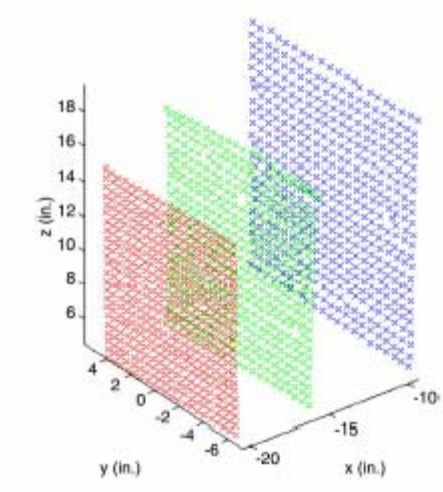


(a)



(b)

Measurement according to the steel ruler: (a) Closeup (b) Sampling.



Grid measurements plotted.

PLANNED FUTURE WORK:

Work will continue on the holographic recording setup and other system hardware components as well as the development of the system software. The DTMH prototype will be integrated and optimized before delivery to SSC.

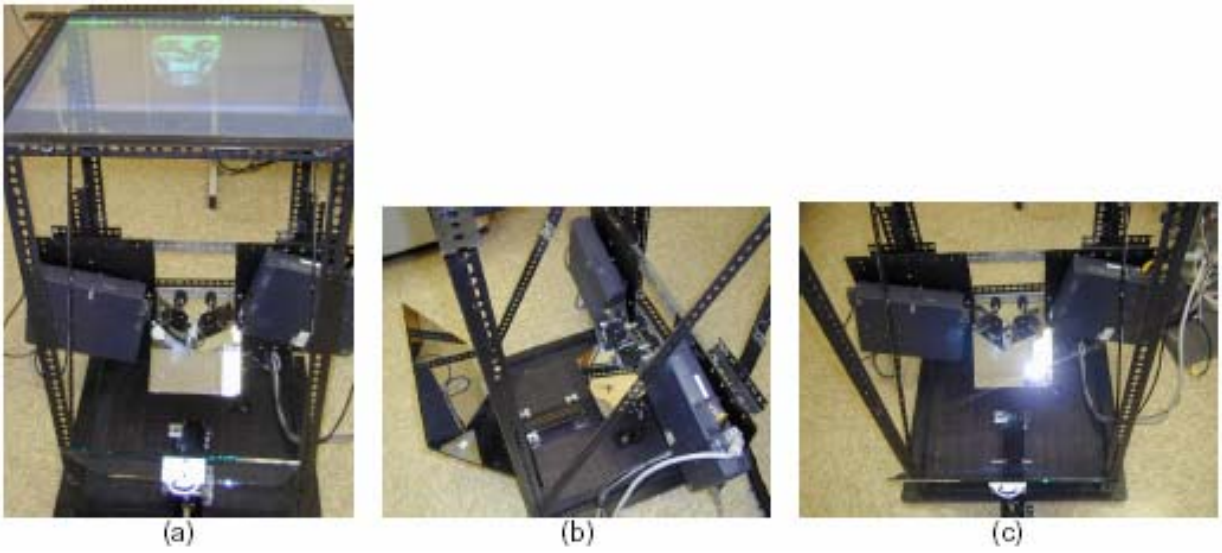


Figure 17-2: (a) Hologram evaluation rig in use; (b) and (c): detail of optics (note extensive use of micropositioners, allowing for a variety of configurations to emulate display geometries).

PROJECT TITLE: An Advanced Multispectral Imager for Marine and Coastal Remote Sensing

PARTICIPATING PARTNER (COMPANY): Duncan Technologies, Inc.

TECHNICAL MONITOR: Bruce Spiering

INITIATION YEAR: FY 2002

SBIR CONTRACT: NAS13-02022

FUNDING: $596,916.00

STATUS OF PROJECT AT END OF FY03: Project delayed due to company merger.

EXPECTED COMPLETION DATE: January 30, 2004

PURPOSE:

The purpose of this contract is to develop a robust and economical aerial imaging system for use in marine and coastal imaging based on Hyperspectral optical imaging technology used in their previous camera systems.

BACKGROUND AND APPROACH:

Management of the Earth's delicate marine environment is becoming a critical aspect in maintaining a healthy planet. While mankind's presence and activities have a continuing impact on all of our oceans, nowhere is the interaction more delicate than at the complex interface between land and water in our coastal ecosystems.

The objective of this project is the development of a tool specifically designed to provide effective characterization and monitoring of these environments. This sensor will provide five bands of spectral imagery at wavelengths ranging from the ultraviolet to near infrared along with a thermal band. Imagery will be acquired with a compact, portable sensor that provides direct acquisition of pixel-registered, geo-referenced imagery at resolutions of 1900 x 1080 or 1600 x 1200 per band. The system will be configured in a compact, portable package that can be implemented on a variety of platforms. Several features will be incorporated to provide high sensitivity and a large dynamic range. The sensor will be calibrated and characterized to enable conversion of acquired digital numbers to true reflectance data. Interfaces to the front-end and back-end software tools that are the heart of the practical applications of remotely sensed data will be developed and integrated into the system.

FY03 ACCOMPLISHMENTS:

This company was bought by Redlake, MASD. The SBIR contract was novated. The control console was successfully brought to an operational state. An IEEE-1394 interface for camera control and acquisition was implemented. Support for the 4020 imaging head running in single tap mode was implemented.

The MegaPlus II product suite includes the sensor modules in Table I. The interline sensors offer electronic shuttering, antiblooming, and large electron well capacity with low readout noise for excellent dynamic range. Interline sensors are the preferred choice for many applications. Full frame sensors are used in applications that require very high quantum efficiency or superior near IR response.

Table 1. MegaPlus II Sensor Modules

Image Head Model	Resolution (H x V)	Pixel Size (um)	Max. Frame Rate (fps)	Color/ Mono	Horizontal Dimension (mm)	Vertical Dimension (mm)	Dynamic Range	Well Capacity (e)
Interline CCD Tethered head Modules								
ES2001	1600 x 1200	7.4	30	RGB/Mono	11.8	8.9	60dB	40,000
ES2093	1920 x 1080	7.4	30	RGB/Mono	14.2	8	60dB	40,000
MS2093-XCCD	1920x1080	7.4	30	RGB/CIR	14.2	8	60dB	40,000
ES4020	2048 x 2048	7.4	15	RGB/Mono	15.2	15.2	70dB	40,000
ES11000	4008 X 2672	9	5	RGB/Mono	37.2	25.7	66dB	60,000
Full Frame CCD Tethered Head Modules								
ES1603	1536 x 1024	9		Mono	13.8	9.2	TBD	85,000
ES3200	2184 x 1472	6.8		Mono	14.8	10.0	78dB	50,000

Fig 1.1 - Specifications of the sensor modules

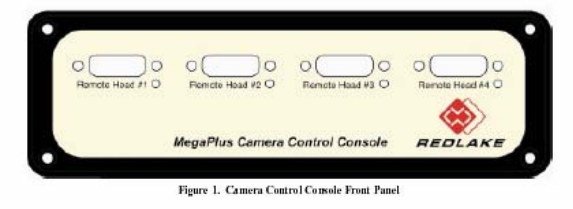


Figure 1. Camera Control Console Front Panel

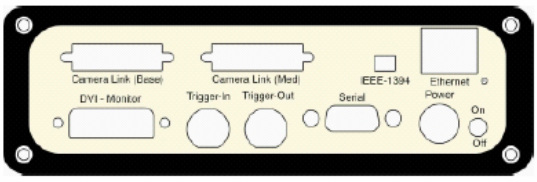


Figure 2. Camera Control Console Rear Panel

PLANNED FUTURE WORK:

Due to the contract novation, this project is behind schedule for implementation of the remote sensing aspects of the system. A no-cost contract extension will be requested, in order to allow Redlake MASD to complete this project, which was originally scheduled for completion in January 2004.

SBIR PHASE II CONTRACTS

INITIATED IN FY2001

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PROPULSION TEST DIRECTORATE

SBIR PHASE II CONTRACTS

INITIATED IN FY2001

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PROJECT TITLE: Unified Test Stand Design and Environmental Impact Model

PARTICIPATING PARTNER (COMPANY): Plumetech

TECHNICAL MONITOR: Peter Sulyma

INITIATION YEAR: FY 2001

SBIR CONTRACT: NAS13-01006

FUNDING: **$**600,000.00

COMPLETION DATE: July 16, 2003

PURPOSE:

The purpose of this contract was to develop software that models the rocket engine test stand environmental impacts to provide an analytical tool for assessing environmental impacts of different test program.

BACKGROUND AND APPROACH:

The design of propulsion test stands and impact of new construction on existing stands and surrounding environments requires the calculation of exhaust plume environments (pressure, radiation and convective heating, and acoustics). The current process is very labor-intensive and requires the use of a multitude of individual non-interacting models, where each model requires an experienced analyst. Plumetech (PT) proposes to develop a PC Windows-based software package that integrates Artificial (AI) techniques and architectural system designs, a CAD geometry module, and graphical inputs with the individual components of plume modeling and plume-induced environments. The software package will be able to determine the subsequent impact on the design, the environment, and the hardware in the area surrounding the stand. With NASA becoming more directly involved in test stand design and testing of propulsion systems, it is essential that NASA have the ability to determine the impact of the environments on test/launch stands. Using this software package, development of test stand and launch complex design and evaluation will be accomplished more accurately, in less time, and at significantly less cost than is possible with any currently existing methods.

FY03 ACCOMPLISHMENTS:

Completed Geometry Package development. Implemented the PLIMP 3-D Geometry/ Flowfield/ Convective Heating Model. Developed the Acoustics Module. Developed the Thermal Analyzer Module. Developed the 3-D Geometry Radiation Module. Developed the Water Cooling Module. Developed the Splash and Recirculating Flow Module. Developed the RP1/LOX Soot Concentration Module. Developed the Test Stand Design and Environmental Tool Module. Integrated and evaluated the modules.

Contract was completed on July 16, 2003. A New Technology Report, SSC-00204 titled ‘Unified Test Stand and Environmental Impact Model,’ was submitted.

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EARTH SCIENCE APPLICATIONS DIRECTORATE

SBIR PHASE II CONTRACTS

INITIATED IN FY2001

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PROJECT TITLE: Profiling Instrument for Analysis of Key Redox Species, pH & Temperature in Wetlands, Marine, and Planetary Environments

PARTICIPATING PARTNER (COMPANY): Analytical Instrument Systems. Inc.

TECHNICAL MONITOR: Dr. Rick Miller

INITIATION YEAR: FY 2001

SBIR CONTRACT: NAS13-01004

FUNDING: $599,972.80

COMPLETION DATE: May 31, 2003

PURPOSE:

The purpose of this contract was to develop an instrument to record marine electro-active data such as the redox species, pH, and temperature in the in-situ environment.

BACKGROUND AND APPROACH:

There currently is no commercially available instrument, which can be programmed and used in real-time to analyze a variety of electro-active species in the marine environment and simultaneously record pH and temperature. The development of a deployable/profiling electrochemical platform would allow for the real time measurement of electro-active species, pH and temperature in the water column, sediments, and soils. Further, the instrument can be moored in position to collect timed data, and used in the analysis of sediments in the oceans, bays, harbors or planet surfaces. With concern about "Hot Spots", where both copper, tin, lead paints from ships and from discarded batteries from lighted buoys is a concern, an instrument such as this could be used to locate contaminated sediments in bays and harbors. A moored electrochemical instrument can also be used to monitor discharge compliance from manufacturing, electrical power plants (for detecting copper or other metal contamination), in monitoring the effluent from hydrothermal vents or used as a Lander on a planetary surface.

FY03 ACCOMPLISHMENTS:

Target computer code for data logging was modified. Target computer code to accept sequencing of experiments was completed. Designs were made to implement simple cell deployment.

The contract was completed on May 31, 2003. A New Technology Report, SSC-00203 titled 'Sensor Placement Device for Placing Sensors in Underwater Sediment,' was submitted.

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PROJECT TITLE: Tunable Bandwidth Filter System for Hyperspectral Sensor Technology

PARTICIPATING PARTNER (COMPANY): Physical Optics Corporation

TECHNICAL MONITOR: Bruce Spiering

INITIATION YEAR: FY 2001

SBIR CONTRACT: NAS13-01005

FUNDING: $599,998.00

COMPLETION DATE: May 17, 2003

PURPOSE:

The purpose of this contract was to develop a tunable filter system for hyperspectral sensors.

BACKGROUND AND APPROACH:

Physical Optics Corporation (POC) will design, fabricate, and analyze a tunable band with filter (TBF) system integrating holographic filter technology with a unique beam forming optical element. In Phase I, POC demonstrated the feasibility of TBF wideband filtering by a simple mechanical rotation of two broadband holographic filters set inside a ball lens. This Phase II effort will optimize the TBF system design, improving the spectral tuning range and resolution in a compact, cost effective prototype integrated into a multispectral camera system. The major areas of TBF prototype system development are: fabricating very broadband sharp edged (`5nm) holographic filter; fabricating large scan angle ($\geq$ 60) large aperture (>2 in. diameter) rotation ball lens with aberration corrector element; and integrating the filter, scanner, and electronic driver unit. POC's subcontractor, Versatron Corporation will test the FHG system, evaluating its performance per Air Force requirements.

The FBHF system can be easily integrated into an existing rote sensing digital video camera system without major modification or effect on the imaging quality of the system. The filter system is electrically programmable, and can be tuned in milliseconds. POC anticipates that this Phase II effort will yield a tunable bandpass filter system that will advance the multispectral and hyperspectral imaging state-of-the-art.

FY03 ACCOMPLISHMENTS:

Fabricated and refined the wide bandwidth holograms. Developed and packaged the Tunable Bandwidth Filter System.

Contract was completed on May 17, 2003. A New Technology Report, SSC-00210 titled 'Tunable Bandwidth Filter System,' was submitted.

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PROJECT TITLE: A Novel Volumetric 3D Display for Satellite Data Visualization

PARTICIPATING PARTNER (COMPANY): Genex Technologies, Inc

TECHNICAL MONITOR: Tom Stanley

INITIATION YEAR: FY 2001

SBIR CONTRACT: NAS13-01039

FUNDING: $600,000.00

COMPLETION DATE: August 31, 2003

PURPOSE:

The purpose of this contract was to develop a high resolution, volumetric 3-D Display System for remotely sensed data.

BACKGROUND AND APPROACH:

The primary objective of this SBIR effort is to develop the hardware and software prototype of a novel high-resolution volumetric three-dimensional (3D) display system that is suitable for visualizing various types of 3D collected by satellite sensors. The volumetric 3D display technique has a 360-degree look-around group viewing capability without wearing any special viewing aid or goggle. It also allows a group of viewers to simultaneously view and analyze 3D data (such as hyperspectral data sets, multi-variate geospatial data, remote sensor data, etc.)

Due to the complexity of satellite data analysis and visualization, the ability to provide sharable three-dimensional visualization and measurement will significantly enhance the efficiency and accuracy of decision-making, validation, and collaborative development environment. A true 3D volumetric display device will literally add a new dimension to the advanced human/computer interface.

FY03 ACCOMPLISHMENTS:

GENEX worked closely with Productivity Systems, Inc. to develop firmware and API, which can be easily integrated into their control software, so that 3D data can be sent onto the DMD chip to form floating 3D imagery volume. The light engine, which is the heart of the 3D display system, was built. The contract was completed on August 31, 2003. A New Technology Report, SSC-00205 titled 'Volumetric 3D Display,' was submitted.

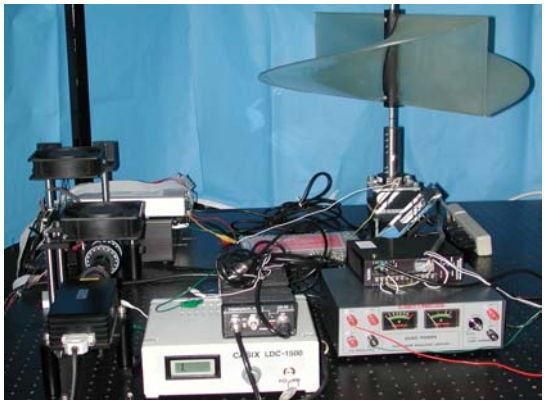

Figure 25-1: Integrated preliminary Helix-SLM system

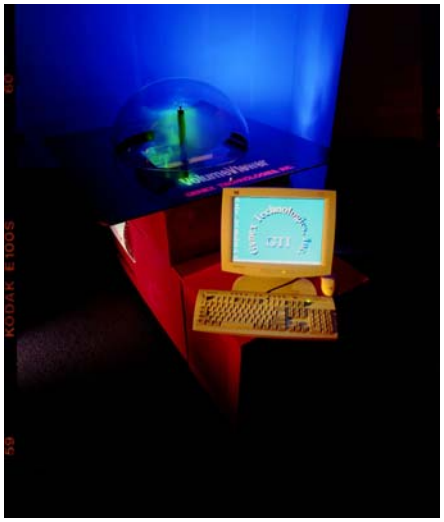

Figure 25-2: Genex VolumeViewer

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SMALL BUSINESS TECHNOLOGY TRANSFER

(STTR)

CONTRACTS

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STTR PHASE II CONTRACTS

INITIATED IN FY2002

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PROJECT TITLE: Nanostructured High Temperature Optical Filters for Protection of Spectroscopic Instrumentation

PARTICIPATING PARTNER (COMPANY): NanoSonic, Inc. teamed with Virginia Tech

TECHNICAL MONITOR: Wanda Solano

INITIATION YEAR: FY 2002

SBIR CONTRACT: NAS13-02029

FUNDING: $499,999.00

STATUS OF PROJECT AT END OF FY03: Objectives of project being met to date

EXPECTED COMPLETION DATE: May 2, 2004

PURPOSE:

The purpose of this contract was to develop and demonstrate robust, high temperature optical low-pass filters formed directly on windows of spectroscopic instrumentation used for rocket engine analysis.

BACKGROUND AND APPROACH:

The objective of this project is to develop and demonstrate robust, high temperature optical low-pass filters that may be formed directly on the windows of spectroscopic instrumentation used for rocket engine analysis. This work could solve the existing problem of excessive thermal loading of spectroscopic system typically used to analyze rocket engine performance. Very high temperature metallic oxide nanocluster thin films with heat-blocking low-pass optical filtering functions and graded coefficients of thermal expansion would be formed by molecular-level electrostatic self-assembly process. This nanoscale self-assembly process inherently leads to the formation of low-defect structures, and the precise ability to achieve graded material properties in functional thin film coatings. Thermal performance of the optical filter coatings to temperatures as high as 1400 C are anticipated based on prior research.

FY03 ACCOMPLISHMENTS:

Titanium dioxide films, which were fabricated with different sized ceramic nanoparticles, were characterized and optimized. Much more uniform films have been fabricated, which makes it possible to produce segmented films using different materials. A successful automated system was developed to fabricate electrostatically self-assembled films from a variety of sources.

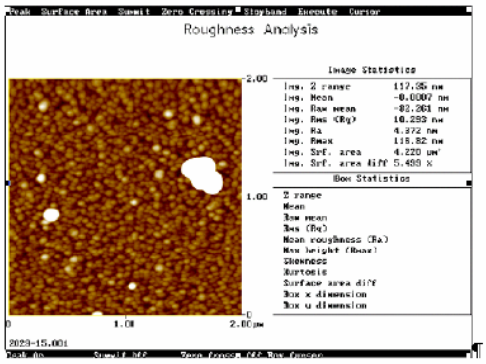

Figure 29-1: 50-bilayer un-sintered TiO2 sample fabricated with 120 immersion times.

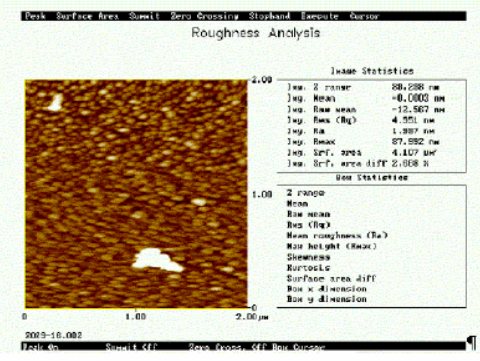

Figure 29-2: 50-bilayer sintered TiO2 sample fabricated with 180s immersion times.

PLANNED FUTURE WORK:

This contract is running far behind schedule. Its scheduled completion date is May 2004, even though it is less than half finished.

The contractor has plans to use their new laboratory automation to catch up.