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Director's Discretionary Fund Report for FY 1993

Ames Research Center, Moffett Field, California

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CONTENTS

INTRODUCTION

The Director's Discretionary Fund (DDF) at Ames Research Center was established to fund innovative, high-risk projects in basic research that are essential to our future programs but otherwise would be difficult to initiate. Summaries of individual projects within this program are compiled and issued by Ames each year as a NASA Technical Memorandum.

These summaries cover 48 projects (both final and ongoing) in Fiscal Year 1993.

The contents are listed alphabetically according to the last name of the primary investigator. Following the narrative reports, an appendix contains a brief description with the financial distribution and status of each of the projects.

Any questions can be addressed to an investigator directly.

Laboratory Investigation of the Growth, Structure, and Apparent Phase Equilibria of Polar Stratospheric Clouds

Investigator(s)
David F. Blake, Ames Research Center,
Moffett Field, CA 94035-1000

Objectives of the study

The chlorofluorocarbon (CFC)-induced depletion of ozone in the polar stratosphere is known to involve heterogeneous chemical reactions on polar stratospheric cloud particles (Solomon, 1986; Tolbert et al., 1987; Molina et al., 1987). The purpose of this investigation is to identify the phases that exist within polar stratospheric cloud (PSC) ice particles. We will do this by growing analog PSC ices under the same conditions as exist in the polar stratosphere and studying their structure. We hope that the results will help to clarify important issues such as the reason for the expansion of the Antarctic ozone hole, the likelihood of an Arctic ozone hole, or the possibility that observed ozone depletions above the midlatitudes will persist or become widespread.

Progress and results

Funding was only made available for this project in May of 1993 and some of the equipment necessary to pursue the research has not yet been received. A quadrupole mass spectrometer for analyzing gases is on order and should arrive by October 15. A gas mixing and gas inlet rack has been designed, built by the glass shop, and installed. A room was cleared and set up for the apparatus, and a surplus carbon evaporator was modified for use as a pumping station. A side-entry goniometer from a surplus electron microscope was modified to fit into the vacuum chamber of the carbon coater. A cryotransfer stage from the electron microscope can now be interfaced into the carbon coater and used as a cold substrate for depositing ices.

Significance of the results: None so far

Publications resulting from study

Molina, M. J.; Tso, T.; Molina, L. T.; and Wang, F. C. Y.: Antarctic Stratospheric Chemistry of Chlorine Nitrate, Hydrogen Chloride, and Ice: Release of Active Chlorine. Science, vol. 238, 1987, pp. 1253–1257.

Solomon, S.; Garcia, R. R.; Rowland, F. S.; and Wuebbles, D. J.: On the Depletion of Antarctic Ozone. Nature, vol. 321, 1986, pp. 755–758.

Tolbert, M. A.; Rossi, Michel J.; Malhotra, R.; and Golden, D. M.: Reaction of Chlorine Nitrate with Hydrogen Chloride and Water at Antarctic Stratospheric Temperatures. Science, vol. 238, 1987, pp. 1258–1260.

Key words

Polar stratospheric clouds, Ozone, Nitric acid hydrate

The Preservation of Organic Matter in Hot Spring Deposits: Developing Search Strategies for a Fossil Record on Mars

Investigator(s)
David F. Blake, Ames Research Center,
Moffett Field, CA 94035-1000
Jack Farmer, SETI Institute,
Ames Research Center,
Moffett Field, CA 94035-1000

Objectives of the study

During an early wet and warm climatic period not unlike that of the Archean Earth, life may have originated and flourished on Mars, only to become extinct as the atmosphere and climate evolved to its present state. We know that Earth's fossil record extends back to about 3.5 billion years. It is not unreasonable that, should life have originated on Mars, a fossil record would exist there as well. In recent years, strategies for exploring Mars have been broadened to address the problem of detecting a fossil record on Mars.

The very best fossil preservation of microbiotas on Earth occurs when organisms are encased in microcrystalline silica immediately following burial. Almost all of the classic Precambrian microbiotas were preserved in this manner. Where might we search on Mars for silica deposits capable of preserving fossils? Recent work indicates that many of the channel networks observed on Mars emanate from point sources associated with impact craters or volcanic terrains where thermal activity is strongly suspected. Therefore, thermally driven spring systems were probably both common and widespread during the early history of Mars.

This study has as its objective the identification of biogenic vs. abiogenic fabrics within modern, near-recent and ancient hot spring sinter deposits on the Earth. We are using state-of-the-art analytical electron microscopy to establish criteria for the unequivocal identification, on a microscale, of relict biogenic and abiogenic materials and fabrics. These criteria will be used to develop a search strategy for future robotic and human exploration of Mars and to further understand the origin and radiation of early life on the Earth.

Progress and results

All of the modern, near-recent and ancient hot spring sinter samples have been collected and curated. We have completed some reconnaisance work involving the sample preparation techniques using an offsite argon ion-beam thinner. The request for our own ion-thinner, which is essential for the sample preparation procedure, has been in the procurement process since January. The RFP for the procurement has just been released and we anticipate that the equipment will be in place by December. We will have a new NRC fellow in our group starting in January who will undertake major portions of this work.

Significance of the results: None so far

Publications resulting from study: None so far

Key words
Mars exobiology, Hot spring sinter, Silicification

Human Exploration Demonstration Project (HEDP)

Investigator(s)
Edward Chevers and David Korsmeyer,
Ames Research Center,
Moffett Field, CA 94035-1000

Other personnel involved
Marc Cohen, Val Mahaffey, Robert Trent, Yvonne Clearwater, Cynthia Null, Ed Force, Gerry Mulenburg, Tom Wynn, Rafael Villegas, and Bob Mah, Ames Research Center,
Moffett Field, CA 94035-1000

Objectives of the study

The Human Exploration Development Project (HEDP) is a multidivision task that addresses the advanced technology requirements necessary to implement an integrated working and living environment for a planetary surface habitat. The HEDP project began in the fall of 1991 and will continue through the summer of 1994. The integrated environment will consist of life support systems, physiological and psychological monitoring of the flight crew, a virtual environment workstation, centralized data acquisition, and habitat systems health monitoring. There will be several robotic systems external to the habitat performing activities to provide representative work loads for the human subjects.

Four basic goals for the HEDP have been established:

1. Enhance the technology development and evaluation process through synergistic cooperation of multiple Ames divisions.
2. Provide a simulator for evaluation of technology in an integrated system setting.
3. Create a realistic environment for introduction of new technology.
4. Identify promising technology concepts to programmatic Centers for new and existing NASA projects.

Scope

The HEDP consists of a working environment contained in a living environment. The living environment will be housed in the Controlled Environment Research Chamber (CERC), and the working environment will be remotely operated to the simulated planetary landscape. The two environments are coupled through an underlying data network that includes a common set of services and provides a medium for overall system integration. Many of these services utilize artificial intelligence technologies to maximize autonomy and minimize crew work loads. The living environment has both life support and life monitoring subsystems. The working environment includes standard and virtual reality workstations. External to the habitat will be robotic devices used as crew work loads and targets for workstation commands. These devices are not intended for development of robots, per se, but to create realistic operational scenarios equivalent to those anticipated on the lunar surface and to develop the robotic controls systems and technologies required.

Status

As of August 1993, the HEDP has finished phase I and is finishing phase II. The second phase has focused on the implementation and initial integration of the project's component technologies. Phase III, the physical installation of the final testbed, will begin in October 1993. Phase IV, the system integration and checkout phase, will begin in January 1994. The demonstration phase of the project will begin in April 1994.

Publications

Clearwater, Y. A.: NASA Lunar Surface Habitat and Remote Exploration Demonstration Project. SAE Paper no. 921194, SAE 22nd International Conference on Environmental Systems, Seattle, Wash., July 13–16, 1992.

Chevers, E. S.; and Korsmeyer, D. J.: The Development of the Human Exploration Demonstration Project (HEDP), A Planetary Systems Testbed. AIAA Paper 93-0558, AIAA 31st Aerospace Sciences Meeting, Reno, Nev., Jan. 11–14, 1993.

Rosen, R.; and Korsmeyer, D. J.: The Implementation of the Human Exploration Demonstration Project (HEDP), A Systems Technology Testbed. Paper no. IAF-93-U.1.538, 44th Congress of the International Astronautical Federation, Graz, Austria, Oct. 16–22, 1993.

Key words

Planetary habitat, Integrated testbed, Simulated habitat

Development of Fiber-Optic Acoustic Sensors for Wind Tunnel Applications

Investigator(s)
Young C. Cho and Paul T. Soderman,
Ames Research Center,
Moffett Field, CA 94035-1000

Other personnel involved
M. G. Irizarry, Ames Research Center,
Moffett Field, CA 94035-1000

Objectives of the study
Acoustic measurements in wind tunnels are subject to certain interference noise effects that are not found in anechoic chambers. Such effects include wind noise, flow-sensor interaction noise, flow induced sensor vibration, deflection of acoustic waves by sensor induced boundary layers, reflections from sensor support components, and noise due to temperature fluctuation. Currently existing acoustic sensor techniques are not adequate to cope with these problems. The objective of this study is to develop new advanced acoustic sensors to eliminate or minimize these interference restrictions. Fiber-optic interferometric sensor technology, which has almost matured in underwater acoustics, is adapted here to develop new sensor techniques for aeroacoustic measurements but with new sensor head designs. This technology utilizes the property that the light wave propagating through optical fiber undergoes phase modulation when the fiber is exposed to external fields. The phase modulation is then interferometrically retrieved and processed to determine the external fields. This technology offers a number of advantages: high sensitivity, wide dynamic range, compact sensor package, light weight, geometric versatility, superb telemetry capability, high temperature tolerance, and immunity to electromagnetic interferences.

Progress and results
NASA's first fiber-optic microphone was developed and fabricated in a breadboard form. Unlike in underwater acoustics applications, no acoustically compliant mandrel was used, but polymeric jackets were used instead as fiber coatings to enhance the acoustic sensitivity. Preliminary tests of this sensor were performed in an anechoic chamber. The test results show that (1) the acoustic sensitivity exceeds estimation by 60 dB, (2) the noise floor is in the range of –4 dB to 10 dB in reference to 20 micro Pascal, which is far below the values required for wind tunnel tests, and (3) the frequency response function is stable but requires further efforts including more elaborate tests and improved sensor head designs.

Significance of the results
The fiber-optic interferometric sensor was developed and tested for the first time ever for aeroacoustic measurements. The test results demonstrated successfully its feasibility as an aeroacoustic sensor. The results enhance the potential of this sensor technique as a powerful instrument to solve complex acoustic measurement problems in wind tunnels that cannot be overcome with the conventional transducer techniques. Furthermore, this technology can easily be applied to studies of pressure fluctuation associated with high speed research and parametric studies of transition as well as other acoustics related research.

Publications resulting from study

1. Cho, Young C.: Fiber-optic Interferometric Acoustic Sensors for Wind Tunnel Applications. SPIE Proc., vol. 1795, 1992, pp. 16–27.
2. Cho, Young C.; and Soderman, Paul T.: Fiber-optic Interferometric Sensors for Measurements of Pressure Fluctuations: Experimental Evaluation. AIAA Paper 93-0738, 31st Aerospace Sciences Meeting, Reno, Nev., January 11–14, 1993.

Key words
Fiber-optic interferometric sensors, Aeroacoustic measurements, Wind tunnel applications

A Prototype Infrared Gas Analyzer for Characterizing Plant Growth During Space Flight

Investigator
James Connolly, Ames Research Center,
Moffett Field, CA 94035-1000

Other personnel involved
Raman Sargis and David Bubenheim,
Ames Research Center,
Moffett Field, CA 94035-1000

Objectives of the study

Accurate and reliable measurement of CO_2 and water vapor is critical for characterizing photosynthesis and transpiration of green plants in space. All food production, air revitalization and water purification functions of plants depend on proper function of photosynthesis and transpiration. Current CO_2 analysis technologies used in ground-based laboratories have several characteristics that would severely restrict and limit their reliable and safe use in space flight. The analyzer design proposed here would utilize alternative component technologies and the operation approach to address each of the limitations and safety problems present in current instrumentation.

Typical portable CO_2 gas analyzers operate based on the infrared radiation absorption of CO_2 gas. As the gas concentration inside the "gas cell" increases, the amount of radiation from the source reaching the sensor diminishes. The measured radiation power is then normalized against a predetermined peak radiation to produce a measurement of the CO_2 gas concentration. The infrared gas analysis method is advantageous over other methods, especially in space because it does not require the use of chemicals to measure gas concentrations as most alternate methods do. However the use of existing infrared gas analysis instruments for high accuracy CO_2 measurements over long periods of time requires regular calibrations, typically daily, and consideration of environmental conditions surrounding the analyzer.

Progress and results

The gas analyzer components requiring improvements were divided into two groups. Within these groups potential solutions were investigated.

Alternative radiation sources

Two sources were investigated to improve the infrared radiation characteristics.

1. Infrared laser: Miniature laser diodes operating at about 250 K have been investigated. Their small size and relatively high operating temperature makes them ideal candidates for use in gas analyzers. The laser beam's energy density is concentrated within a narrow bandwidth where CO_2 gas absorption lines exist. The wavelength of the laser may be tuned to that of a singular gas absorption line . This scheme may also be used to calibrate the instrument by tuning the laser into regions where gas absorption lines do not exist or are extremely weak.

Currently the necessary technology to develop infrared laser diodes has emerged. However, these units do not exist because of the high cost of development and lack of commercial interest. Also, laser manufacturers lack the necessary laser characteristic requirements to develop the proper laser for gas analysis.

To encourage the development of the infrared laser diode, efforts where placed to initiate transfer of technology. The goal is to use commercial funds in exchange for marketable technology developed by NASA. To accomplish our goal, a Joint Sponsored Research Program (JSRP) has been initiated. The JSRP is currently being managed by the American Technology Institute (ATI). ATI is responsible for analyzing the industry and assisting with the transfer technology to commercial companies in exchange for development funds. A JSRP proposal has been completed and will be released to selected companies by ATI.

Once the funds are available, the success of the development would depend on accuracy of requirements and the manufacturer's ability to design to requirements. Therefore the characteristics of the laser were studied using computer simulation as well as "simulated" laboratory experiments. Certain absorption bands in the 2 μm and 4 μm regions were analyzed in detail for various path lengths and environmental conditions. Simulation results indicate that the bands in the 2 μm region will not provide the desired 1 ppm resolution. This task will be especially difficult at high gas concentrations (10,000 ppm). The absorption bands in the 4 μm region can provide the desired resolution if the laser beam can maintain adequate power and low noise

characteristics. However, since the laser diodes are not currently available, these techniques were used to estimate the worst case scenario under which a laser diode may be used in a gas analyzer.

In addition to the study on the operating wavelength, experiments were conducted to estimate the minimum laser power. If the IR radiation power is lower than a threshold limit, then the gas measurement, especially at the higher concentrations, will be inaccurate. If the laser power is inadequate the radiation will immerse in background noise beyond recognition. Test results indicate that a minimum of 200 μwatt of IR radiation power is required to allow analyzer development. The measurements were based on 4.1 μm CO_2 absorption bands using a 16-cm path length.

The preliminary results of these efforts have been discussed with leading laser manufacturers to establish feasibility. The results of technical meetings with one private company followed by their in-house studies indicated that development of both the 2 μm and 4 μm laser diodes is within their technical ability. The estimated cost of development is $100,000.

2. Gas-filled flash bulb: Unlike the laser, a flash bulb is a wide band radiation source. The hypothesis is that by pulsing an IR radiation source the radiation of different wavelength will have distinct signal characteristics.

The IR radiation of the flash bulb was studied using a breadboard gas analyzer that was constructed to allow the study of various radiation sources. Also computer codes were written to simulate the typical output of a black body radiation source. The results overwhelmingly supported the hypothesis. Figure 1 exhibits a hypothetical black body source whose temperature has increased from room temperature to 5,000 K and then decreased to room temperature in a half-sinusoid shape. The X-axis represents wavelengths from 1 μm to 5 μm and the Y-axis is the temperature range from 300 K to 5,000 K. The Z (vertical)-axis demonstrates the IR radiation power. A close examination of the graph reveals the variations in IR patterns based on their wavelength. While the longer wavelengths exhibit shapes closer to a half sinusoid, the shorter wavelengths (2 μm) have sharper envelopes with steeper rising and falling edges. The envelopes of specific wavelengths may be recognized by employing pattern recognition techniques; then they may be used to measure the amount of radiation power within the given wavelength range.

Because of time and budget constraints a complete prototype was not developed. The breadboard setup provided enough information to support the concept but required significant enhancements and additions to be upgraded to a fully functioning prototype.

Radiation measurement and analysis

The main factors that determine the quality of radiation measurement are the sensor noise and radiation noise levels. Both reduction and characterization of noise help enhance the quality of radiation measurement.

Infrared radiation sensors are inherently sensitive to fluctuations in temperature. Therefore it is critical that the temperature of the sensor be monitored and actively controlled. The IR sensor element used is mounted on a thermoelectrically cooled (TEC) plate. The temperature of the sensor was monitored using a thermistor, which was attached to the TEC plate. The results indicated stable sensor temperature at –30°C, which allowed for low sensor thermal noise.

Studies conducted in the area of digital signal processing (DSP) indicated that DSP methods may be used to improve the gas concentration measurement.

Significance of the results

The efforts of the past year resulted in the identification of various subsystems and the design and construction of a breadboard CO_2 analyzer unit to allow experimentation with different components and analyzer configurations. Feasibility studies indicated that a miniature IR laser as well as a special type of high energy flash bulb may be used as alternate IR radiation sources in CO_2 gas analyzers.

The feasibility studies also identified specific miniature diode requirements to allow their development. Also project efforts have initiated a process for a joint effort between NASA and commercial companies to develop technology that is mutually beneficial.

Successful implementation of either of the alternate IR radiation sources will eliminate the use of traditional mechanical choppers or beam splitters. The characteristics and performance of the IR radiation sensing subsystem, currently designed, will meet design requirements. DSP methods may also allow simultaneous multiple gas concentration measurements.

Key words

Gas exchange, Photosynthesis, Respiration, Transpiration

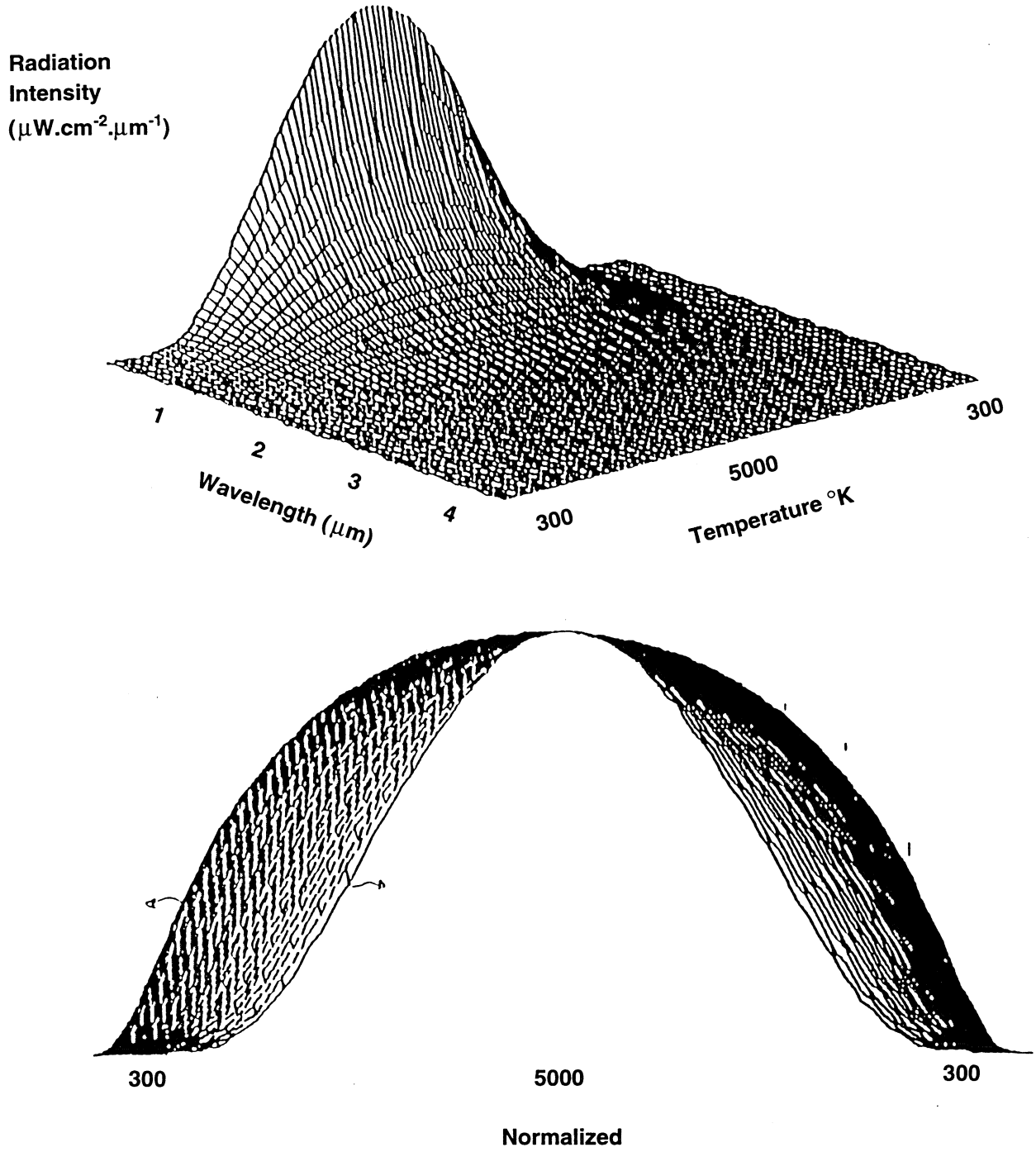

Figure 1. Black body electromagnetic radiation.

Origins of Planetary Systems: Observations and Analysis

Investigator(s)
Kent Cullers, Ames Research Center,
Moffett Field, CA 94035-1000
Laurance Doyle, SETI Institute,
Ames Research Center,
Moffett Field, CA 94035-1000

Objectives of the study
The detection of extrasolar planetary systems is of vital importance to our understanding of the place our planet has in the cosmos, the origin of our solar system (whether it is unique or not), and an accurate estimate of the number of possible habitable planets in our galaxy. However, detecting extrasolar planetary systems is one of the most difficult observational problems in astronomy today, and each method has its difficulties. The photometric method, which measures a drop in the brightness of the star due to the transit of a planetary body in the line-of-sight, is the most sensitive detection method, but it assumes that the planetary orbital plane is seen edge-on by the observer (Borucki and Summers, 1984, Borucki et al., 1988). The photometric method can detect a drop in the brightness of a star (1% for a Jupiter-sized planet and 0.1% for an Earth-sized planet) due to the transit of a planet in the line-of-sight (two-color photometry removes ambiguities due to stellar variability, starspots, or limb darkening; see Borucki and Summers, 1984; Schneider et al., 1990; Schneider and Chevreton, 1990, 1991). Even though this method is the most sensitive (medium-sized, 30-in. telescopes can be used), it relies critically on the condition that the planetary orbital plane be in the observer's line-of-sight. This condition exists because the orbital plane of the planetary system has to be less than 2° from the line-of-sight of the observer to obtain a measurable planetary transit. Therefore, for a random distribution of planetary orbital plane inclinations, over 1,000 stars would have to be monitored for over a year to obtain one detection. This method is unique, therefore, in that with present technology it is not detection limited, but probability limited. This study will improve that probability in two ways: (1) We will preconstrain the likely single star planetary orbital planes by compiling a catalogue of stellar rotation axes inclinations to the line-of-sight which, in turn, will give the expected planetary orbital plane for single systems. We can then designate ahead of time which systems are close enough to being edge-on so that the photometric detection method may be used. (2) We will monitor eclipsing binary stars—which have expected planetary orbital planes that are already edge-on, have two stars with which to confirm a planetary transit, and have stable planetary orbital regions that have been shown to exist for most configurations of such close systems—for evidence of such extrasolar planetary systems. This effort will occur during the second year of funding.

Progress and results
This year is the first for this study, but we have already determined the rotation axis inclination from the line-of-sight for over 200 stars using stellar rotation periods (determined from the CaII H&K emission line spectra in the case of late-type stars and variations in the magnetic field spectral lines in the case of early-type stars; after Doyle, 1988). We expect to submit this new stellar parameter catalogue for publication before the end of this year. In the process of compiling this catalogue we have also discovered a number of astrophysically interesting relationships between younger and older stars, including indications that T Tauri stars (premain sequence stars) have the same velocity distribution as stars already on the main sequence. This result is significant in further revealing the actual angular momentum processes that stars undergo during the planet forming stage.

Significance of the results
We are applying the above determinations to provide improved detection statistics for the photometric method—specifying a list of nearly edge-on systems to be monitored (present accuracy is limited to about ±8° at $i \approx 90°$. This constraint would narrow the possible number of stars in a sample that could be successfully monitored for photometric detection of extrasolar planets to about one-seventh the previous ``random'' sampling. Selection of infrared excess stars might further constrain this selection (Backman and Gillett, 1988; Doyle and Backman 1990). In addition, however, this determination of expected extrasolar planetary orbital planes can be very useful for the other detection methods.

For example, a specification of the planetary orbital plane could remove proper motion and parallax vectors—large secondary effects—from the expected astrometric wobble of a star caused by a planetary system (Scargle, 1988; Levy et al., 1988). Pole-on systems could also be specified for direct

imaging efforts as well as preferred candidates for astrometric measurements (accuracies of ±0.5° can be achieved at i ≈ 0°). One could also directly compute masses of stellar companions obtained using the radial velocity method. Some present measurements already show very promising results if the system's inclination can be calculated (Campbell et al., 1988; Robinson, 1990, where very low mass companions are indicated, but these measurements await determination of the sine of the inclination from the line-of-sight, i).

The photometric method for detecting extrasolar planets benefits the most from this study and becomes a very viable technique using existing modest equipment when the probabilities of detection can be improved. We have outlined two major contributions to this improvement. One is predetermining the expected planetary orbital plane using asymmetries in stellar atmospheres to derive the stellar rotation axes inclinations, and the second is extending photometric observations of eclipsing binary stars where the extrasolar planetary orbital plane is already expected to be edge-on. Both results bring the observing tasks required to detect extrasolar planetary systems to a manageable level for a collaboration of this size and to begin constraining the probabilities well enough so that, in case of nondetections, significant knowledge about extrasolar planets existing around some single stars as well as short-period double stars may be gained.

Publications resulting from study

We are planning to publish the first Catalogue of Stellar Rotation Axes Inclinations this year. We will be applying these results in the second year of this DDF research using the photometric method to detect extrasolar planetary systems around nearby single and eclipsing binary stars.

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Key words

Extrasolar planets, Stellar inclinations, Star spots

Monitoring Global Change During the Last 10,000 Years

Investigator(s)
Hector L. D'Antoni, Ames Research Center, Moffett Field, CA 94035-1000

Objectives of the study

1. To compare two environmental processes developed within the last 10,000 years in two independent regions by means of pollen analytic and remote sensing data.
2. To calibrate predictive tools to hindcast postglacial vegetation processes in southwestern Oregon and Southern Patagonia and Tierra del Fuego in terms of remote sensing.
3. To produce new data and to interpret both new and current data in terms of vegetation history, nitrogen, and carbon and water fluxes.

Progress and results

There is not sufficient information yet to compare both regional processes. However, the literary search on Oregon found an extensive work by Calvin Heusser (1960) mostly restricted to Pacific environments of Oregon. Some 25 sites were studied by the late Henry Paul Hansen from 1930–1950. By the time of the development of the ^{14}C dating method by W. Libby in 1949 (Libby, 1954), Hansen produced very little. Therefore, most of his valuable and still original work for the interior of Oregon is no longer in use. I collected all these papers and I studied the data with modern statistical techniques. I will be trying to recruit a graduate student who would revisit the sites and take carbon samples from Hansen's stratigraphies in order to get them ^{14}C dated.

In 1993 M. Spanner and I published a work using only modern data (Spanner and D'Antoni, 1993). Later I tested these models on pollen data from six sedimentary profiles ranging from 3,500 to 12,000 years BP (before present). Results were summarized in a communication and a poster at the 26th meeting of the American Association of Stratigraphic Palynologists (AASP): Pollen Analysis in Southern Patagonia: from Space to Time. My presentation was attended by not only the AASP members but also some 10 specialists from the American Geological Association (that also was holding a meeting in San Diego). Currently I am preparing a paper on this work. While setting the palynology laboratory, I also was restudying an important pollen profile from central Mexico. I identified a problem in the published work (by Straka and Ohngemach) and using numerical models I produced two paleotemperature curves for central Mexico for the last 10,000 years. A paper, Paleotemperatures of La Malinche: A Palynological Hypothesis, was peer reviewed and accepted by Grana and is currently in press. As a result of the last three papers I published in Grana, the chief editor, Mervi Hjelmroos, visited Ames to see the pollen laboratory I created with DDF funds. She was well impressed by our facilities. I discussed some of these topics in the Early Detection of Global Change Workshop held at the Aspen Global Change Institute, Colorado.

New data are currently being produced for Oregon (modern pollen) and Tierra del Fuego and southern Patagonia (aspartic acid racemization). More data are needed for comparisons. The subjects of water, nitrogen and carbon fluxes that are available for Oregon faced us with a difficult problem in southern South America. In fact, due to the process of ozone depletion over mid latitudes, it is possible that there are no more "pristine" conditions in Patagonia. This project encouraged me to submit a research project to NASA Headquarters and, since the problem has never been studied at the terrestrial ecosystem level, I asked 50 top scientists (including some colleagues from Ames) to review the project. With no exceptions I received positive reviews and encouragement to submit the proposal. I also received positive comments from NASA Headquarters. Later, I discussed this matter at the Early Detection Workshop in Aspen. In due time I will report to the Chief Scientist on these matters.

Significance of results

Results are showing that the proposed method works correctly and the difficulties we faced lead us to open a new research area of great scientific significance.

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Key words
Quaternary environments, Palynology and remote sensing, Paleoclimate and climate prediction

Schmidt-Cassegrain Long-Range Laser Velocimeter

Investigator(s)
Stephen E. Dunagan, Ames Research Center, Moffett Field, CA 94035-1000

Objectives of the study

Full-scale aeronautical test programs utilizing the NFAC wind tunnels require the best available measurement instrumentation. Laser velocimetry (LV) provides an important noninvasive method for the measurement of velocity at a point. The design of a suitable instrument for the large NFAC wind tunnels faces technical challenges in the areas of test section access, optical aperture, laser power, and flow seeding.

Progress and results

A two-component dual-beam LV system for the 40- × 80-Foot Wind Tunnel has been designed and is in the process of fabrication. The instrument design is based on the use of high quality, large aperture Schmidt-Cassegrain telescope optics to perform both the laser-beam-focusing and scattered-light-collection functions. Uncoupled orthogonal measurement of two coordinates of velocity may be made. To avoid the need for large, high quality windows in the test section, the instrument is configured as a streamlined optical assembly mounted on the floor of the test section and translated in the streamwise and cross-stream directions. The laser velocimeter probe volume is translated in the vertical direction by means of zoom optics. Coaxial back-scattered light is collected through the same optical system and analyzed for Doppler shift. Single-mode polarization preserving fiber-optics transmit light from the remotely located laser into the optical assembly. A multimode fiber conveys the scattered light to remotely located photodetectors. Frequency domain signal processing will permit analysis of the Doppler signal with a very poor signal-to-noise ratio.

A prototype optical system has been set up and evaluated in the optics lab. Results to date show promise, with high signal to noise ratio as the primary indicator. Some problems have arisen as well; in particular, the very small number of fringes present in the probe volume is problematic for digital Fourier-transform burst-signal processing schemes. An alternative digital autocorrelation processing scheme is presently being investigated.

Significance of the results

These results are adequate to prove the viability of the design concept. Designs for a prototype instrument pod and traverse have been completed. Fabrication and assembly of the instrument will proceed on an aggressive schedule with anticipated wind tunnel deployment on the High Speed Research Test in November 1993.

Publications resulting from study

A paper is presently in process that describes the design and application of the instrument. It will be presented at an appropriate aerospace instrumentation forum as soon as experimental data are available for inclusion.

Key words
Laser Doppler velocimeters, Flow measurement, Wind tunnels

Investigation of the Scales of Turbulence in Hypersonic Rarefied Flow

Investigators
William J. Feiereisen, Ames Research Center, Moffett Field, CA 94035-1000
Donald Baganoff and Sanjiva Lele, Stanford University, Stanford, CA 94305

Other personnel involved
Avijit Goswami, Stanford University, Stanford, CA 94305

Objectives of the study

Turbulent flows are composed of eddies of a wide range of sizes. Direct simulations attempt to accurately reproduce all the size and time scales in a flow, against which turbulence models may be compared or turbulent flow physics studied. Similitude arguments, which have traditionally been employed to estimate this range of scales, have led to conclusions that the smallest spatial scales in the flow, characteristic of the eddies that dissipate the turbulent kinetic energy, are much larger than the mean free path and, therefore, viscous shear stress and heat transfer as modeled by the Navier–Stokes equations are properly represented. The parameters of these arguments have been chosen to represent normally encountered turbulence consistent with flows of engineering interest such as aircraft or turbomachinery. For hypersonic vehicles, which fly in the upper atmosphere, it is appropriate to reassess these arguments to determine if turbulent flow can exist under conditions where the smallest scales are no longer properly modeled by the linear transport terms of the Navier–Stokes equations. If turbulent flow can exist at the low Reynolds numbers in this flight regime, then a standard similitude argument suggests that the smallest eddies are in the free-molecular/continuum transition regime and a stochastic direct simulation would be required in order to properly represent the turbulent dissipation. In this light, it was the objective of this work to investigate the following three questions:

1. Can turbulence exist under conditions corresponding to high speed flight in the upper atmosphere?
2. Do the dissipation length scales become of the same order of magnitude as the mean free path and what implication would this have for the modeling of these scales?
3. Can a Monte-Carlo simulation method be used to produce a direct simulation of turbulent flow under rarefied conditions?

Approach

Simulations of isotropic homogeneous turbulence were performed by two completely different methods, each recognized as appropriate for application in its flow regime. The continuum flow regime was modeled with a direct Navier–Stokes solver (DNS). This method solves the full Navier–Stokes equations on a finite-difference mesh. The continuum assumption is implicit in its use of linear constitutive relations for viscous stress and heat flux. The spatial derivatives are approximated using a compact sixth-order accurate finite-difference scheme and time advancement is carried out using a fourth-order Runge-Kutta scheme (Lele, 1992). The rarefied flow scheme is a version of the Direct Simulation Monte-Carlo method adapted to vector architectures (McDonald, 1988). It models the gas using discrete particles that communicate through collisions by exchange of momentum and energy. It relies on a stochastic approach to model collisions as opposed to tracking the history of each individual particle through a binary encounter. The domain is discretized into a finite number of cells whose main function is to identify possible collision partners. The collision frequency is set so as to produce the right macroscopic behavior. The time step is chosen to be small so that one may decouple collisions and free migration of particles at each time step. Since the particle simulation is based on a stochastic method, its accuracy depends partly on the chosen sample size (number of particles per cell). Increasing the sample size per cell reduces the statistical variations in the results.

Initial study has involved simulations in two dimensions, recognizing that turbulent physics requires the third dimension. Identical velocity fields of isotropic homogeneous turbulence were created to use as initial conditions for Navier–Stokes code and for a discrete particle simulation code.

This study focuses on a comparison between the predictions of the two simulation techniques by studying the temporal decay of a simple two-dimensional fluctuating flow in a square box with periodic boundary conditions. The initial state of the flow is given by

constant pressure and temperature throughout and a velocity field that characterizes homogeneous and isotropic turbulence of an incompressible fluid. Since the flow is constrained to remain two dimensional, there can be no stretching of vortex lines and hence no further production of turbulent kinetic energy. Therefore, one may only study the problem of turbulence decay in two dimensions. Comparisons are first made in the near-continuum regime where the two methods are expected to agree and then carried out under more rarefied conditions where the two are expected to exhibit differences. The Knudsen number, Kn, defined as the ratio of the mean-free path length for the molecular motion to some characteristic length in the flow, is a measure of the degree of rarefaction in the flow and is an important parameter in studying possible differences between the two predictions.

In order to make comparisons in a time dependent problem, it is necessary to assure that the two simulations are initialized at exactly the same conditions. Although both methods employ nondimensional variables, the governing parameters in the two are quite different. In DNS the main parameters are the initial reference Reynolds number. In a particle method, one of the most important parameters is the Knudsen number, Kn.

In the DNS code, the initial velocity field was chosen such that it was divergence free and had a magnitude equal to the specified value of the rms Mach number. In addition, it satisfied a specified initial energy spectrum function in Fourier space with the phases of the velocity components chosen at random. In order to match the initial velocities in the two schemes the resultant values from the DNS initialization were input directly into the particle simulation. This input ensured that the same initial Mach number and energy spectra were being used in the two codes. The temperature and pressure distributions were set to be uniform, initially. Whereas this implementation is trivial in the Navier–Stokes simulation, it requires careful consideration in the Monte-Carlo method. Here, the particle velocities for each cell have to be picked from a velocity distribution function, f, which has a given temperature (variance) and a given fluid velocity (mean).

In this comparative study, the initialization procedure was found to be very important. In particular, the choice of the initial velocity distribution function in the particle method plays a key role because it sets the initial state of stress and hence the initial decay rate of the mean fluctuating kinetic energy. The spherical Maxwellian distribution was found to be overly simplistic because it does not produce a shear stress. The use of an ellipsiodal distribution based on the Navier–Stokes state of stress fails when this stress becomes nonphysical, which occurs for Knudsen numbers of 5/32 and above.

Liu and Lees (1961), however, proposed an approximate method for the solution of the Couette flow problem that may be used as a starting point for the construction of a suitable velocity distribution. They assumed a two stream Maxwellian with no temperature gradient across the plates. If the initial strain rate field in a cell is imagined to be created by a Couette flow, it is possible to use Liu's and Lees' distribution to initialize the particle simulation.

The initial divergence-free strain rate field obtained from the Navier–Stokes initialization is rotated to an orientation that corresponds to pure shearing strain. In general, it is possible to decompose this shearing strain field in each cell into a Couette flow plus a rotation. Since the initial temperature field is uniform throughout the box, the assumption of no temperature gradient across the plates holds. In the process of producing Liu's and Lees' distribution from the strain rate field, it is apparent that the effect of the rotation on the velocity distribution function has been ignored. In order to use their method, it is necessary to be able to show that f is invariant under rotation. It has been shown that f indeed satisfies this condition under a general Euclidean group of transformations (Speziale, 1981).

Test cases were then run using Liu's and Lees' velocity distribution function to initialize the particle method. The Knudsen number was varied through the sequence 1/32, 2/32, 5/32, and 8/32. The rms fluctuating Mach number was fixed at 0.4. The problem of nonphysical stresses that were being encountered in using the Navier–Stokes state of stress to define the ellipsoidal distribution was now successfully eliminated. The temporal decay of mean kinetic energy thus obtained is shown in figure 1. Whereas the DNS and the particle method showed close agreement for values of Kn of 1/32, 2/32, and 5/32, some differences began to be observed for Kn = 8/32. For the last case, the DNS overpredicts the amount of decay. This overprediction is a consequence of its linear constitutive stress-strain law, which tends to overpredict the shear stress at higher values of Kn. Figures 2 and 3 show the calculated energy spectra for Kn = 1/32 and Kn = 5/32 and indicate relatively close agreement between both methods for the continuum and, surprisingly, for the rarefied case also.

Liu's and Lees' velocity distribution function worked well for the range of test conditions studied. The temporal decay of the mean kinetic energy showed a near perfect agreement at a Knudsen number of 1/32, which represents the near continuum,

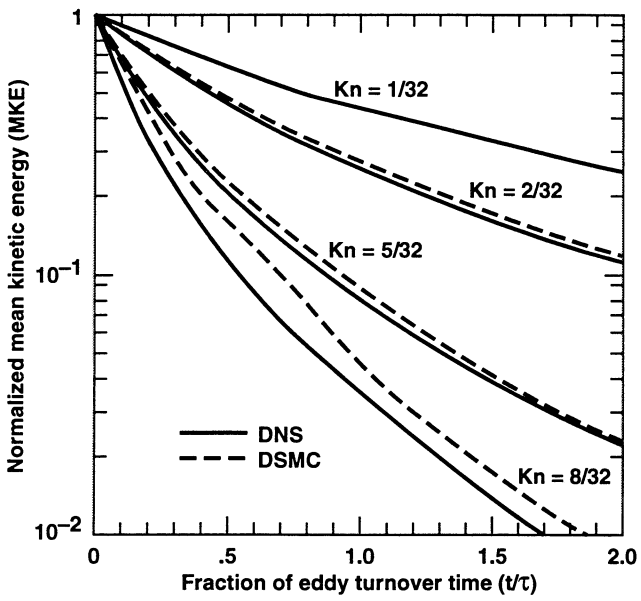

Figure 1. Kinetic energy decay.

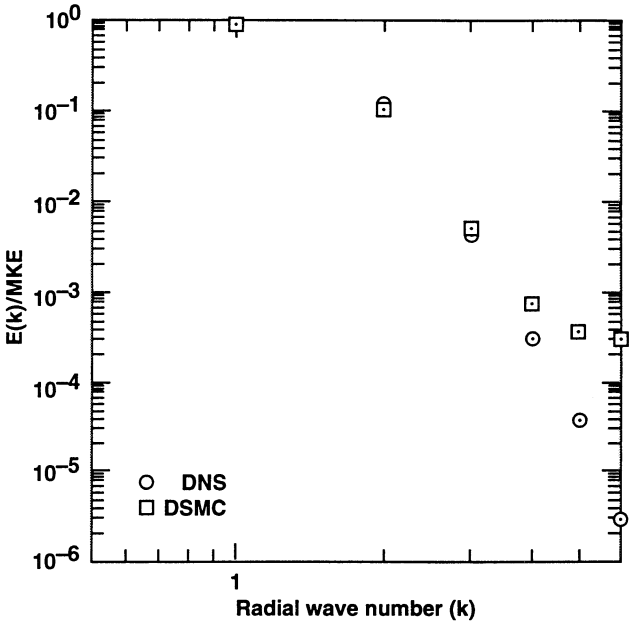

Figure 3. Turbulent kinetic energy spectra for Knudsen number 5/32 at t = tau.

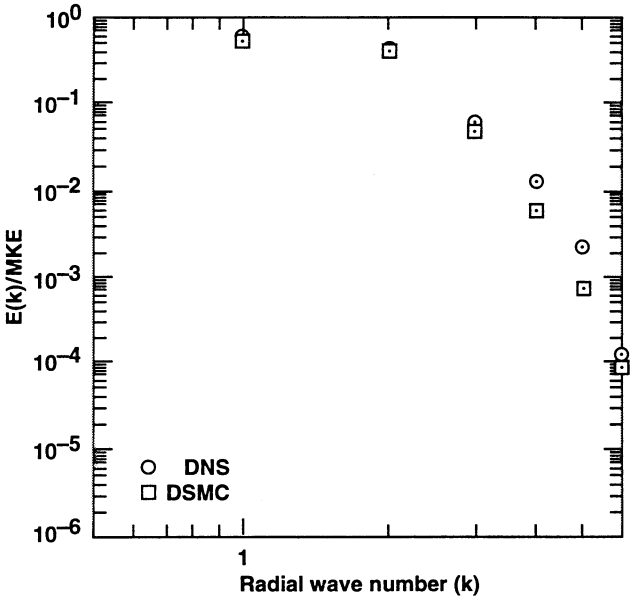

Figure 2. Turbulent kinetic energy spectra for Knudsen number 1/32 at t = tau.

and a reasonably good agreement up to a Knudsen number of 5/32. Since this range is believed to cover much of the regime of practical interest, it indicates that the DNS can continue to be used in flows having a reasonable degree of rarefaction. Beyond this point the DNS overpredicted the amount of decay.

This work indicates that direct Navier–Stokes simulations of turbulent flow are valid much farther into the rarefied flow regime than was previously thought. This conclusion, based upon comparisons of the decay rate of turbulent kinetic energy and the form of the calculated energy spectra, does not fit with previous ideas of the viscous behavior of fluids at high Knudsen numbers. This discrepancy occurs possibly because the velocity gradients as calculated are much smaller than those that are seen in shock waves where non-equilibrium effects determine the structure. Even though the small eddies are in the traditional rarefied flow regime, as characterized by the Knudsen number, a more useful measure of the applicability of the DNS is probably related to a measure of the velocity gradients rather than a Knudsen number based on the size of the small eddies. Other higher order statistical measures of turbulence will need to be compared before this conclusion can be completely upheld. If it is upheld, however, DNS simulations can form the basis for turbulence modeling advancements on hypersonic flows while sparing the expense of Monte-Carlo simulations.

Publications resulting from the study

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Goswami, A.; Baganoff, D.; Lele, S.; and Feiereisen, W.: A Comparative Study of Turbulent Decay Using Navier–Stokes and A Discrete Particle Simulation, AIAA-93-3093, AIAA 28th Thermophysics Conference, Orlando, Fla., July 6–8, 1993.

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Key words

Rarefied flows, Direct simulation Monte-Carlo, Turbulence simulations

Analytical and Experimental Studies of Rotorcraft Vertical Climb Performance

Investigator(s)
Fort F. Felker, Ames Research Center,
Moffett Field, CA 94035-1000
Robert M. McKillip
Continuum Dynamics, Inc.,
Princeton, NJ 08543

Introduction

The accurate prediction of rotorcraft vertical climb performance is a challenging problem in rotorcraft aerodynamics. It is not uncommon for the most widely used vertical climb performance analysis method (momentum theory) to overpredict the power increment required to climb by 50% or more. The lack of an accurate analysis creates a severe difficulty during the development of a new helicopter. The U.S. Army specifies a minimum level of vertical climb performance that is acceptable and imposes severe penalties if a newly developed helicopter cannot meet the specification. Since the analysis is not accurate, it is impossible to know whether or not a proposed design can meet the specification until testing of the prototype helicopter is under way. At that point in the development cycle, design changes to meet the specification are very costly.

A combined theoretical and experimental investigation into rotorcraft performance in vertical climb was completed with the objective of providing an accurate analytical capability to the U. S. rotorcraft industry. High-quality performance data were acquired in the Princeton Long Track. This facility allowed for the model to be moved through still air in a controlled environment, eliminating the uncertainties in axial flight speed and wall interference effects common in low-speed wind tunnel tests. An improved boundary condition was developed for a state-of-the-art free-wake analysis. The improved analysis provides superior results when compared with the methods typically used by industry.

Experimental results

An 8-ft-diameter four-bladed hingeless model rotor was used in the experiments at the Princeton Long Track. The model was mounted on a traversing carriage with the rotor shaft horizontal. The speed of the carriage could be precisely controlled, eliminating any uncertainty in the axial flight velocity. A six-component balance was used to measure rotor forces, moments, and torque. The collective pitch was held constant during each data run (with zero cyclic), and two different collective pitches were examined in the test.

Figure 1 shows the variation in rotor thrust with axial flight velocity, and figure 2 shows the

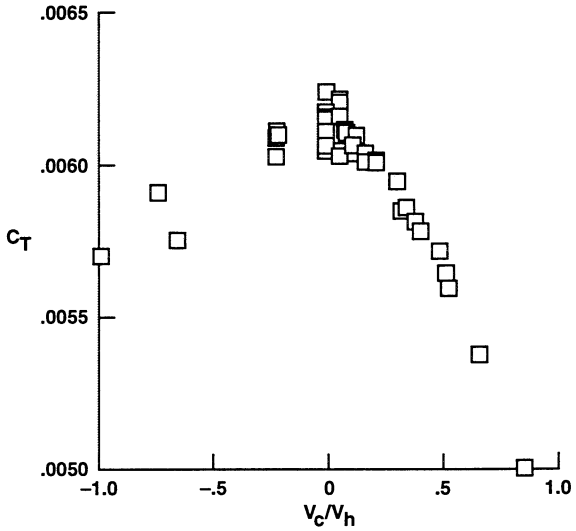

Figure 1. Effect of vertical climb velocity on measured rotor thrust coefficient.

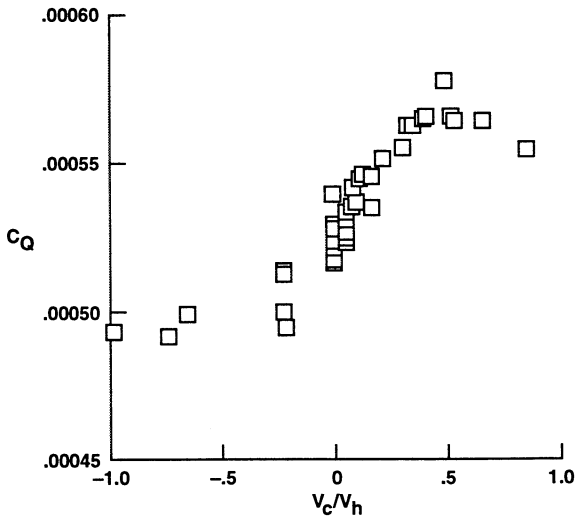

Figure 2. Effect of vertical climb velocity on measured rotor torque coefficient.

variation in rotor torque. These data were obtained with a collective pitch of 10.9 deg, giving a nominal hover thrust coefficient of 0.00615. Because the data were acquired at fixed collective, increasing the vertical climb velocity reduces sectional angles of attack on the blade and reduces the thrust coefficient. In spite of the reduced thrust, the rotor torque increases with increasing climb velocity up to a nondimensional climb velocity of 0.5, where the reduction in thrust is finally large enough to cause a corresponding reduction in torque.

Analytical results

Predictions of rotor performance in vertical climb were made using the free-wake analysis EHPIC and the commonly used momentum theory. A new tip vortex boundary condition was developed for EHPIC, which allows the tip vortex to more closely follow the experimentally observed tip vortex geometry in the near-wake region just aft of the blade trailing edge.

Figure 3 presents a comparison of the predicted and measured rotor thrust in vertical climb, and figure 4 presents a comparison of the predicted and measured rotor torque, using the free-wake analysis. The data were acquired with a collective pitch of 10.9 deg (as in figs. 1 and 2). For the analysis, the collective pitch was slightly reduced (to 10.6 deg), so that the predicted and measured thrust coefficients would match in hover.

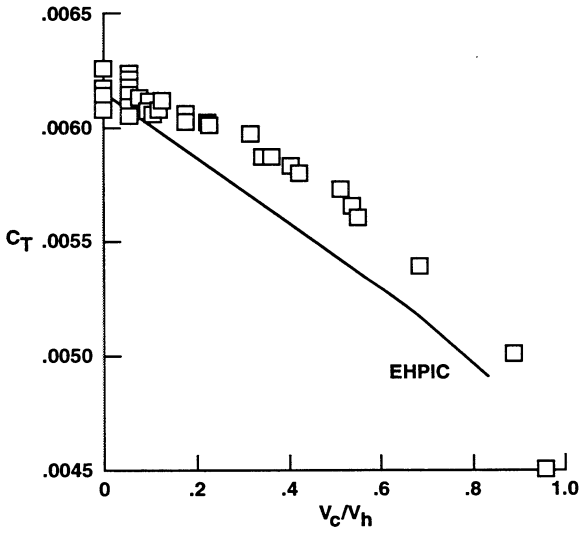

Figure 3. Comparison of predicted and measured rotor thrust coefficients using a free-wake analysis. Collective pitch held fixed.

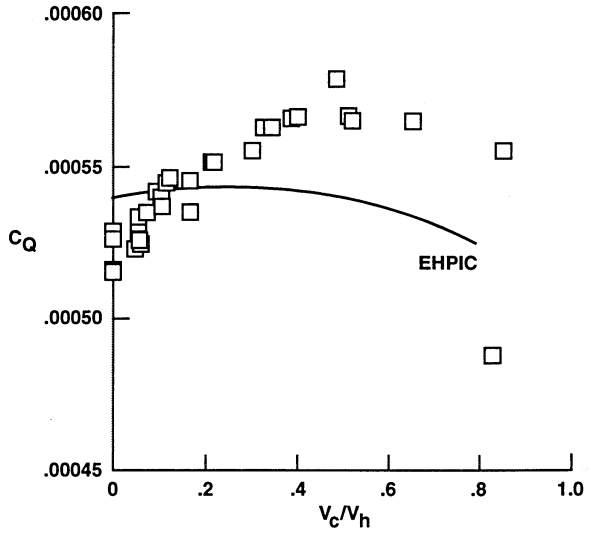

Figure 4. Comparison of predicted and measured rotor torque coefficients using a free-wake analysis. Collective pitch held fixed.

Figure 3 shows that the analysis underpredicts the thrust as the climb velocity increases, although the slope of the thrust versus climb velocity curve appears to be correct at the higher climb velocities. Figure 4 shows that the analysis overpredicts the rotor torque in hover by 3.8%. The errors in predicted torque in hover typically range from 0-5% with this analysis, so the error in hover is within the expected range. Figure 4 also shows that the increase in torque as the vertical climb velocity increases is underpredicted (consistent with the underprediction in thrust).

The results in figures 3 and 4 suggest that better predictions could be obtained if the collective pitch used in the analysis were allowed to vary in order to match the observed thrust coefficient. This was done, and the results are shown in figure 5. This figure shows that the shape of the power versus vertical climb velocity curve is well predicted by the free-wake analysis. The offset in power is fairly constant over the range of climb velocities, which suggests that there is an error in the profile power prediction (from airfoil tables). The results shown in figure 5 represent a substantial improvement in predictive capability when compared with the results obtained using momentum theory.

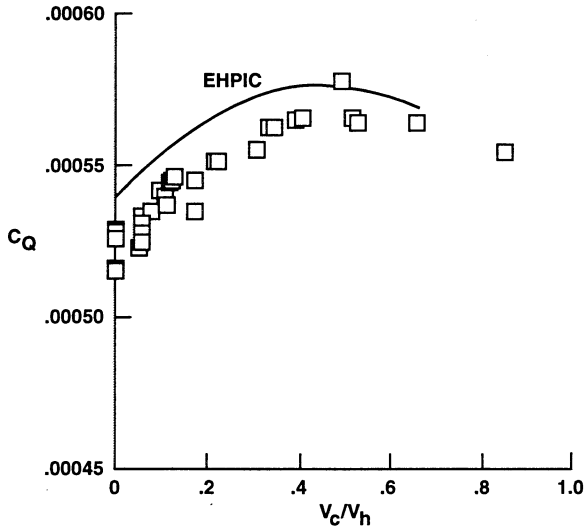

Figure 5. Comparison of predicted and measured rotor torque coefficients using a free-wake analysis. Collective pitch adjusted to match thrust.

Concluding remarks

A combined theoretical and experimental investigation of rotor performance in vertical climb and descent has been completed. New high-quality experimental data were obtained, which are free of uncertainty in axial flight speed and wind tunnel wall effects. An improved boundary condition was developed for a free-wake analysis. The modified analysis provides more accurate results than the commonly used momentum theory. See Felker and McKillip (1994) for more details.

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Key words

Helicopter, Aerodynamic performance, Rotor performance

Continuous-Flow Apparatus for Studies of Gas- and Liquid-Phase Adsorption Dynamics

Investigators
John E. Finn and Sanford S. Davis,
Ames Research Center,
Moffett Field, CA 94035-1000

Other personnel involved
Phuong Nguyen, De Anza College,
Cupertino, CA 95014
Bradley Davis, University of California,
Santa Barbara, CA 93106
Bruce DeVantier, Southern Illinois University,
Carbondale, IL 62901–6603
Glenn Deardorff, Sterling Federal Systems,
Ames Research Center,
Moffett Field, CA 94035-1000

Objectives of the study

Spacecraft life support system designs usually include several subsystem components that use adsorption directly or indirectly to remove excessive or unwanted chemical species from fluid streams. These components include devices for CO_2 removal, gas-phase trace contaminant control, water purification and polishing, and contaminant monitoring. Adsorption-based processes will likely be important to future generations of life support systems as well, as adsorption processors usually have several characteristics that make them attractive for fluid purification in space environments. A partial list includes simple construction and passive operation, good energy efficiency, applicability to both gas and liquid streams, and potentially regenerable operation.

This work focuses on applying some new numerical techniques to modeling the complex adsorption column behavior seen in life support applications, and designing and building new experimental equipment for validating those techniques and models. The modeling work uses a finite difference method based on a discrete dispersion relationship developed originally for wave problems in acoustics (Davis, 1989, 1991) to solve the diffusion-convection-reaction equation that results from a differential mass balance on an adsorption column. Solutions to this set of nonlinear, strongly coupled partial differential equations are sets of waves often having steep fronts that prove to be challenging problems for numerical methods (Finlayson, 1992).

The experimental objective of the work is to assemble an apparatus for combining contaminant species with a gas stream whose composition, flowrate, and humidity are carefully controlled, passing the stream through a test adsorption column at a controlled temperature, and analyzing the column effluent for multiple contaminant species on a continuous basis. The data obtained can be compared with results from numerical simulation.

Progress and results

Experimental work

During this period most of the work went into building and testing the experimental apparatus. An abbreviated schematic of the equipment is shown in figure 1. The general flow of the process air stream is easy to follow, but some of the particular techniques used to meet the experimental objectives are worth pointing out.

Producing an air stream whose relative humidity can be specified and quickly varied between 0 and 95+% at temperatures from 10° to 50°C is often difficult due to mass transfer limitations. This problem was solved here by using a compact hydrophobic hollow fiber membrane module (Hoechst-Celanese, 5PCM-106). De-ionized water flowing through the tube side at a pressure higher than the gas (shell-side) pressure humidifies the gas completely. At all flowrates studied to date (to 5 standard liters/min), the gas emerges from the module virtually at the dewpoint without entrained water. The mass flowrate of this stream and that of a stream of dry air are maintained at a ratio; humidification and mixing of these streams are performed at a specified temperature to produce a combined stream with the desired properties.

Continuous analysis of the effluent stream by mass spectroscopy proved to be impossible for our analyzer (Hewlett-Packard 5971) due to the high ion source pressure caused by the constant presence of nitrogen. To solve this problem we turned to rapid chromatography of relatively frequent (30-sec interval) samples of the stream. For our initial experiments on a stream containing CO_2 and water, a short (5 cm) packed column with an appropriate sorbent was used. The method we developed delays the entry of CO_2 and water into the detector until just after the N_2 plug exits. Using this method we achieved nearly

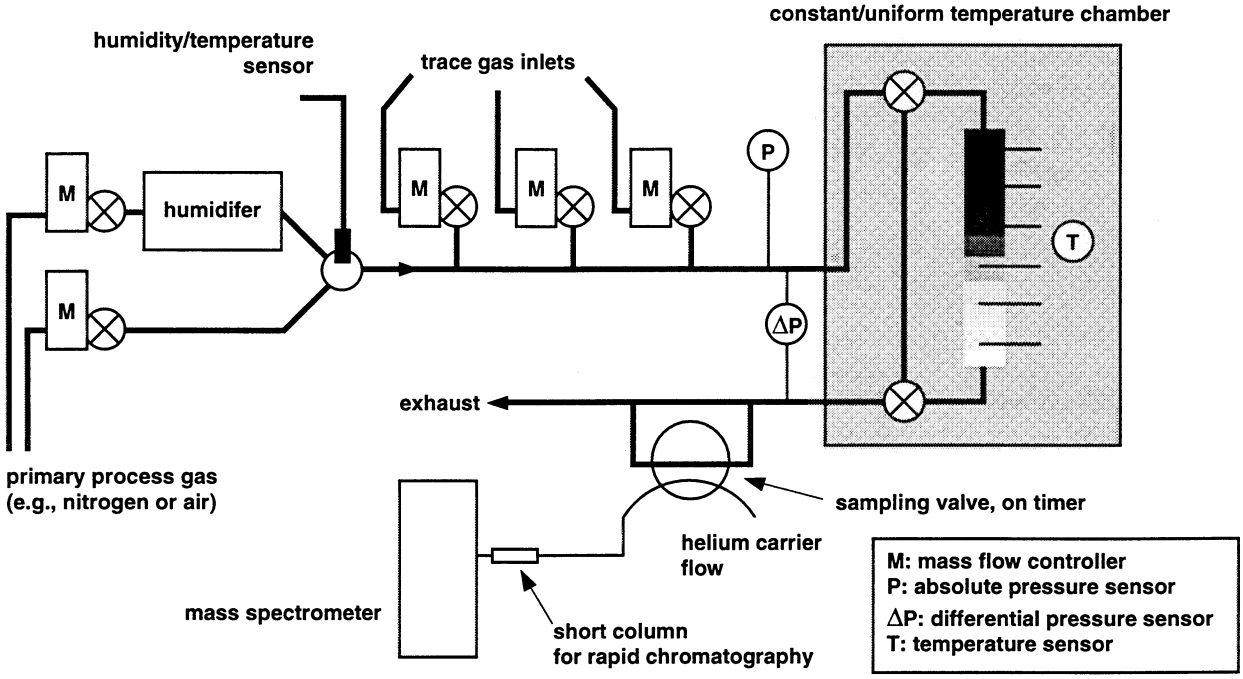

Figure 1. Simplified schematic of apparatus for studying adsorption column dynamics.

continuous process monitoring and very high sensitivities (<1 ppm).

Data acquisition from pressure and temperature sensors and control of the mass spectrometer are performed with one computer. Also, the equipment is designed so that adsorption columns being studied can be regenerated online and easily exchanged. Investigations of other gas processors, such as catalytic oxidizers, are easily performed on the same equipment.

Sample results from the apparatus are shown in figure 2. The figure shows the breakthrough of CO_2 from an adsorption column containing 13X zeolite molecular sieve (UOP, 1/16 in. pellets). The CO_2 concentration in the effluent is higher than that of the inlet by approximately 40% due to displacement of adsorbed CO_2 by water. This "rollup" effect, a result of strong interactions between water and CO_2 in the adsorbed phase, is one of several phenomena in air revitalization system design that are important to understand and simulate accurately.

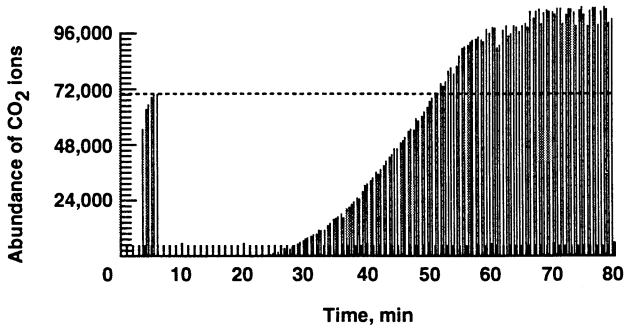

Figure 2. Carbon dioxide concentration in column effluent from a typical experiment: 0.5% CO_2, balance N_2 at 20°C and 42% relative humidity, 1,000 standard cm^3/min flowing through a 10 × 1.9 cm column of 13X zeolite molecular sieve. The figure shows abundance of mass 44 ions as a function of time in minutes. Peaks at start of run are samples of the column influent.

Modeling work

Significant progress in the numerical and modeling work was made by Prof. Bruce DeVantier. In particular, a finite element analog to the discrete dispersion relation finite difference method was obtained; the analog may allow more natural handling of boundary conditions and nonlinearities and is still being investigated.

Simulations using the model for adsorption from multicomponent gas streams produces large amounts of numerical information. This information is much easier to assimilate using scientific visualization

techniques. Ames' Advanced Graphics Laboratory assisted us by developing a tool for use on Silicon Graphics computer workstations. The tool animates the multiple waves that are solutions to the model equation, allowing one to easily see the consequences of interactions between adsorbed species.

Significance of the results

This work has produced several important results in both modeling and experiments. The modeling work provides the basis for high accuracy and computationally efficient simulations of multicomponent adsorption column behavior. The work is critical to safe and reliable operation of adsorption-based processors in life support systems for long-duration space missions. Because of its general nature, it can also be used for applications outside of life support.

The versatile apparatus constructed, which is essential to the continuing validation work on the models, required development of analytical methods for near-continuous process monitoring. The use of a mass spectrometer enables us to analyze a gas stream for many chemical species simultaneously with one analytical instrument and with very high sensitivity.

Publications resulting from study: None so far.

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Key words

Adsorption column dynamics, Finite difference, Air revitalization

Development of Modal Filtering Techniques for Online Estimation of Structural Vibration Parameters

Investigator(s)
Lawrence C. Freudinger,
Dryden Flight Research Facility
Edwards, CA 93523-0273

Other personnel involved
Stuart J. Shelley and Randall J. Allemang,
University of Cincinnati
Cincinnati, OH 45227-0072

Objectives of the study

Monitoring the dynamic characteristics of a vibrating mechanical system is currently a time consuming and expensive undertaking, but is often necessary from a safety or health maintenance perspective. A specific example familiar to the investigator is flight flutter testing and aeroservoelastic flight testing of aircraft. The objective of this work is to develop a new concept called discrete modal filtering for the purpose of monitoring the vibration characteristics of mechanical systems.

Discrete modal filters are essentially coordinate transformations that take advantage of certain properties of a mechanical system's vibrating shapes (modal vector orthogonality) in order to separate and condense measured information (sensor arrays) into less but more meaningful data. This concept can be exploited to improve the effectiveness of future online estimation schemes for vibrating systems.

Progress and results

Discrete modal filtering was successfully used to implement an online modal state monitor for a slowly time-varying truss structure. This online monitor was actually demonstrated at the International Modal Analysis Conference in February 1993, in the technology exhibit area. The demonstration utilized 47 response sensors and tracked a single mode with updates every 10 seconds. This demonstration served as proof-of-concept for online modal parameter monitoring using modal filters.

A study was subsequently undertaken to investigate the effect of modal filtering on the variance of the estimated modal parameters. However, it became apparent during the course of this study that meaningful comparisons were too difficult because the estimation algorithms that were being used could not provide variance estimates in a straightforward fashion.

An unexpected spinoff from this study was the necessary reformulation of classic experimental modal parameter estimation algorithms into a robust time domain algorithm that also produces empirical variance estimates for modal frequency and damping and is surprisingly simple to use. It is a null space approach which is related to a type of identification approach known as subspace identification. The study is continuing using the null space estimation algorithm.

As of this writing, investigations are ongoing to explore both practical as well as more esoteric aspects of discrete modal filters. First, discrete modal filters are being used in aircraft vibration tests and the results compared to established approaches. Second, the identification of feedback mechanisms using a model reference approach is under study as an application benefiting from the use of modally filtered data. Third, the identification of modal filters and subsequent updating based on new information is being reformulated in an H-infinity framework in order to incorporate uncertainties and to better understand overall observability of modal filters. Fourth, and perhaps most significantly, an unsolicited proposal seeking to implement modal filtering and distributed data processing options in commercially available data acquisition software has been recieved by NASA and is currently being considered. All these items are a direct result of reports and presentations made by the researchers on this project.

Significance of the results

The significance of the work started here is that experimental modal test methodologies of the future will likely incorporate online algorithms that use sensor array data that have been condensed to more manageable and meaningful information using discrete modal filters. Users of the new technology should be able to conduct vibration tests in much less time and, given improved data analysis tools in an online environment, assimilate the meaning of the measurements online as well. Some *Star Trek* fans cannot help but see this concept summarized many times on television via the phrase "*Captain! Sensor arrays indicate . . .*"

Publications resulting from study

Freudinger, Lawrence C.; Shelley, S. J.; and Allemang, R. J.: Online Parameter Estimation Using the Discrete Modal Filter. Final Report for NASA Ames Research Center University Consortium, Interchange NCA2-642, June 1992.

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Shelley, Stuart J.; Freudinger, L. C.; and Allemang, R. J.: Development of an Online Modal State Monitor. Eleventh International Modal Analysis Conference, Kissimmee, Fla., Feb. 1–4, 1993, pp. 173–183.

Freudinger, Lawrence C.; and Field, Richard V., Jr.: Null Space Pole Estimation with Error Bounds. Twelfth International Modal Analysis Conference, Honolulu, Hawaii, Jan. 31–Feb. 3, 1994.

Key words

Vibration mode, Spatial filtering, Modal response

Computational Modeling of Femtosecond All-Optical Switches Directly from Maxwell's Equations

Investigator(s)
Peter M. Goorjian, Ames Research Center, Moffett Field, CA 94035-1000
Allen Taflove, Northwestern University, Evanston, IL 60208

Other personnel involved
Rose M. Joseph and Susan C. Hagness, Northwestern University, Evanston, IL 60208

Objectives of the study

Intense activities are under way in photonics to develop all-optical switching devices. Experimenters have produced all-optical switches capable of 100-femtosecond responses using light pulses. Also, there are experimental observations of spatial soliton interactions, which could be used for optical switches. The applications are to advanced digital signal processors and optical computers. Optical processors are potentially 1,000 times faster than electronic computers. They are expected to be capable of 10^{13} operations per second, compared to 10^{10} operations per second of current electronic computers, such as the Cray-90. Optical signal processors could interface directly with ultrawideband optical fiber communications systems. The main development that is needed for optical circuits is to develop femtosecond all-optical switches and logic gates.

The need for a new algorithm to aid in this research is based on the following considerations. Laboratory construction alone without computer simulations would be prohibitively lengthy and costly. However, current methods, both computational and analytical, use the nonlinear Schrodinger Equation (NLSE), a scalar equation, to approximate Maxwell's equations, which are a system of vector equations. Hence the NLSE neglects the vector wave effects. Also the NLSE omits the optical carrier of the electromagnetic pulse. By using the full vector nonlinear Maxwell equations, the electromagnetic field can be more accurately modeled in applications to 2-D and 3-D integrated optical circuits with characteristic dimensions close to the optical wavelength, i.e., on the order of 0.1 to 10 optical cycles.

The objectives of this study are the following. The initial goal is to develop algorithms and computer codes for modeling femtosecond all-optical switches and logic gates on a 10-nanometer distance scale with the full-vector, nonlinear Maxwell equations. As part of this objective, a capability will be developed to model nonlinear optical materials, including linear and nonlinear, instantaneous and dispersive effects in the electric polarization in material media. The next step will be to develop a capability to model millimeter-scale 2-D and 3-D integrated optical circuits. In this stage the optical carrier of the electromagnetic field will be retained so that interactions of the pulses with geometry features on the size of the optical wavelength, such as material inhomogeneities, (e.g., crossing fibers), can be accurately modeled. The final step will be to use the codes to develop candidate designs for femtosecond all-optical switches, logic gates, and ultimately, integrated optical circuits. In addition, another application is being developed. Here modeling is being implemented into the codes for simulating the propagation of 50 to 100 femtosecond pulses in semiconductor lasers.

Progress and results

The first algorithm has been developed that solves the full-vector Maxwell equations in nonlinear dispersive optical materials. The modeling includes the optical carrier of a signal. Also the modeling includes the nonlinear quantum effects such as the Kerr and Raman interactions. A finite difference method is used to solve Maxwell's equations and also the ordinary differential equations that determine the linear and nonlinear dispersive effects.

The capability of the algorithm has been demonstrated by calculations using the 2-D vector nonlinear Maxwell's equations for propagating and scattering temporal and spatial solitons in material media having linear and nonlinear instantaneous and Lorentzian dispersive effects in the electric polarization.

Figure 1 shows the electric field of a propagating optical soliton carrier pulse in a dielectric waveguide. Notice that the pulse is not dispersing because of the nonlinear effects. A video of these calculations shows the optical cycles moving foward through the pulse because the phase velocity of the carrier wave is greater than the group velocity of the pulse. Figure 2 shows the collision of two equal-amplitude, counter-propagating solitons. After the collision, the two pulses regain their original shapes. Figure 3 shows the simulation of the parallel copropagation of two inphase, equal-amplitude spatial solitons. The separation provides the basis for an all-optical switching

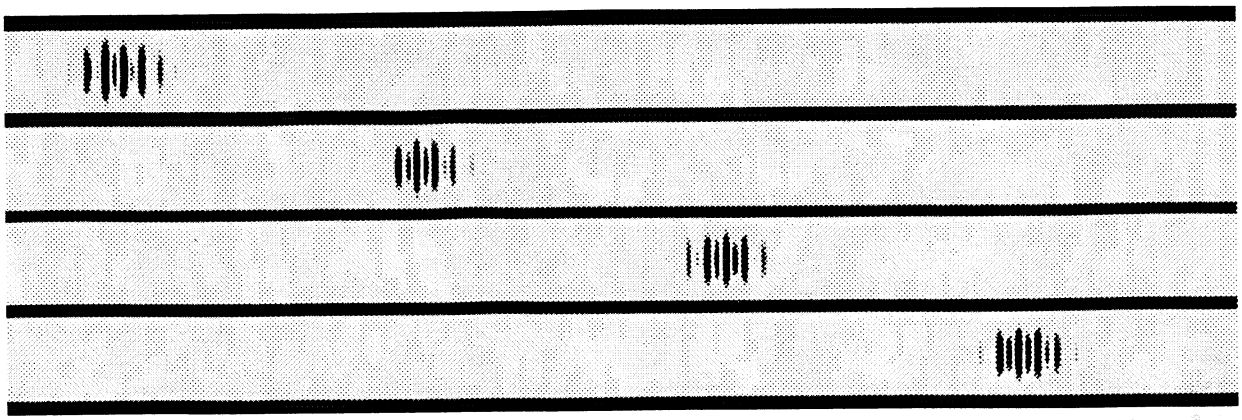

Figure 1. Electric field of a propagating optical soliton carrier pulse with initial hyperbolic secant envelope (λ = 2.19 μm, τ = 14.6 fs) in 1-μm thick Lorentz medium dielectric waveguide, including quantum effects such as the Kerr and Raman interactions.

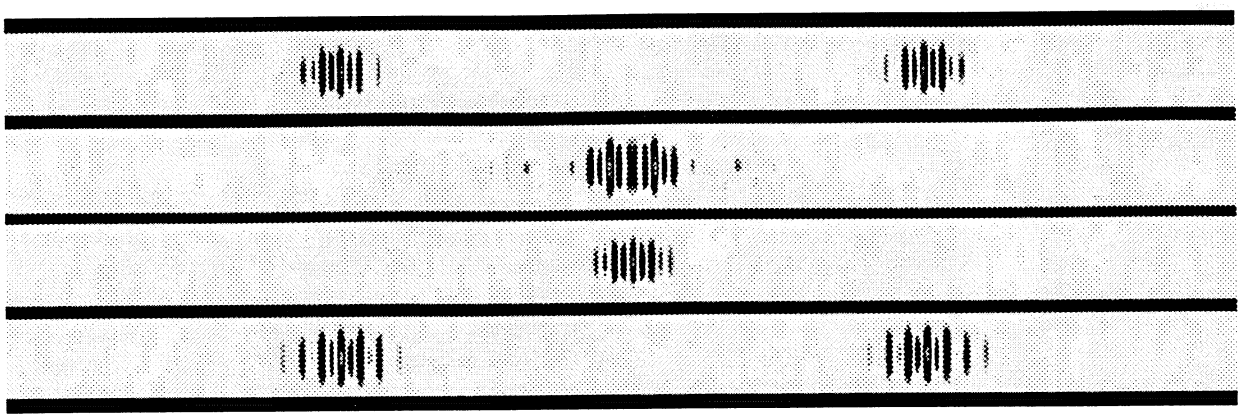

Figure 2. Electric field of colliding counter-propagating solitons corresponding to figure 1 (approaching, destructively interfering, constructively interfering, separating).

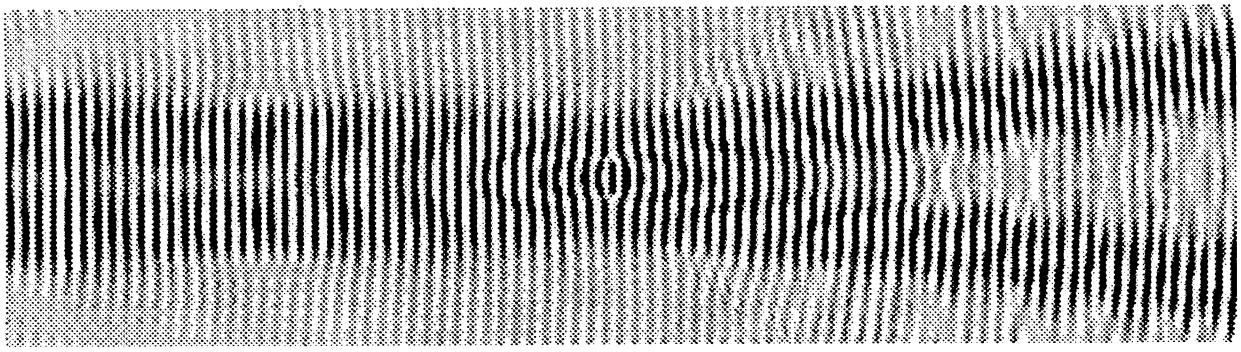

Figure 3. Electric field of two parallel, inphase, copropagating spatial solitons showing alternating attraction and repulsion interactions for a uniform dielectric medium having a finite nonlinearity.

mechanism because, without the second beam, a single beam will travel undeflected.

Significance of the results

These calculations of propagating and scattering temporal and spatial solitons show that this algorithm has the capability of modeling electromagnetic fields in nonlinear optical materials. The modeling is fairly complete in that it includes the optical carrier wave, the full vector electromagnetic field, and the quantum effects of the Kerr and Raman interactions. Upon further development of the geometric capabilities, this algorithm will be able to model optical devices such as optical switches. The resulting code can then be used in a design mode to aid the laboratory fabrication of such devices. Ultimately, this approach has the potential to provide 2-D and 3-D modeling capability for millimeter scale integrated optical circuits having sub-μm engineered inhomogeneities.

Publications resulting from study

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2. Goorjian, P. M.; Taflove, A.; Joseph, R. M.; and Hagness, S. C.: Computational Modeling of Femtosecond Optical Solitons from Maxwell's Equations. IEEE J. Quantum Electronics, special issue on Ultrafast Optics and Electronics, vol. 28, no. 10, Oct. 1992, pp. 2416–2422.
3. Goorjian, P. M.; Joseph, R. M.; and Taflove, A.: Direct Time Integration of Maxwell's Equations in 2-D Dielectric Waveguides for Propagation and Scattering of Femtosecond Electromagnetic Solitons. Integrated Photonics Research Topical Meeting, Optical Society of America and IEEE/Lasers and Electro-Optics Society, Palm Springs, Calif., March 22–24, 1993.
4. Goorjian, P. M.; Joseph, R. M.; and Taflove, A.: Calculations of Femtosecond Optical Solitons from the Vector Nonlinear Maxwell's Equations, Short Wavelength V: Physics with Intense Laser Pulses. Second Topical Meeting. Optical Society of America, San Diego, Calif., March 29–31, 1993.
5. Joseph, R. M.; Goorjian, P. M.; and Taflove, A.: Direct Time Integration of Maxwell's Equations in Two-Dimensional Dielectric Waveguides for Propagation and Scattering of Femtosecond Electromagnetic Solitons. Optics Letters, vol. 18, no. 7, April 1, 1993.
6. Goorjian, P. M.; Joseph, R. M.; and Taflove, A.: Calculations of Femtosecond Temporal Solitons and Spatial Solitons Using the Vector Maxwell's Equations, Nonlinear Guided-Wave Phenomena. Third Topical Meeting, Optical Society of America and IEEE/Lasers and Electro-Optics Soc., Cambridge, England, Sept. 19–22, 1993.

Key words

Computational nonlinear optics, All-optical switches, Femtosecond temporal and spatial solitons

Tension and Compression Effects of Cell Behavior

Investigator(s)
Rosalind A. Grymes and Christine Sawyer,
Ames Research Center,
Moffett Field, CA 94035-1000

Objectives of the study

Our experimental model system consists of mammalian cell cultures grown on flexible membranes in six-chamber array. Eight of these arrays can be accommodated in a baseplate assembly connected to a vacuum source. The vacuum draws the flexible membranes downward, creating a defined environment of uniaxial stretch that is transduced by the membrane to the layer of cells growing on the membrane. A solenoid provides rapid release of the vacuum to allow fast cycling. It is possible to reliably provide maximal stretch to this system at frequencies of 0.5 hertz. The membranes are impermeable to liquids and gases and are specially treated with an amino coating that permits attachment and spreading of anchorage-dependent cells. Figure 1 is a diagram of the deformation of the membrane and the resultant stretch.

Our objectives were to:

- Evaluate the effect of mechanical stretch on the growth of fibroblasts, studying a range of force inputs.
- Investigate potential interactions between growth factor response and the mechanical force stimulus.

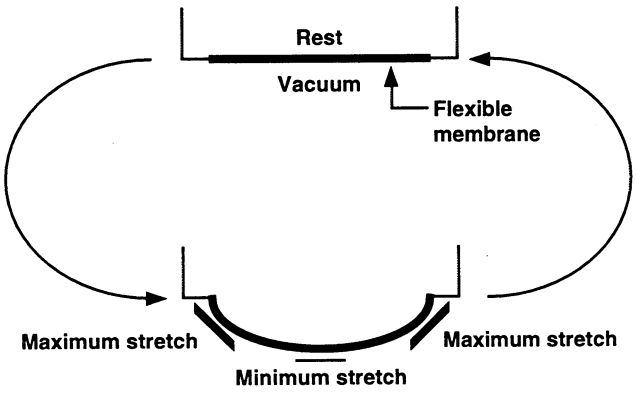

Figure 1. Deformation of the flexible membrane by applied vacuum, resulting in membrane elongation and stretch. Adapted from Banes, et al., American Biotechnology Laboratory, May 1990, pp. 12–22.

- Observe by photomicroscopy the progress of healing when wounds are created experimentally in two-dimensional layers of fibroblasts; is there an effect of added force on healing behavior?

In determining the response of normal dermal (skin-derived) cells to various regimens of applied mechanical stretch, we noted two significant, related behaviors. First, cells could be successfully cultivated over a wide range of protocols involving both static and cyclic stretch. The cultures exhibited no observable deterioration over the course of the experiment (up to seven days). Control cells were parallel cultures grown on the same flexible membrane material but backed by rigid polystyrene and not exposed to stretch. Both the stretched cultures and controls showed similar growth kinetics, measured by daily counts of actual cell numbers and by radionuclide labeling of newly synthesized DNA. However, we found that the behavior of stretched and control cultures became more and more similar in sequential experiments, regardless of the applied stretch protocol. In figure 2, the cumulative results of multiple stretch regimens are combined. The two curves, control and stretch, cannot be distinguished within one standard deviation. This adaptation is not related to the applied stretch; it is directed by adaptation of the cells to the flexible substrate. It is a result of the dynamic interaction between the cells and the flexible membrane, mediated by the ability of the membrane to resist intracellular tension generated by cytoskeletal structures—the internal support network that provides structure to the cell.

Progress and results

We next evaluated the ability of fetal dermal cells to respond to the soluble growth factor platelet-derived growth factor (PDGF) under conditions of applied cyclic stretch. Cell proliferation was followed as described above, by labeling newly synthesized DNA and counting cells. The stretch regimen used was 12.5 kPa of vacuum (translating to 20% maximal membrane elongation) at 6.67 cycles/minute. Under these conditions, the fetal cells demonstrated two very different behaviors, shown in figure 3, that depended on the application of stretch. In the mechanically active environment, the cells demonstrated an increased growth response, but this response was independent of the concentration of growth factor added. In addition, the proliferation response reached a set point

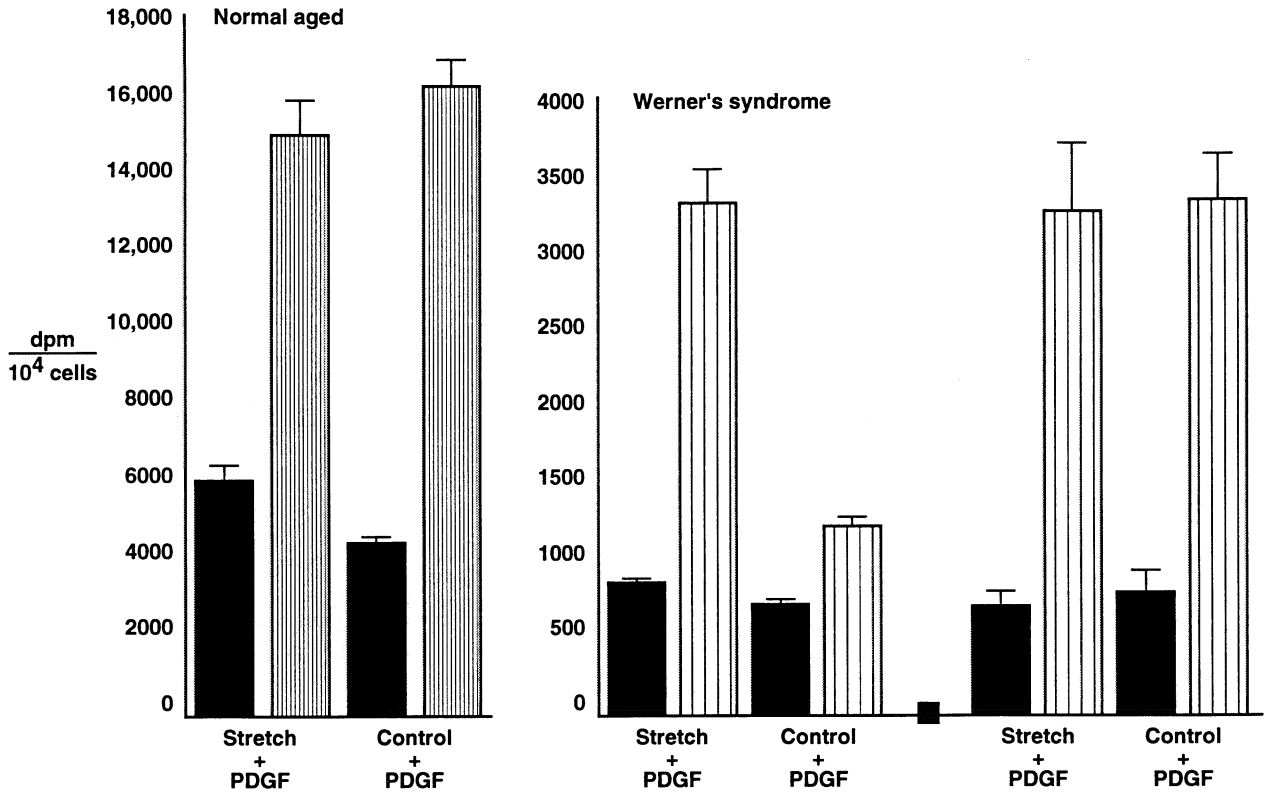

Figure 2. The graphic on the left shows the response of normal aged skin fibroblasts to both stretch and PDGF, applied separately or simultaneously. The y-axis value measures amounts of radioactive thymidine incorporated into newly synthesized DNA. The graphic on the right shows the results from two different and temporally sequential experiments on the Werner's syndrome cells.

and did not deviate from this point over the dose range tested (0–8 maximal units/ml). In contrast, the control cultures exhibited a normal response to PDGF, which rose linearly to a plateau. The half-maximal stimulation was achieved at approximately 2 maximal units/ml of PDGF. This value was approximately equal to the stretch-activation setpoint. Clearly, the cells used were capable of mounting a normal response to the growth factor applied and the concentrations of PDGF provided were adequate for maximal response. However, under the applied stretch regimen, these cells primarily responded to the stretch stimulus and not to the soluble growth factor. The two stimuli were not additive, in this case, and therefore appear to utilize different (although perhaps not isolated) intracellular signaling systems.

Using the information obtained in our preliminary experiments, we selected one stretch regimen and one concentration of PDGF for our continuing work. Normal aged dermal cells were compared with dermal cells derived from a subject with premature aging syndrome, Werner's syndrome. This genetically

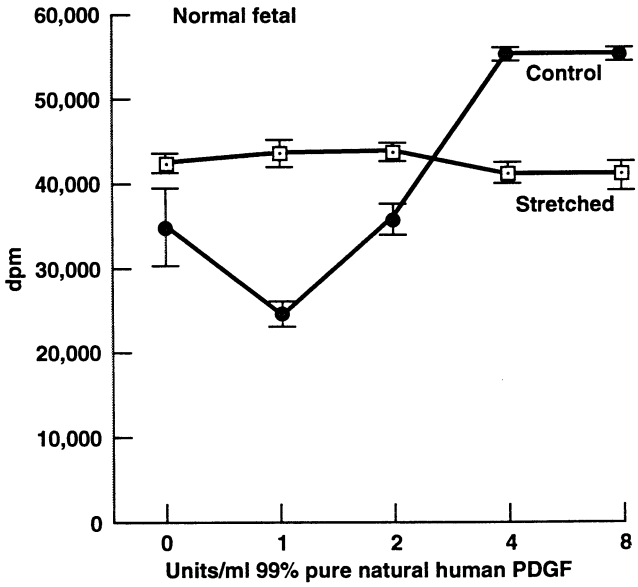

Figure 3. PDGF dose response of normal fetal dermal cells under conditions of stretch or absence of applied stretch (control).

acquired disease of accelerated aging is characterized in vitro by "nonresponsiveness" to PDGF. Experiments had previously demonstrated that the PDGF receptors on Werner's syndrome cells were normal in affinity and number and that the nuclear sequences required to transmit some secondary signals were normal. It was our intention to study the ability of the mechanically active environment to interact with the PDGF receptor pathway in these cells. Both cell types, normal and Werner's syndrome, were adapted to the flexible membrane substrate for at least three sequential passages prior to the initiation of these studies.

The first Werner's syndrome cell assay was surprising. Six hours after PDGF treatment and simultaneous application of stretch, these cells demonstrated a proliferative response to the growth factor only under the mechanically stretched condition. In this experiment we were also investigating many other parameters of cell growth and response, including the production of messenger RNA for the immediate early gene c-fos and its downstream target, collagenase type I (a enzyme critical for tissue remodeling processes). Only two chambers were dedicated to the DNA synthesis timepoint. We repeated the study, incorporating a protocol that designated six chambers to this analysis, and an additional three chambers to the direct cell counts. Once again, we observed a large response to the applied growth factor, under the stretched conditions only. Control chambers continued to demonstrate the same failure to respond that is classically associated with Werner's syndrome cells. Normal aged cells respond to the applied PDGF under either the stretched or static condition. In a third set of experiments, we again demonstrated the unique response of the Werner's syndrome cells to PDGF and applied stretch. Once again, however, we were surprised. In this last study, the Werner's syndrome cells also responded to PDGF by proliferating in the absence of applied stretch. We propose that this gradual shift in the ability of these cells to mount a mitogenic response to the soluble growth factor PDGF is part of the spectrum of cellular adaptation to the malleable substrate discussed above.

Significance of the results

The results of these studies are shown graphically in figure 4. In the mechanically active environment, where the stretch stimulus was present, Werner's syndrome cells are able to appropriately proliferate in response to PDGF. Over time, the dynamic interaction between the cells and their substrate is itself a powerful stimulus and results in an adaptive behavior that rewires the cell's internal signaling pathways and permits normal PDGF response to occur. The impact

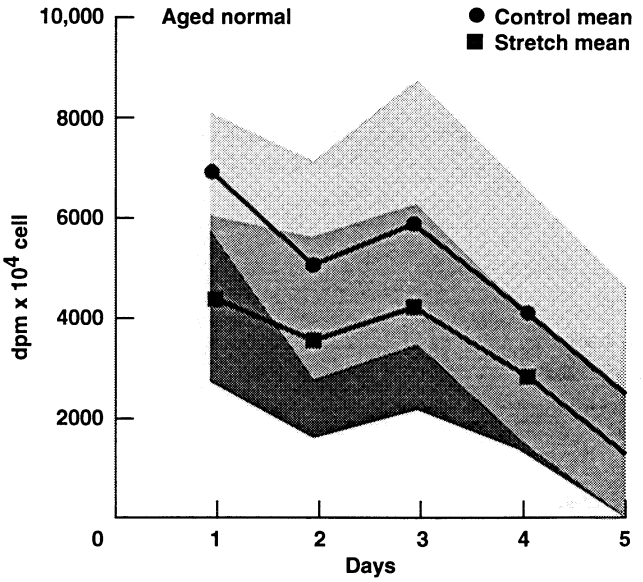

Figure 4. Cumulative results from multiple studies of different stretch regimens, using normal aged skin cells, demonstrate that the control and stretch cultures do not differ significantly from each other. They lie within one standard deviation of each other, as indicated by the shaded regions.

of tensional force balance participating in the regulation of cellular signaling has been discussed in the literature and demonstrated in isolated artificial systems. We have discovered a novel demonstration of the validity of these concepts. The central role of the cytoskeleton in the perception of stretch and the cell's response to stretch has been established, and we have determined that force perception/response behavior depends on an interconnected cell population of critical size. We believe that this model system will allow further experimentation on the mechanism of intercellular communication that permits individual cells to respond coordinately to applied environmental forces.

While pursuing another segment of our study, observing the regrowth of cell sheets after artificial "wounds" were created in the culture wells, we noted that the skin cells aligned their cell bodies parallel to the direction of applied stretch. In the circular wells, this response translates to a radial array of cells like the spokes of a wheel. We examined the nature of this behavior in several ways. First, we evaluated the impact of cell density on "orienteering." All cell strains examined, including skin fibroblasts of different chronological ages and corneal (eye) fibroblasts, require a specific minimum of cell-cell contact to initiate orienteering behavior. In the fetal cells, the requirement is particularly stringent. Sparse cell cultures fail to orient parallel to the applied stretch, and

dense cultures distribute the stretch across multiple cell bodies such that the perceived direction is an apparently nonlinear complex function. The application of drugs that depolymerize the cytoskeleton affect orienteering in a dose dependent fashion. We have found that low doses (62.5 ng/ml) of this drug do not seriously affect growth, but they inhibit orienteering and cause a weakening of the cytoskeleton that can be observed using immunofluorescence microscopy.

Publications resulting from study

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2. Grymes, Rosalind A.; and Sawyer, Christine: Dermal Fibroblasts in a Mechanically Active Environment. NASA-ARC Paper presented at the American Society for Gravitational and Space Biology, Oct. 1993.
3. Sawyer, Christine; and Grymes, Rosalind A.: Human Dermal Fibroblasts Orient in Response to Applied Stretch. Abstract submitted to Western Regional Society for Investigative Dermatology Meeting, Feb. 1994.

Key words

Physical forces and mammalian cells, Cell biology, Growth factor response

The Deuterium Abundance in the Interstellar Medium

Investigator(s)
Michael R. Haas and Alexander G. G. M. Tielens,
Ames Research Center,
Moffett Field, CA 94035-1000

Other personnel involved
Edwin F. Erickson, Ames Research Center,
Moffett Field, CA 94035-1000

Objectives of the study

Understanding the origin and evolution of the Universe is a fundamental problem in astrophysics. It is generally accepted that the Universe formed with a "Big Bang" at very high density and temperature. At that point, the Universe consisted of photons and various exotic elementary particles. Upon expansion and cool down, these particles decayed and/or combined and simple nucleons such as hydrogen and helium were formed. Upon further expansion, under the influence of their own gravity, these atoms formed stars and these stars then nucleosynthesized the heavier elements, such as C, N, O, and Fe.

The early Universe can be studied through its relics, the 3 K background radiation, and the relative abundances of the isotopes of H and He. Among the latter, deuterium stands out as the most powerful constraint because it is rapidly destroyed at high nucleon densities. Thus, the deuterium/hydrogen (D/H) ratio measures the time spent at high densities; i.e., the expansion rate of the very early Universe. The goal of this research is to infer the D/H ratio from observations of several rotational lines of HD and H_2 in gas that has only recently been heated by interstellar shock waves.

Although observations of many different deuterated molecules have already been made, the interpretation of these measurements is generally uncertain because the observed species are typically only minor reservoirs of deuterium and corrections for the unseen deuterium are substantial and largely unknown. This situation is contrary to that for warm (~500 – 2000 K), dense gas that has been heated by interstellar shocks. Here the deuterium chemistry is dominated by neutral-neutral reactions, in particular, $D + H_2 \rightarrow H + HD$. The conversion of D into HD by this reaction is much faster than the shock cooling time and all the deuterium is expected to be in the form of HD. Similarly, all the hydrogen is expected to be molecular. Since this shocked gas is warm, the emission is relatively strong, thereby presenting an excellent opportunity to probe the total gas phase deuterium abundance using observations of a single species. Hence, the detection of these HD transitions will yield the most direct determination of the D/H ratio to date.

Progress and results

We proposed to use the facility Cryogenic Grating Spectrometer (CGS) aboard the Kuiper Airborne Observatory (KAO) to observe several far-infrared transitions of HD and H_2 in the Orion molecular shock. This particular shock, which is believed to be associated with the embedded protostar IRc2, was chosen because it is nearby (~500 pc), has been well studied, and is relatively well understood. The temperatures and column densities of the shock-heated gas can be inferred from observations of high-J CO. We have completed a theoretical calculation of the predicted line intensities for the lowest lying rotational levels (quantum number J) of the $\upsilon = 0$ vibrational level for a two-component model with an H_2 column of 2×10^{20} cm^{-2} at a temperature of 2,000 K and an H_2 column of 4×10^{21} cm^{-2} at 750 K. The brightest lines are the 0-0 R(4), R(5), and R(6) transitions, which occur at wavelengths of 28.51, 23.03, and 19.43 μm, respectively. Fortuitously, the atmospheric transmission in the vicinity of all three of these transitions is extremely good at KAO altitudes (≥41,000 feet). These transitions should be detectable with the CGS, but will require careful observations because the strong dust continuum emission from the nearby Kleinmann-Low (KL) nebula sharply reduces the contrast in the lines.

The Si:Sb back-illuminated blocked impurity band (BIBIB) detectors originally proposed for and funded by this investigation are still the detectors of choice because of their extended long wavelength coverage (~40 μm) and excellent sensitivity. However, these detectors have not yet been procured because they are still under development at the Rockwell International Science Center and because of the time required to get a Purchase Request for items over $25,000 through the Ames procurement system. Preliminary discussions with procurement representatives occurred in late August 1992 and the initial Request for Proposal (RFP) was finally released to industry in March 1993. Only after receiving a response to this RFP did we fully appreciate the tremendous development cost of these detectors and realize that we could not support such an activity with the available funds. A major

problem is that the plate scale (13 in. mm^{-1} of the current CGS instrument) and the diffraction limited beam sizes achievable on the KAO telescope (5 in. at 20 μm) are incompatible with the relatively small pixel size (75 μm), which has become the de facto standard for the 128 × 128 BIBIB arrays and their associated cold multiplexers. Since there is no room in the CGS focal plane for the necessary reimaging optics and no chance of independently funding the requisite multimillion dollar development of custom hybrid arrays, we have chosen to concentrate on obtaining a one-dimensional array for the CGS and to pursue funding for a new KAO instrument that could take full advantage of the existing and anticipated two-dimensional arrays that are being independently developed with other funds. To this end, we have negotiated an arrangement with Rockwell and its prime contractor for the Si:Sb BIBIB development whereby we can obtain appropriate detector material at no cost. In this case, the only charge to us will be for the packaging and cryogenic testing of the desired detector assembly, which fits comfortably within our available DDF funding. The final details of this procurement are presently being worked out.

Because of the long delays in obtaining the desired Si:Sb BIBIB detectors, we have explored other avenues for meeting our present scientific objectives. We are currently installing a one-dimensional array of Si:As BIBIB detectors in the CGS, which are on loan from Rockwell. We have cloned our existing cold preamplifier design and have fabricated a 13-channel preamplifier for use with this detector set. We are currently scheduled to fly the Si:As BIBIBs aboard the KAO in early November 1993 to begin our observations of the Orion shock. Whereas the current Si:As BIBIBs are incapable of observing the important 0-0 S(0) line of molecular hydrogen at 28.2 μm or the 0-0 R(4) line of HD at 28.5 μm, both of which require the extended wavelength coverage of the Si:Sb BIBIBs, they are capable of observing the shorter wavelength (≤26 μm) 0-0 R(5) and R(6) lines of HD and the 0-0 S(1) line of H_2 with good sensitivity. However, because of the larger pixel size and the one-dimensional nature of this array, our spectral resolution and spatial coverage of the shock will be less than originally anticipated. Nevertheless, we feel that this configuration will permit us to detect several of the brighter HD lines in at least one position in the Orion shock (shocked molecular hydrogen peak 1).

Our discussions with Rockwell concerning the anticipated performance, development cost, and physical format of future two-dimensional midinfrared detector arrays has prompted us to consider building a new KAO instrument in order to more fully exploit this exciting technology. We have developed a preliminary design for such an instrument, which we have called the Ames InfraRed Echelle Spectrometer or AIRES. Relative to the current CGS, it will have improved spectral resolution (up to a factor of 15), slightly smaller spatial pixels, and imaging capability in the cross-dispersion direction. This instrument will include several options for reimaging optics, so that it can take advantage of a variety of different array formats as they become commercially available and thus obviate costly development of custom array formats. We are refining the AIRES design with the goal of making airborne observations in less than three years.

Publications resulting from study: None so far

Key words
Infrared detectors, Airborne astronomy, Deuterium, Molecular hydrogen

Determination of Polar Stratospheric Cloud Onset Over Antarctica Using Cloud Top Temperature Retrievals from the NOAA Advanced Very High Resolution Radiometer (AVHRR) Satellite Imagery

Investigator(s)
Steve Hipskind, Ames Research Center,
Moffett Field, CA 94035-1000
Kathy Pagan, San Francisco State University,
San Francisco, CA 94132
Steve Gaines, Sterling Software,
Ames Research Center,
Moffett Field, CA 94035-1000
Oswaldo Garcia and Patricia Foschi,
San Francisco State University,
San Francisco, CA 94132

Polar stratospheric clouds (PSCs) that form in the cold stratosphere over Antarctica play a crucial role in the destruction of ozone and lead to the formation of the ozone hole. Although many of the chemical processes involving PSCs and ozone depletion have been known for years, the actual timing of the onset and duration of PSCs and their geographic extent are not well understood. The objectives of this study are to determine whether advanced very high resolution radiometer (AVHRR) data can be used to detect PSC temperatures in the stratosphere over Antarctica and to differentiate them from the extremely cold Antarctic surface temperatures. In addition, the development of an automated PSC detection scheme will allow processing of a large volume of data in order to assemble a climatology of PSCs.

During the last year, AVHRR imagery covering the time period from April to October 1992 was obtained from the Arctic and Antarctic Research Center at Scripps. Several hundred images were processed using the Meteorological Satellite Downlink and Display System at Ames. The images were filtered and processed automatically using FORTRAN programs and script files developed specifically for this project. The minimum temperature was located in each image, and the temperature range in which PSCs are likely to form were highlighted. The areal extent of the PSC temperature range was calculated using ERDAS software. This initial processing of the data showed that temperatures within the PSC range could be detected using AVHRR imagery.

The problem that remains is to differentiate the imagery between the temperatures at which PSCs can form and the cold surface temperatures present in Antarctica. The use of surface temperature data from the Antarctic Automatic Weather Station Data network, NMC soundings, and temperature and aerosol extinction coefficient data from the CLAES instrument aboard the Upper Atmosphere Research Satellite (UARS) satellite has resulted in the ability to distinguish thicker PSCs from surface or lower cloud cover in a sampling of the imagery. These results can be incorporated into more sophisticated PSC detection algorithms.

AVHRR data has been shown to be useful in detecting the optically thick PSCs, and with the use of ancillary data, they can be distinguished from cold surface temperatures. By building upon these initial results, a long term climatology of PSCs can be constructed, since AVHRR provides excellent temporal and spatial coverage of the polar regions on a daily basis.

Work during the second year of this project will focus on the detection of optically thin PSCs. The radiance temperatures of these PSCs are affected by the radiation upwelling from below, making classification by temperature alone impossible. A preliminary attempt using multispectral imagery to determine a unique feature space for PSCs proved useful. Traditional multispectral analysis, textural analysis, and filters that focus on local differences will be tested. In addition, new analyses and filters will be developed as needed. Information from these analyses will be combined using a rule based approach to develop a classification scheme for detection of optically thin PSCs.

Initial results of this project were presented at the HSRP/AESA annual review meeting at Virginia Beach in June 1993. Commitments for presentation included: the DDF poster session on November 9, 1993, at NASA Ames, a presentation in conjunction with J. Mergenthaler, A. Roche, and J. Kumer from Lockheed Research Lab at the AGU annual meeting in San Francisco in December 1993, an Earth Science Pre-Lunch seminar at NASA Ames on December 15, 1993, a seminar at Lockheed Research Lab for the CLAES group in the fall of 1993, and a presentation at NASA

Ames Birds of a Feather image analysis group on January 5, 1994.

Key words
Polar stratospheric clouds, AVHRR, Satellite imagery, Remote sensing, Image analysis

Real-Time Automated Diagnosis System for the Ames Research Animal Holding Facility

Investigator(s)
David L. Iverson and Stephanie Herrin,
Ames Research Center,
Moffett Field, CA 94035-1000

Other personnel involved
Lilly Spirkovska, Ames Research Center,
Moffett Field, CA 94035-1000

Objectives of the study

Formal reliability analyses, such as failure modes and effects (FMEA), fault tree, or digraph analyses, are performed on many engineered systems. These analyses contain a wealth of information that can be used to help build automated diagnosis systems. A significant amount of effort can be saved by using reliability analysis information to build a diagnostic system since much of the knowledge engineering required for such a system will be done by the reliability engineers while performing the analysis.

In order to take full advantage of the information contained in these reliability analyses, appropriate knowledge representations and reasoning techniques must be used. The objectives of this study were to improve knowledge engineering and automated monitoring and diagnosis technology by developing general techniques for constructing automated diagnosis systems using information from reliability analysis models.

One system that has benefited from this work is the Ames Research Animal Holding Facility (RAHF). The RAHF is a Spacelab module that is used to house and monitor animals in orbit so the effects of space flight and microgravity can be studied. A detailed Matrix FMEA reliability analysis was performed on the RAHF by the Ames Flight Equipment Engineering Branch (SPD). With further research into the use of reliability analyses for automated diagnosis, the information contained in the RAHF analysis has been put to work for RAHF payload support personnel by developing an automated system to help detect, identify, diagnose, and repair problems that may occur in the RAHF system.

Progress and results

In the first year of research we devised a systematic method for converting Matrix FMEA reliability models into object-oriented diagnostic knowledge bases. The structured approach of the Matrix FMEA method facilitates knowledge base construction. A diagnostic knowledge base was built from the SPD RAHF Matrix FMEA for use with the Fault Tree Diagnosis System (FTDS) developed in the Ames Spacecraft Data Systems Research Branch (FIS). This knowledge base was designed in a modular fashion and it can be updated to accommodate different RAHF configurations.

During the second year, we developed a telemetry monitoring system that uses rule based and model based techniques. The system monitors RAHF telemetry in real time to detect anomalies in the RAHF systems. The telemetry monitoring and diagnosis systems were integrated to allow immediate diagnosis of any detected failures. Fault detection methods included in the RAHF Matrix FMEA provided connections between the monitoring rules and the diagnosis system. The FTDS was augmented to provide recovery advice for diagnosed failures using information from RAHF payload malfunction procedures manuals, RAHF system experts, and the RAHF FMEA analysis.

The monitoring and diagnosis systems were combined with a graphical user interface that displays RAHF telemetry parameters in an easily comprehended format. The complete Real-Time Automated Diagnosis (RAD) system was tested with RAHF telemetry from the SLS-1 mission and SLS-2 training simulations. RAD was then installed in the NASA Marshall Space Flight Center Payload Operations Control Center and the NASA Ames SLS Telemetry Monitoring Area for use by payload operators and engineers during the SLS-2 mission in October 1993. RAHF personnel made extensive use of RAD to monitor the status of two RAHFs onboard Space Shuttle Columbia and the rodents housed in those RAHFs. RAD will also be used for postflight analysis of archived telemetry data.

Significance of the results

This research has produced general techniques for using traditional reliability models for automated diagnosis. With these techniques, an automated monitoring and diagnosis system can be produced for any system that undergoes a Matrix FMEA analysis. This system saves a great deal of time and expense that can instead be devoted to knowledge acquisition and knowledge engineering activities. Our studies have also provided insight on how reliability analysts can modify their analyses to further facilitate diagnostic

reasoning by including information such as failure detection methods, criticalities, and recovery procedures.

Publications resulting from study

This work was published in the Proceedings of the Sixth International Conference on Industrial and Engineering Applications of Artificial Intelligence and Expert Systems by Gordon and Breach Science Publishers. The conference was held in Edinburgh, Scotland, on June 1–4, 1993.

Key words

Monitoring and diagnosis, Matrix failure modes and effects analysis, Reliability modeling

Stratospheric Aerosol Particulates: Simulation of Their Morphology, Physical Properties, and Chemistry

Investigator(s)
Richard L. Jaffe, Ames Research Center,
Moffett Field, CA 94035-1000

Objectives of the study

It is believed that nitric acid-water aerosols play an important role in the chemistry of polar stratospheric clouds (PSC) that are responsible for the formation of the ozone hole at polar latitudes during the early spring. The aerosol mechanism involves the conversion of chemically inactive forms of chlorine (such as HCl) to active forms (Cl_2 and HOCl) on the surfaces of micron-sized nitric acid-water droplets that comprise the PSC. The properties and chemistry of these aerosols are not well understood. Laboratory measurements have generally not accurately reproduced the ambient conditions and in situ measurements are difficult.

A new approach for studying the morphology and properties of nitric acid-water aerosols is to use molecular simulation techniques. First the nature of the interaction between nitric acid and water molecules is deduced from ab initio quantum chemical calculations. Then atomistic classical mechanics simulations of ensembles of nitric acid and water molecules are carried out. Both the bulk and surface structures of these molecules can be ascertained. Finally, simulations of collisions between HCl molecules and the aerosol surface will be carried out to study the gas-surface kinetics. From these calculations, the sticking coefficient can be determined.

Progress and results

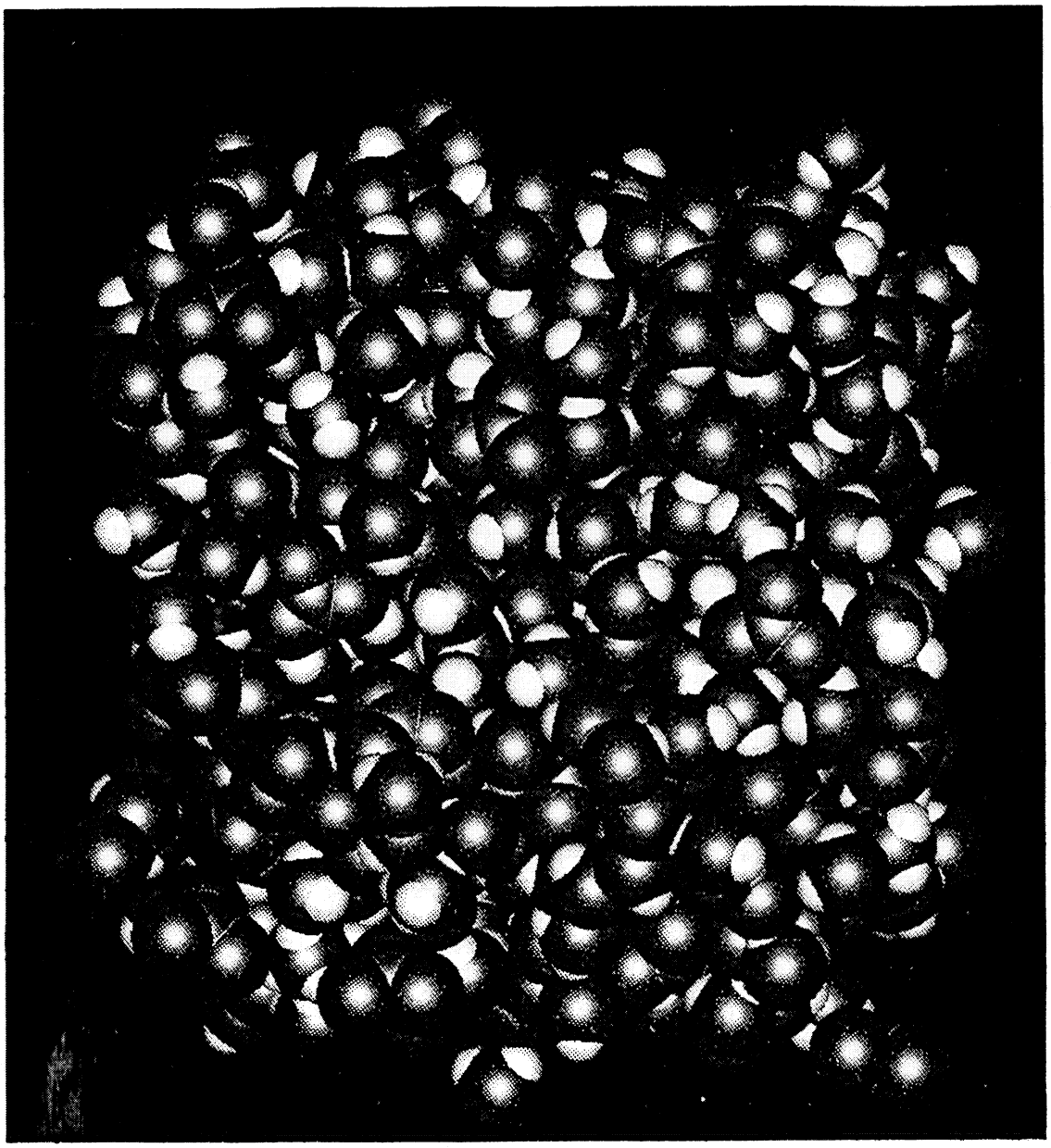
Progress has been slower than anticipated because of unforeseen limitations in the commercial software package selected for this work. During the 18-month period of this project, potential energy functions for nitric acid-water systems have been determined. These include representations for both charge-neutral species and ion pairs ($NO_3^- \cdot H_3O^+$). The bulk structures of crystalline and amorphous ensembles of charge neutral molecules and ion pairs corresponding to nitric acid trihydrate (NAT) and nitric acid monohydrate (NAM) have been determined. These are the two prevalent forms of hydrated nitric acid in aqueous solution and in ice. The NAT and NAM ensembles consist of 125 nitric acid molecules and the appropriate number of water molecules at densities corresponding to experimental values (1.6–2.0 g/cm^3). For these conditions, each ensemble occupied a cubic box of dimension 25.3 Å. A computer generated drawing of a typical NAT ensemble is shown in the figure. Further studies to elucidate the phase diagram for these systems must await the availability of a new release of the simulation software (scheduled for January 1994).

Significance of the results

The results of these simulations will be used to help make connections between experimental measurements on NAT films and in situ measurements of PSCs. It is not known if the NAT-water ice particles present in PSCs have the same properties and reactivities as the NAT films generated in laboratory experiments. Simulations can be carried out for both conditions to bridge the gap between these two sets of data.

Key words

Nitric acid trihydrate, Polar stratospheric clouds, Polar ozone hole



Computer generated drawing of a typical NAT ensemble.

The Use of Molecular Fossils for the Interpretation of Paleoenvironments

Investigator(s)
Linda L. Jahnke, Ames Research Center, Moffett Field, CA 94035-1000

Other personnel involved
Elaine Munoz, Ames Research Center, Moffett Field, CA 94035-1000
Tsegereda Embaye, San Jose State University, San Jose, CA 95192

Objectives of the study

The most important biological influence on the evolution of this planet was the development of oxygenic photosynthesis. This process, which evolved within a group of photosynthetic bacteria, transformed Earth's atmosphere from an anaerobic to an oxygen-rich one. However, clear paleobiological evidence of the timing of this transition and the biochemical evolution that led to it is lacking. Recent technical advances in the microanalysis of organic matter have made it possible to detect residual molecules (biomarkers) in proterozoic (2.5 to 0.6 billion years) sedimentary rock characteristic of specific groups of microorganisms. Biomarker analysis is proving to be a powerful tool for decoding the record of ancient biochemistry found in the geological record; however, further information about the biomarkers of photosynthetic organisms is necessary to fully interpret information about the evolution of oxygenic photosynthesis present in sedimentary rocks.

Two types of photosynthesis are carried out by bacteria, anoxygenic and oxygenic. Anoxygenic photosynthesis is more primitive and involves conversion of a reduced compound such as hydrogen sulfide to elemental sulfur or sulfate. With oxygenic photosynthesis, the evolution of a more complex electron transport system allows conversion of water to molecular oxygen. Whereas all cyanobacteria can grow by oxygenic photosynthesis, some are also able to grow by anoxygenic photosynthesis; they are referred to as facultative cyanobacteria. Facultative cyanobacteria are thought to be an evolutionary model for the development of oxygen-evolving photosynthesis from the more primitive anoxygenic types.

This study addresses the need to more fully understand the synthesis of a type of biomarker molecule, the hopanoids, in photosynthetic bacteria, and any relationship that the presence of these biomarker molecules might have to the evolution of oxygenic photosynthesis.

Progress and results

Initial work involved the growth of several types of photosynthetic bacteria and development of methods for the isolation and identification of any hopanoid molecules present in these organisms. Four marine, purple photosynthetic bacteria (anoxygenic types) were grown and any isolated hopanoid identified by gas chromatography-mass spectrometry (GC-MS). Of the four types only one organism, *Rhodospirillum salexigens*, contained any appreciable amount of hopanoid, the C32 hopanol (fig. 1), which is common to the freshwater strains of purple photosynthetic bacteria. The others, *Rhodobacter sulfidophilus* and two strains of *Rhodopseudomonas marina*, contained only trace amounts of hopanoid. Further work on the influence of oxygen on the synthesis of hopanol in *Rs. salexigens* demonstrated that only slightly less hopanol was synthesized when cells were grown aerobically in the dark as compared to photosynthetically in the absence of oxygen.

Work was also initiated with several cyanobacteria either known to or thought to be capable of anoxygenic photosynthesis. A facultative cyanobacterium isolated from a sulfide-rich hot spring in New Zealand, *Oscillatoria amphigranulata*, was obtained from R. Castenholtz (University of Oregon). Although this organism did contain hopanoid material, the growth rate of this organism was deemed too slow to be a potential candidate for anoxygenic growth experiments. Further work was, therefore, carried out to characterize two new cyanobacterial isolates from a sulfide-rich microbial mat found at Guerrero Negro,

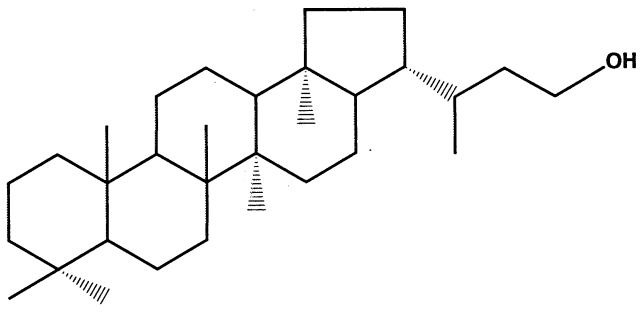


Figure 1. Structure of the C32 hopanoid isolated from marine purple photosynthetic bacteria.

Baja California Sur, Mexico. We have found that both cyanobacteria, a *Pseudanabaena* sp. and a *Oscillatoria* sp., are capable of photosynthetic conversion of carbon dioxide to cell material using either water (oxygenic) or hydrogen sulfide (anoxygenic) as the electron donor. Hopanoids were isolated from both organisms, and growth rates were vigorous. The *Oscillatoria* sp.was also found to be capable of anoxygenic photosynthetic growth using reduced carbon substrates as a source of electrons and carbon (this process is referred to as photoheterotrophy). This process allowed for anoxygenic photosynthetic growth of this organism without consideration of the toxic effects associated with the use of sulfide. We found that the lipid biomarkers characteristic of oxygenic photosynthesis were also present in cells grown anoxygenically. Further work on the influence of sulfide on the growth of these two cyanobacteria and the synthesis of hopanoid molecules is anticipated.

Significance of the results

Marine ecosystems have played a major role in deposition of organic matter both in the present and in the Proterozoic. The characterization of C32 hopanoids in *Rs. salexigens* (principally a saltern organism) but not in *Rb. sulfidophilus* or *Rp. marina* (characteristic of marine benthic communities) demonstrates that the purple phototrophs are not a good source of these biomarker molecules in the latter marine environments. The marine cyanobacterial isolates from Guerrero Negro contained considerably greater quantities of the hopane biomarkers in this study. In the case of *Rs. salexigens*, the isolation of hopanoids from cells grown under both aerobic and anaerobic conditions corroborates the theory that oxygen is not required for synthesis of this molecule and that the presence of hopanoids in sedimentary organic matter should not be equated with the presence of oxygen-utilizing organisms.

The initial studies to characterize the nature of the photosynthetic potential of the Guerrero Negro isolates will provide a basis for future work, not only on the influence of anoxygenic photosynthesis on hopanoid and other biomarker molecules, but also on the evolution of phototrophic bacteria and oxygenic photosynthesis. The versatile metabolic capability of the *Oscillatoria* GN sp. clearly points to the significance of microbial mat communities and the importance of studying the constituent organisms to gain insights for development of evolutionary models depicting paleoenvironments.

Publications resulting from study

Jahnke, L. L.; and Munoz, E.: Characterization of Two Facultatively Anoxygenic Cyanobacteria Isolated from a Hypersaline Microbial Mat. Abstracts of the 93rd General Meeting of the American Society for Microbiology, 1993, p. 253.

Key words

Photosynthetic bacteria, Molecular fossil

Flight Measured Wall Pressure Fluctuations Beneath Swept Shock/Boundary-Layer Interactions

Investigator(s)
Steven A. Johnson,
Dryden Flight Research Facility,
Edwards, CA 93523-0273

A proposed research experiment titled "Flight Measured Wall Pressure Fluctuations Beneath Shock/Boundary-Layer Interactions" has been initiated and funded under the NASA Ames Director's Discretionary Fund Program. Funding for the proposed experiment began June 7, 1993.

The author and principal investigator for the experiment is Steven A. Johnson at the NASA Ames-Dryden Flight Research Facility located at Edwards, California.

The goal of the proposed study is to assess the acoustical loads generated by a swept shock/boundary-layer interaction in a flight environment (free of wind tunnel turbulence) and to gain a better understanding of the physical mechanisms involved in their generation. Such an understanding is the first step in any attempt to control or limit acoustic loading on flight vehicles. Also, more fundamentally, the interaction unsteadiness is critical in formulating physically accurate flow models and interpreting existing data.

Since funding was awarded last June, much has been accomplished. The flight hardware has been designed and fabricated. A prototype signal conditioning card has been designed and fabricated. In addition, 12 ultraminiature high response Kulite transducers and two power supplies have been procured.

In fiscal year 1994, a complete benchtop checkout of the integrated system is planned—including flight hardware, power supplies, signal conditioning, and data acquisition. After the systems operation is successfully demonstrated, a series of four high speed flights will be carried out using the newly acquired NASA F-15B as the carrier aircraft.

Key words
Unsteady pressures, Shock/boundary-layer interactions, Flight research

Pyrosensors for the Detection of Chemical Compounds in Planetary Environments

Investigator(s)
Dan Kojiro and Thomas C. Shen,
Ames Research Center,
Moffett Field, CA 94035-1000

Other personnel involved
H. Coufal, IBM Almaden Research Center,
San Jose, CA 95120

Objectives of the study

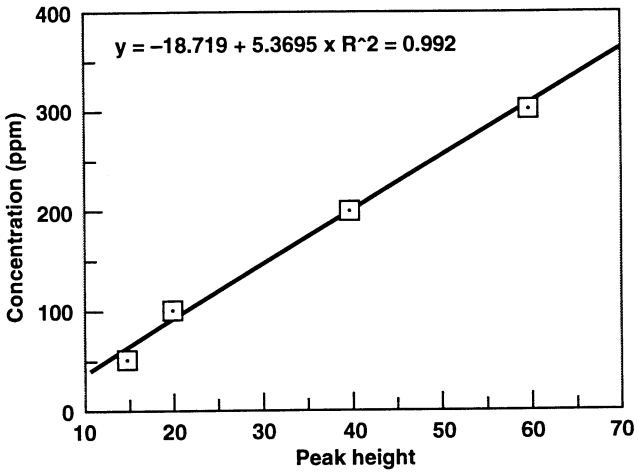
To develop pyrosensors for determination of the possible oxidant in the Martian soil.

Progress and results

There are two approaches using the pyroelectric principle in determination of chemical compounds in solution. In the first approach the heat generated by an exothermal or endothermal chemical reaction and sensed by a pyrosensor allows for the continuous quantitative detection of some substances.

In the second approach, the sample absorbs energy and the heat generated travels to the nearby sensor, which is not in the path of the laser light. This heat creates an electric signal that is measured and translated into an analytical concentration.

We have applied the first approach and design to construct our own pyrosensors. The sensor provides a very stable baseline and demonstrates that hydrogen peroxide concentration can be determined from 40 to 300 ppm with a reasonable calibration curve, as shown in the figure. In recent collaboration with H. Coufal, IBM Almaden Research Center, Calif., the sensor was shown to be sensitive to 100 nJ of energy. Using this sensor, hydrogen peroxide concentrations can be detected as low as 1 ppm in a 50 µL sample size with 300 mV signal amplitude.



Calibration curve for hydrogen peroxide.

Significance of the results

A sensor with sensitivity of 100 nJ of energy was developed. Using this sensor, hydrogen peroxide concentrations can be detected as low as 1 ppm in a 50-µL sample size with 300-mV signal amplitude.

Publications resulting from study

Shen, Thomas; and Kojiro, Dan: Pyrosensors for Analyzing Oxidants on Martian Soil. ACS Meeting, Denver, Colo., 1993.

Key words

Pyroelectric, Pyrosensor, Hydrogen peroxide

Practical Evaluation of a New Method to Reduce Helicopter Rotor Hub Loads

Investigator(s)
Sesi Kottapalli, Ames Research Center,
Moffett Field, CA 94035-1000

Objectives of the study
The objectives of this research study are

1. Design a root based torsional damper based on analytical results.
2. Fabricate a root torsional damper or set of dampers with parametric variations in damping.
3. Bench test the root torsional damper to obtain data to substantiate the payoff of this approach.

These proposed objectives form a risk reduction program, the culmination of which would be to draw up plans for a full-scale wind tunnel test. The wind tunnel test is not a part of the current proposal. However, subsequent to a successful bench test, the follow-on activity will fall outside of that supported by the Director's Discretionary Fund.

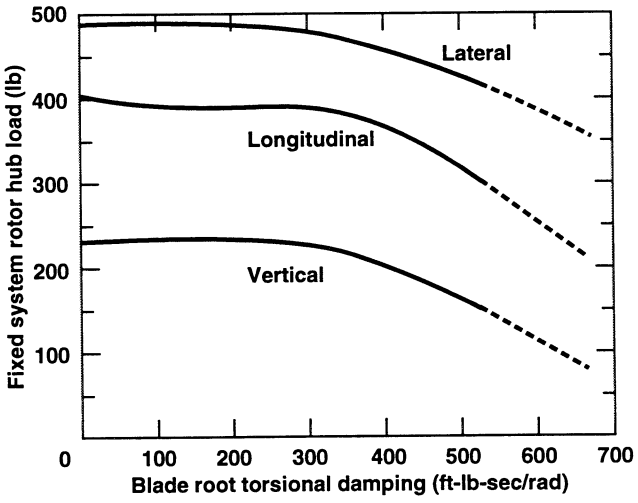
Progress and results
It is analytically predicted that for the helicopter considered (S-76), rotor hub loads will be uniformly reduced in all three directions simultaneously by the application of blade root torsional damping, as shown in the figure.

Significance of the results
The analytical results are very encouraging. The next step will be to initiate design of the root torsional damper and take preparatory steps toward its fabrication.

Publications resulting from study

Kottapalli, S.: Blade Root Torsional Dampers to Reduce Hub Loads. AIAA 33rd Structures, Structural Dynamics and Materials (SDM) Conference, Dallas, Tex., AIAA Paper 92-2449, April 1992.

Key words
Blade root torsional damping, Rotor hub loads, Helicopter, Rotorcraft vibration



Rotor hub shear variation with blade root torsional damping for S-76, 160 knots airspeed, 10,000 lb thrust.

Stanford-NASA Ames Cooperative Program in Global Change

Investigator(s)
James G. Lawless and Philip B. Russell,
Ames Research Center,
Moffett Field, CA 94035-1000
Gary Ernst, Stanford University,
Stanford, CA 94305

Other personnel involved
Marc L. Imhoff, Pamela Matson,
David DesMarais, Gregory H. Rau,
Robert Chatfield, John Vastano,
Thomas A. Blake, Charles Chackerian, Jr., and
James R. Podolske, Ames Research Center,
Moffett Field, CA 94035-1000
Carolyn Malmstrom, Harold Mooney,
Manuel Lerdau, Peter M. Vitousek,
Margaret Bac, James C. Ingle, Lilliana Borceau,
Joseph Oliger, Michael D. Di Rosa,
Ron Hanson, Rachel Freifelder, and
David U. Hooper, Stanford University,
Stanford, CA 94305

Objectives of the study

The purpose of the Stanford-NASA Ames Cooperative Program in Global Change is to bring together the unique skills and facilities available at Stanford and Ames to answer key questions on the functioning of the Earth's atmosphere and ecosystems, especially as impacted by human activities. Most of the DDF funds have been used to support a variety of research tasks carried out by students under the joint advisorship of Stanford and Ames scientists. The remainder of the funds helped support a joint seminar series conducted at Stanford and Ames.

A subsidiary objective was to identify proposal opportunities through which continued funding could be obtained for the Stanford-Ames Program or for joint research tasks.

Progress and results

The following research tasks were funded:

- Surface coatings, varnishes, and subsoil structures in deserts as indicators of global climate change.
- Numerical flow simulation study for inflight atmospheric sampling measurements.
- Influence of temperature on soil carbon pools.
- Remote estimation of vegetation biomass using airborne synthetic aperture radar (AIRSAR).
- Regional CO_2 flux in Hawaiian ecosystems: 1958-1986.
- Ecosystem-level controls on the emissions of nonmethane hydrocarbons (NMHC) from vegetation.
- Molecular and isotopic characteristics of ocean carbon: implications for global variability of atmospheric and oceanic CO_2.
- A one-box chemical model for trace species in the atmosphere.
- Prototype development for an ultrasensitive OH detector.
- Grass invasions, deforestation, and climate change in the seasonally dry tropics.
- The effects of plant functional group diversity on nutrient cycling in a California serpentine grassland.

Several of these tasks are complete and have resulted in Ph.D. theses (see Publications, below). Others are still in progress, to be completed in FY94 using the funding in Joint Research Interchange NCA2-768. This work will be described in the Joint Research Interchange (JRI) Final Report, which is due December 1994.

The seminar series was used both to bring a number of distinguished speakers to Stanford and Ames and to provide an opportunity for Stanford and Ames researchers to inform the combined Stanford/Ames community of their research.

Significance of the results

The results of the above research tasks, some of which are still in progress, are diverse. However, they all address the factors that control the biogeochemical cycling of carbon, nitrogen, and other elements in terrestrial and marine ecosystems and the atmosphere, and the impact of human activities on them. Improved understanding of this cycling is key to advancing our ability to predict how human activities and natural processes will interact to determine future climate changes and the ability of human civilization to adapt to this change.

Initially it was hoped that a source of funds could be found to block-fund continued operations of the Stanford-NASA Ames program. Although such a source has not been identified (and hence a

block-funding proposal was not written), many useful collaborations were developed, and they are expected to lead to proposals targeted at specific research tasks in response to future solicitations (e.g., NASA Research Announcements).

Publications resulting from study

Bac, Margaret: Molecular and Isotopic Characteristics of Oceanic Carbon: Implications for Global Variability of Atmospheric and Oceanic CO_2. Ph.D. Thesis, Stanford University, in progress.

Borceau, Lilliana: The Application of DAE Solvers for Advanced Atmospheric Chemistry Modeling. M.S. Thesis, Stanford University, 1993.

DiRosa, Michael D.: Development of an Ultrasensitive OH Detector. Ph.D. Thesis, Stanford University, in progress.

Freifelder, Rachel: Microclimate Change and Fire Following Forest Grass Conversion in Seasonal Dry Tropical Woodland. M.S. Thesis, Stanford University, 1993.

Hooper, David U.; and Peter M. Vitousek: Effects of Plant Functional Group Diversity on Nutrient Cycling in a California Serpentine Grassland. Bulletin of the Ecological Society of America. Supplement, vol. 74.2, 1992, p. 280.

Imhoff, Marc L.: Remote Estimation of Vegetation Biomass Using AIRSAR. Ph.D. Thesis, Stanford University, 1993.

Lerdau, Manuel; Litvak, M.; and Monson, R.: Plant Chemical Defense: Monoterpenes and a Growth-Differentiation Balance Hypothesis. Trends in Ecology and Evolution, vol. 9, no. 2, Feb. 1994.

Lerdau, Manuel; Dilts, S.; Allwine, E.; Westberg, H.; and Lamb, B.: Monoterpene Emissions from Ponderosa Pine. J. Geophys. Res., in press.

Lerdau, Manuel; and Penuelas, J.: Los Monoterpenos (in Spanish). Mundo Cientifico, vol. 13, 1993, pp. 61–64.

Lerdau, Manuel: Ecological Controls Over Monoterpene Emissions in Conifers. Ph.D. Thesis, Department of Biological Sciences, Stanford University, 1993.

Lerdau, Manuel: Contributed paper on Non-methane Hydrocarbon Emissions Controls in Conifers. First IGAC Scientific Conference. Biosphere–Atmosphere Interactions, Eilat, Israel, Apr. 1993.

Lerdau, Manuel: Contributed paper on Ecosystem and Physiological Controls Over Biogenic Non-methane Hydrocarbon Emissions, Ecological Society of America, Annual Meeting, Madison, Wis., Aug. 1993.

Townsend, Alan R.: Influence of Temperature on Soil Carbon Pools. Ph.D. Thesis, Stanford University, 1993.

Windeler, Don: Spectral Mineral Mapping of Scarns and Hornfelses of the Yerrington District, Nevada, Using Airborne Multispectral Imagery. M.S. Thesis, Stanford University, 1993.

Key words

Global change, Biogeochemical cycles, Atmosphere, Biosphere interactions

The Study of Ozone Depletion Chemistry Using Ab Initio Quantum Mechanical Methods

Investigator
Timothy J. Lee, Ames Research Center,
Moffett Field, CA 94035-1000

Other personnel involved
Julia E. Rice, IBM Almaden Research Center,
San Jose, CA 95120
Celeste M. Rohlfing, Sandia National Laboratory,
Livermore, CA 94551
Alistair P. Rendell, Daresbury Laboratory,
Warrington, England

Objectives of the study

Extensive documentation of the destruction of the ozone layer, especially over the Antarctic, has been obtained over the past 16 years. Much has been learned about the mechanisms involved in the formation of the Antarctic ozone hole, and yet there remains considerable chemistry of chlorine, fluorine, bromine and nitrogen oxides that is not understood. Until recently, ab initio quantum chemistry has contributed little to the understanding of atmospheric chemistry. To a large extent, this is because low-level ab initio quantum mechanical methods are not very reliable for molecules that contain several electronegative atoms bonded together. However, in the last 5 to 8 years considerable progress has been made in the development of highly accurate and much less expensive methods. The objectives of this study were twofold. First, we proposed to study the chemical reactions involved in ozone depletion with special emphasis on the chemistry that takes place in the Antarctic ozone hole. Initially, chlorine oxides of chemical formulas Cl_2O_2 and Cl_2O_3 were targeted, but other important and potentially important Cl reservoir species, such as ClOOH, have also been investigated. The second objective was to demonstrate that the newly developed high-level ab initio methods are capable of yielding very accurate results for molecules composed of several electronegative atoms bonded together, and therefore are capable of providing important understanding and data in the study of atmospheric chemistry. An initial high-level ab initio study of three isomers of Cl_2O_2 was completed in the first year of this project, and the results of this investigation demonstrated beyond doubt that the newly developed ab initio methods are capable of attaining the very high accuracy required for the study of molecules that are of atmospheric interest. Therefore, the second year of this DDF project has focused on the study of important chemical species and chemical reactions taking place in the formation of the ozone holes. One example is the protonation reaction of chlorine nitrate ($ClONO_2$), which is thought to be a possible mechanism for elimination of $ClONO_2$ by heterogeneous reaction on the surfaces of polar stratospheric clouds (PSCs).

$$H^+ + ClONO_2 \rightarrow ClONO_2H^+ \quad (1)$$

As we had previously studied the protonation reactions of $HONO_2$ and CH_3ONO_2, the results of which suggest the importance of reaction (1), the thermochemistry of reaction (1) was studied. In addition, the structures, vibrational spectra, and thermochemical stability of other chlorine oxides have also been investigated.

Progress and results

The study of the thermochemistry of reaction (1) showed that indeed the most stable form of protonated chlorine nitrate is a complex between NO_2^+ and HOCl, demonstrating how $ClONO_2$ may be depleted in the Antarctic ozone hole. That is, $ClONO_2$ will react on the surface of PSCs via a proton catalyzed mechanism. Formation of the HOCl . . . NO_2^+ complex is quickly followed by reaction of NO_2^+ with the companion anion, possibly OH^- (forming HNO_3, which then remains adsorbed to the PSC and is later transported out of the stratosphere when the PSC "falls") or NO_3^- (forming N_2O_5, which readily reacts with H_2O to form HNO_3, etc. . . .). The ab initio study also provided explanations for why nitric acid/ice compositions that are high in nitric acid are less reactive toward $ClONO_2$ (the proton affinity of HNO_3 is larger than that of $ClONO_2$, and therefore the protons are less accessible to $ClONO_2$), and why elevated concentrations of HOCl are observed in the Antarctic ozone hole (formation of the complex leads to some HOCl escaping back to the gas phase). Hence, our computational study together with experimental studies performed by Professor Mitchio Okamura at the California Institute of Technology have provided convincing evidence of the importance of the proton catalyzed mechanism, along with a detailed description of the specific mechanism.

We have also been concerned with the identification of molecules that act as Cl reservoir species in the

Antarctic nighttime, as well as in other stratospheric environments in which radiation from the Sun is filtered (such as at certain latitudes). One possible species that has been identified is ClOOH. The ab initio study on this species showed that it is thermally quite stable to simple dissociation pathways, i.e.,

$$ClOOH \rightarrow ClO + OH + \Delta E_2 \quad (2)$$

$$ClOOH \rightarrow ClO + OH + \Delta E_3 \quad (3)$$

$$ClOOH \rightarrow ClO + OH + \Delta E_4 \quad (4)$$

with ΔE_2 and ΔE_3 determined to be 33.4 and 31.4 kcal/mol, respectively. As there is no experimental information available for ClOOH, its molecular structure and vibrational spectrum were also determined in order to aid in laboratory identification. Note that the reverse of reactions (2) and (3) serve as "ozone depletion termination steps." Given the concentrations of Cl and OOH in the Antarctic ozone hole during the springtime, when ozone depletion is actively taking place, it seems likely that the concentration of ClOOH will become high during the periods of reduced radiation from the Sun. Concentrations of ClO will also be high, but the concentration of OH is generally considered to be much lower and so the reverse of reaction (2) may not be as important. Nonetheless, it seems evident that ClOOH will readily form, and it is therefore important to determine the possible photodissociation of ClOOH. This study is in progress.

We have also identified two low-lying isomers of Cl_2O_3, which may be viewed as arising from the two lowest energy structures of Cl_2O_2 by replacing a terminal Cl atom with a ClO group. These two isomers may be written as ClOOOCl and $ClOClO_2$. Given that the most likely stratospheric reactants for formation of Cl_2O_3 are ClO + OClO, it would seem that the $ClOClO_2$ isomer is probably of more interest in atmospheric chemistry. Note that formation of $ClOClO_2$ is also an "ozone depletion termination step."

The molecular structure, vibrational spectrum and thermodynamic stability of other chlorine oxides, such as ClNO, $ClNO_2$, and cis- and trans-ClONO have also been investigated in order to fill gaps in the experimental data, to resolve some discrepancies, or in some cases to correct erroneous interpretations of experimental data.

Significance of the results

The investigation of the protonation reaction of chlorine nitrate has produced a detailed description of the most likely mechanism for the depletion of $ClONO_2$ in the Antarctic ozone hole and has provided explanations for the increased concentrations of gas phase HOCl and the reduced reactivity for HNO_3/ice compositions containing high concentrations of HNO_3. The ClOOH study has shown that ClOOH is indeed thermally quite stable and that it is likely to be present in the stratosphere as a Cl reservoir species, particularly in the Antarctic and Arctic nighttimes, where it could possibly be a major Cl reservoir species due to its formation from "ozone depletion termination reactions." These studies have certainly enhanced our understanding of atmospheric chemistry, and whereas it may be some time before we attain a complete understanding of the Earth's atmospheric chemistry, it is clear that computational chemistry, because of its relatively low cost and suitability for the study of unstable species (for which laboratory studies are often very dangerous if not impossible), has much to offer.

Again, the most significant conclusion from these studies is that ab initio quantum mechanical methods have clearly been shown to yield very accurate structures, vibrational spectra, and thermodynamic information for molecules composed of several electronegative atoms—the type of molecule that is most prevalent in the upper atmosphere. The results thus far demonstrate that the study of atmospheric chemistry through the use of quantum mechanical methods is very informative and a useful complement to experimental studies.

Publications resulting from study: First year

1. Lee, T. J.; and Rice, J. E.: FONO: A Difficult Case for Theory and Experiment. J. Chem. Phys., vol. 97, 1992, p. 4223.
2. Lee, T. J.; Rohlfing, C. M.; and Rice, J. E.: An Extensive Ab Initio Study of the Structures, Vibrational Spectra, Quadratic Force Fields and Relative Energetics of Three Isomers of Cl_2O_2. J. Chem. Phys., vol. 97, 1992, p. 6593.

Publications resulting from study: Second year

1. Lee, T. J.; and Rice, J. E.: Ab Initio Study of the Chlorine Nitrate Protonation Reaction: Implications for Loss of $ClONO_2$ in the Stratosphere. J. Chem. Phys., vol. 97, 1993, p. 6637.
2. Lee, T. J.; and Rendell, A. P.: Ab Initio Characterization of ClOOH: Implications for Atmospheric Chemistry. J. Chem. Phys., vol. 97, 1993, p. 6999.
3. Lee, T. J.: A Coupled-Cluster Study of XNO (X = H, F, Cl): An Investigation of Weak X-N Single Bonds. J. Chem. Phys., in press.

4. Lee, T. J.: Ab Initio Characterization of $ClNO_2$, cis-ClONO and trans-ClONO. J. Phys. Chem., in press.
5. Lee, T. J.: A Coupled-Cluster Study of HNO_2 and FNO_2. Chem. Phys. Letters, in press.

Key words
Atmospheric chemistry, Chlorine oxides, Chlorine nitrate

Surface Shear Stress Measurement Using Liquid Crystal Polymers

Investigator(s)
B. G. McLachlan and J. H. Bell,
Ames Research Center,
Moffett Field, CA 94035-1000
M. L. Brandes and M. Gouterman,
University of Washington, Seattle, WA 98195

Objectives of the study
Assess the feasibility of using liquid crystal polymer (LCP) film coatings for surface shear stress measurement in aerodynamic testing.

Progress and results
1. A prototype benchtop flow chamber was designed and constructed to evaluate coating response to shear stress.
2. The study demonstrated quantitative birefringent response of LCP coatings to aerodynamic shear stress.
3. Thermal noise of the imaging array (CCD sensor) was identified as a significant problem in measurement apparatus.
4. A number of trial LCP coatings were produced and tested.

Significance of the results
The feasibility of using the birefringent response of LCPs as the mechanism to measure aerodynamic shear stress fields was demonstrated. The significance of our LCP approach is that it does not suffer the drawbacks of the present shear stress field measurement methods (oil film interferometry and low mass liquid crystals) and has other advantages in comparison to them.

Publications resulting from study: None so far

Key words
Aeronautical sensor, Aerodynamic shear stress measurement, Liquid crystal polymer

Investigations of Supersonic Combustion Using Unique NASA Ames Facilities

Investigator(s)
Gene P. Menees, Ames Research Center, Moffett Field, CA 94035-1000
Jean-Luc Cambier and Henry G. Adelman, Thermosciences Institute, Ames Research Center, Moffett Field, CA 94035-1000

Objectives of the study

To demonstrate how some unique Ames experimental facilities, combined with new, state-of-the-art computational capabilities, can be used to investigate some key problems in supersonic combustion and hypersonic propulsion. The approach is therefore composed of several components. An array of codes will be used to help analyze various aspects of the flow. Notably, a new code for the simulation of nonequilibrium arc-jet flows will be developed and validated. It will be used in particular to predict the flow features in the Direct Connect Arc-Jet Facility (DCAF) in order to correctly estimate the contamination and nonequilibrium effects during the flow expansion. It will also be coupled to a radiation code, which analyzes the molecular and atomic emission and absorption features, along a line of sight. This method will allow us to examine the potential of various nonintrusive diagnostic methods. The proposed work also includes conceptual studies of propulsion experiments to be conducted in the DCAF. These proposed experiments will aim at answering some key questions in supersonic mixing and combustion, and will investigate new propulsive concepts. Engineering analyses, experiment design, test plan, and preliminary cost estimates will be performed.

Progress and results

The first objective was to obtain an accurate, reliable computational fluid dynamics (CFD) capability for the simulation of arc-jet flows. Preliminary analysis of existing codes showed some important deficiencies in the capabilities, the numerical methods, or the modeling assumptions. For example, existing codes assume the same value of temperature for vibrational and electronic excitation modes, equal to the temperature of free electronics. This assumption is not necessarily valid, and the validity of it depends on the density of free electrons. Additionally, there is no accounting for radioactive recombinations, nor the energy loss through volumetric emission. Finally, we need to develop a code with the capability to model all aspects of the arc-jet flow, including the high-temperature arc region. We can then interface with a combustion code for the modeling of the experiment itself. Therefore, new codes have been written to accurately model all aspects of the arc-jet flow. The principal component is a nonequilibrium plasma code named Mahler, which uses a detailed thermochemical model of the plasma. Notably, each electronic state can be convected separately, allowing for non-Boltzmann distributions of excited states. This feature is important in expanding flows. The coupling between chemistry and other excitation modes is made in a completely consistent way: for example, the average vibrational energy removed during dissociation is allowed to vary with both translational and vibrational temperature, and is related to the energy replaced during recombination through the detailed balance principle. This unique model allows for the chemical processes alone to restore thermal as well as chemical equilibrium. This important physical characteristic is not possible with previous models used by other researchers. Other codes are being developed to focus on other aspects of the arc-jet flow, or to provide more approximate but more efficient simulations. For example, another version treats the plasma as a two-fluid model and could be used for the simulation of the arc itself.

The Mozart combustion code is being upgraded to include a generalized grid embedding technique and a two-equation turbulence model, which will allow us to model newly proposed fuel injector designs, principally the Spiralling Struts and their complex geometries. In preparation for these studies, a simulation of the flow field, from the nozzle throat to the injectors, has been completed. Boundary layer thickness and heat transfer to the combustor walls have been predicted.

Significance of the results

The progress made in modeling of nonequilibrum phenomena will allow us to model the complete arc-jet facility with great accuracy, from the arc region to the nozzle expansion and the combustion experiment. It will also allow us to estimate precisely the effects due to thermal and chemical nonequilibrium on hypersonic combustion flows.

Publications resulting from study

Cambier, J-L.; and Moreau, S.: Numerical Simulation of a Molecular Plasma In A Collisional-Radiative Nonequilibrum. 24th AIAA Plasma Dynamics Conference, Orlando, Fla., July 1993. AIAA Paper 93-1985.

Cambier, J-L.; and Moreau, S.: Validation of a TVD Plasma Code with Collisional-Radiative Nonequilibrium. 25th AIAA Plasma Dynamics Conference, Colorado Springs, Colo., June 1994.

Key words

Arc-jet, Supersonic combustion

Mixing, Combustion, and Thrust Enhancement by a Pulsed Detonation Wave Augmentor

Investigator(s)
Gene P. Menees, Ames Research Center, Moffett Field, CA 94035-1000
Jean-Luc Cambier and Henry G. Adelman, Thermosciences Institute, Ames Research Center, Moffett Field, CA 94035-1000

Objectives of the study

To investigate the use of unsteady waves in a supersonic combustor (scramjet) in order to enhance the mixing and combustion rates. In this concept, blast waves are produced at the end of small detonation tubes embedded in the combustor walls, and they propagate into the main combustor stream. The interaction between the strong pressure waves and the mixing layer stimulates the formation of mixing vortices, while shock heating of the mixture allows for very rapid combustion. The detonation tubes are rapidly cycled and triggered in sequence. The concept of a Pulsed Detonation Wave Augmentor (PDWA) can lead to significant improvements in scramjet engine performance.

Progress and results

Preliminary computational fluid dynamics (CFD) studies of various generic engine configurations were performed in order to estimate the effectiveness of the concept and to identify the key elements for future parametric studies. The numerical simulations were performed using a two-dimensional, time-accurate Navier–Stokes code, coupled to the full chemical kinetics of hydrogen-air combustion. Two configurations were studied. The first one, named "transverse coupling," used a detonation tube with small holes on the side. Blast waves can be generated at these holes from the high pressure region behind the detonation wave. The emitted blast waves then interact with a free mixing layer in a supersonic combustor. This configuration was effective for strong blast waves, but it suffered from relatively large stagnation pressure losses. The problem stems from the presence of high pressure sources at fixed locations, which had the effect of generating strong oblique shocks within the supersonic combustor (see fig. 1). Reducing the overpressure in the detonation tube reduced these losses, but it also reduced the effectiveness of the blast waves in increasing the mixing and combustion.

The second configuration, "axial coupling," simply used a shorter tube, and the blast wave was generated at its exit, from the decay of the detonation wave. After diffraction at the tube exit, the wave could then interact with a free mixing layer. The advantage of this concept is that most of the high pressure flow is directed downstream in the combustor. As expected, the stagnation pressure losses are now much smaller. The efficiency of this device at promoting mixing and combustion is also observed to be very good. As the blast wave diffracts at the tube exit, the mixing layer is compressed and heated by the passage of the wave. This reaction triggers an immediate combustion of the fuel in that region. The fuel layer is then pushed by the blast wave, and starts to roll up. This process creates regions of large vorticity as well as a stretching of the mixing interface, both being beneficial features for mixing enhancement. Further heating and ignition takes place at various locations during the interaction between this single pulse and the mixing layer. These features can be seen in figure 2, which shows a time sequence of the temperature contours (up to 275 microseconds from the time at which the detonation wave reaches the tube end). It is important to notice that there is no strong, steady oblique shock generated by the pulse and that the fuel layer is considerably altered by the passage of the shock structure.

A detailed examination of the flow also revealed an interesting phenomenon. As the shock moves through the fuel layer, interface instabilities are seen to develop. These are the Richtmyer-Meshkov instabilities, which are known to promote mixing between driver and driven gas, for example, during shock tunnel operation. The same effect can be put to good use here, since it is our goal to accelerate the mixing process. This effect occurs for unsteady shock waves only, and for waves propagating normal to the fuel-air interface. This effect can be contrasted with the more conventional baroclinic effect, which operates only when pressure and density are misaligned. Another feature that was observed in both configurations studied was the existence of a transmitted shock within the fuel layer, which could propagate faster than all other flow structures. This feature is possible because of the very high speed of sound in the pure fuel (H_2). This feature may be of interest in other applications, notably external combustion.

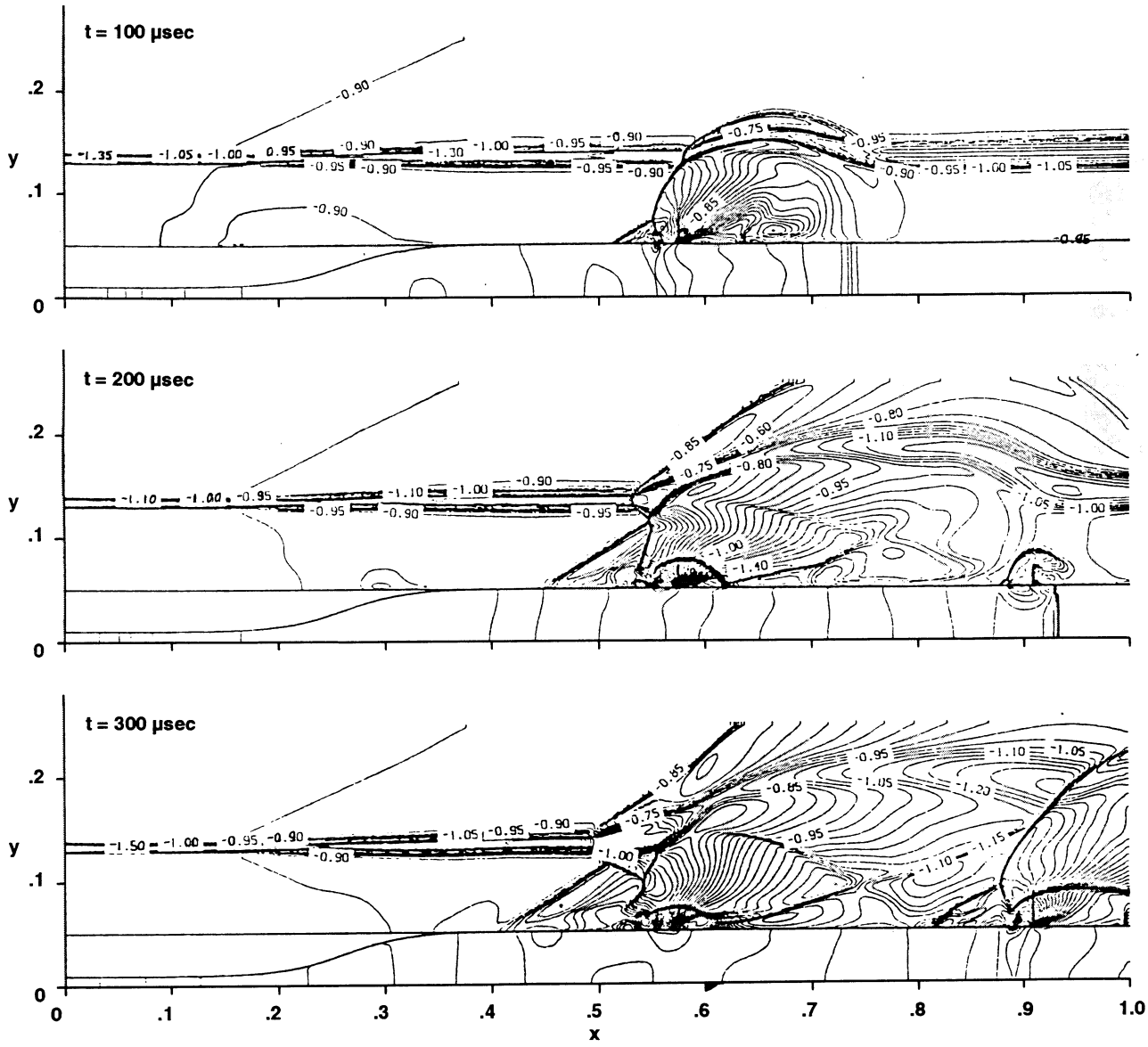


Figure 1. Shock structure for the PDWA in transverse coupling mode. Blast waves generated at the side vents in the detonation tube interact with the free mixing layer in the supersonic combustor. A complex pattern of strong shocks is generated as a result.

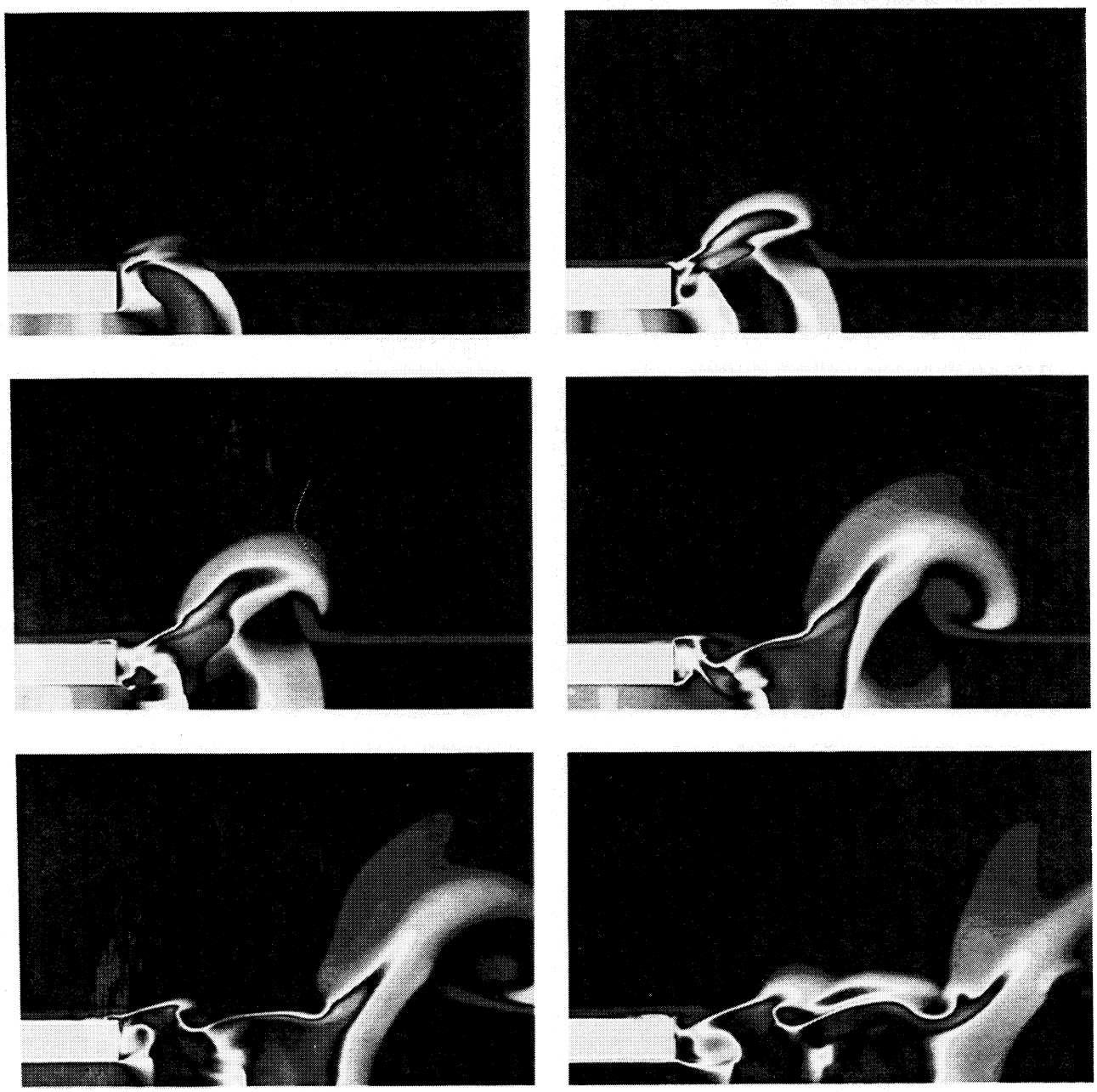


Figure 2. Time sequence of temperature contours. PDWA operation. Rapid combustion is seen in frame 2 (75 microseconds). Fuel layer is seen to rollup and breakup. Strong mixing vortices are generated.

Significance of the results

The PDWA concept was designed with the following goals: enhancement of the mixing, acceleration of the combustion, and thrust increase, with minimal losses and high efficiency. The preliminary computational results show that these goals can be simultaneously achieved with careful choice of the design configuration. The thrust enhancement comes from the detonation wave itself, which is a very efficient propulsive mechanism (near-constant volume combustion). The detonation can be directly initiated, in the appropriate mixture, with very small electrical power requirements. Rapid cycling of the tube is possible, and it is made more effective by a series of tubes fired in sequence. The mixing and combustion enhancements are clearly demonstrated by the numerical simulations. It is clear that the concept has enormous potential, and it should be verified experimentally, as well as theoretically, through a progressive series of tests and more detailed numerical simulations. Variations of the PDWA concept can also be considered and applied, for example, in stimulated external combustion or nozzle combustion. If successful, the PDWA concept can lead to significant improvements in hypersonic air-breathing engine performance.

Publication resulting from study

Cambier, J-L., et al.: Numerical Simulations of a Pulsed Detonation Wave Augmentation Device. 29th AIAA Joint Propulsion Conference, Monterey, Calif., AIAA Paper 93-1985, June 1993.

Key words

Scramjet, Mixing enhancement, Detonation, Thrust augmentation

Ablating Surface Heat Transfer Estimation for Flight Application

Investigator(s)
Greg Noffz and Mike Bowman,
Dryden Flight Research Facility,
Edwards, CA 93523-0273

Objectives of the study

Flight vehicles can be instrumented with subsurface thermocouples such that inverse analysis procedures can yield useful estimates of surface heat transfer. If the vehicle has an ablating heat shield, however, temperature time histories from subsurface thermocouples no longer provide enough information to estimate heat flux at the surface. This situation arises because the problem geometry is changing and thermal energy is leaving the surface with the ablation products. An ablator recession rate is now required to estimate heat transfer to the surface.

This research effort has concentrated on developing a capacitive gage concept in which the ablator has a dielectric effect on the capacitor's fringe region. Relying on a capacitor's fringe region enables the gage to be flush mounted in the vehicle's permanent structure and not intrude into the ablative heat shield applied over it. Our goal is to develop this concept into a gage(s) capable of measuring the recession of low temperature ablators that are applied in thin (0.020–0.060 in.) layers.

The work has been concentrated in two main tasks. First, candidate gages were fabricated and tested with each successive generation becoming more sophisticated in its packaging. Second, different gage geometries were modeled using finite elements.

Progress and results

A method of measuring the small changes in capacitance, which involves making the gage part of a series resistive-inductive-capacitive (RLC) "load" at the end of a waveguide, has been tested. Radio frequency (RF) energy is sent to the RLC circuit via the waveguide from a signal generator. If the load is excited at its resonant frequency, all the energy from the source is dissipated in the load's resistance. If the load's resonant frequency now changes (say, due to a change in capacitance), some of the RF energy will be reflected back toward the source. This reflected energy is detected by a reflection coeffecient bridge (RCB), which outputs a dc signal proportional to the impedance mismatch at the load.

The gage geometries were produced from circuit board material using common etching techniques. The inductor and resistor, together with the gage form the RLC termination, were attached to the backside of the circuit board. Preliminary tests were performed with this arrangement but the need for a shielded, mechanically stable termination was obvious. This led to the development of the second generation packaging system shown in figure 1. The gage, etched from circuit board material as before, has a resistor and toroidal inductor soldered to its backside. A Delrin chassis supports this assembly and the entire system is surrounded by a brass casing. The RLC termination is connected to a coaxial cable through a modified male bayonent navy connector (BNC). The entire assembly is potted with room temperature vulcanizing (RTV). The brass casing is electrically connected to the shield side of the coaxial cable. As hoped for, only the face of the gage is sensitive to its surroundings.

Nine candidate designs in both first and second generation packages have been lab tested using the waveguide/RCB arrangement. Delrin shims of various thicknesses were used to simulate the ablator. Although manufacturing problems (warping and tapering) with the shims have prevented us from obtaining true "Delrin calibrations" for the candidate gages, remarkable consistency between different gages of the same geometry was observed. One of the better examples is shown in figure 2. RCB output versus Delrin shim thickness is shown for two gages (serial numbers 001 and 005), both with conductor and gap widths of 0.020 in. Shim imperfections are detected by both gages. Gage sensitivity drops off for shims greater than about 0.050 in. The RCB arrangement gives a large percentage change in mV output for the range of interest and is insensitive to cable/hardware arrangement and local RF energy. Qualitative tests of the gage's sensitivity to temperature gave encouraging results.

Various gage geometries were modeled using a commercially available finite element code. The models are two-dimensional and intended to illustrate the effect of conductor width and spacing on gage sensitivity. The PC board and uncharged "ground plane" are included. The infinite domain of the physical problem is simulated with the finite domain of the model with the use of absorbing boundary conditions. Elements above the conductors can be assigned the permittivity either of ablator or of air. Ablator thicknesses

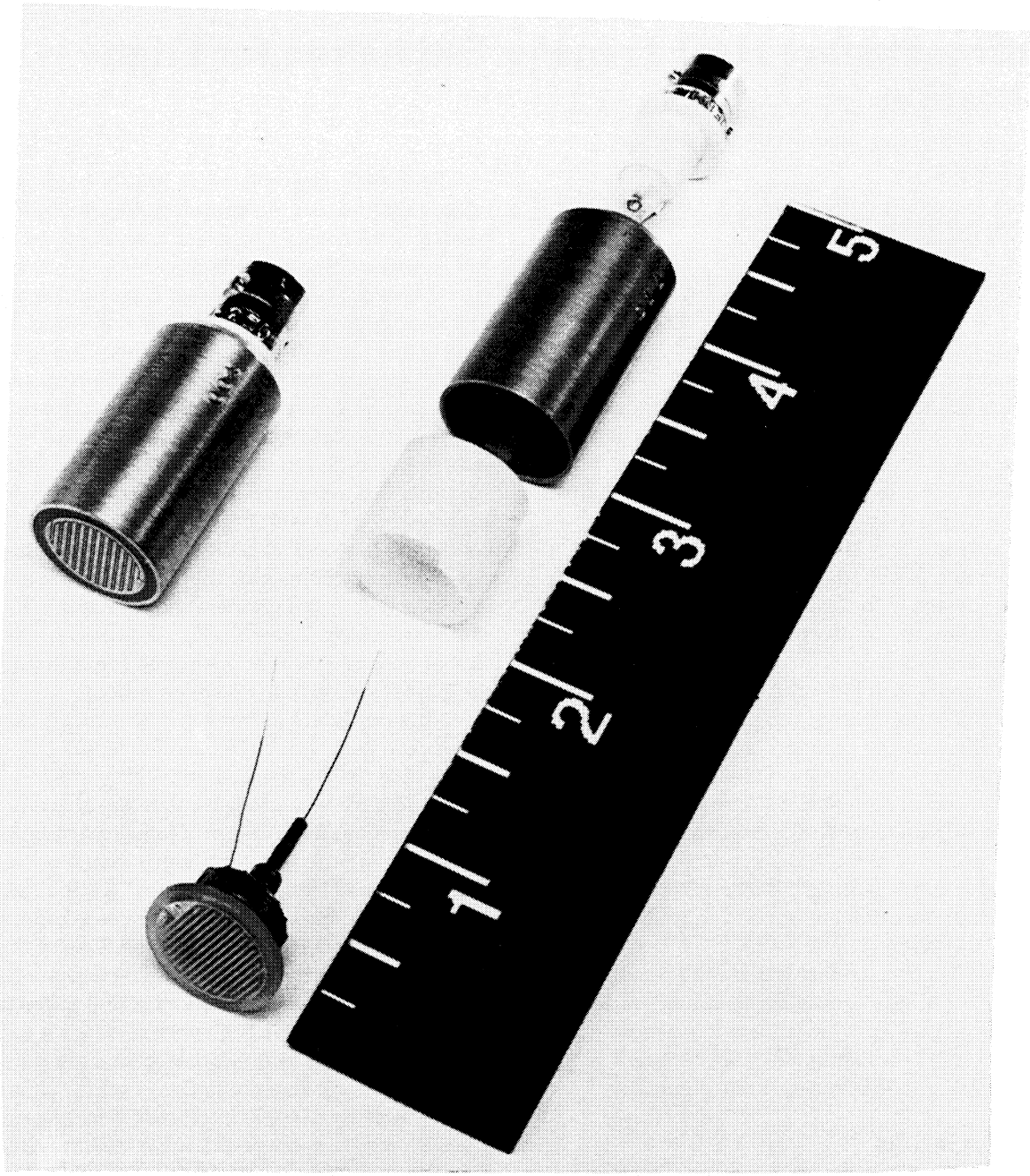


Figure 1. Second generation packaging system.

of 0.0, 0.010, 0.020, 0.030, and 0.050 in. are simulated for each gage geometry. Figure 3 shows the results from two gage geometries, one with a conductor width of 0.005 in. and a gap width of 0.020 in. (5.20) and one with a conductor width of 0.010 in. and a gap width of 0.020 in. (10.20). As expected, the largest change in gage capacitance takes place when the last 0.010 in. of ablator is removed. In these two cases, varying ablator thickness above 0.030 in. does not change gage capacitance much, whereas in the intermediate range (0.010 in.–0.030 in.) the 10.20 geometry is more sensitive. Generally, the geometries with wider conductor widths and gaps tended to be more sensitive at thicker ablator thicknesses than those geometries with thinner conductor widths and gaps. This trend was also observed in lab tests.

A multiplexing system incorporating an RF switch that will allow four gages to be operated with a single signal generator and RCB is being developed.

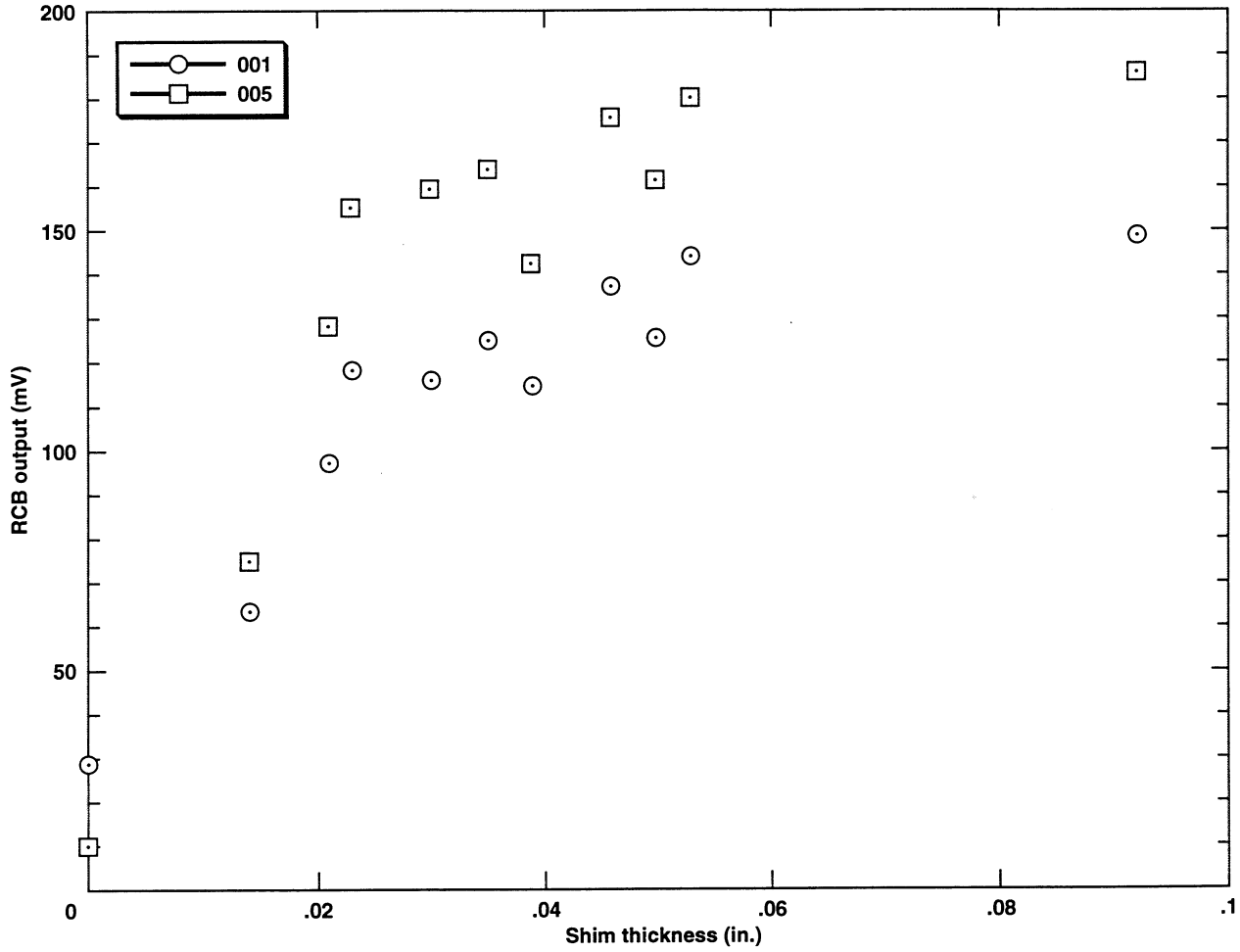


Figure 2. RCB output versus shim thickness.

Significance of the results

Finite element model (FEM) analysis confirms some of the observations made during lab tests and a third generation gage geometry is being produced, incorporating lessons learned. The packaging system developed provides mechanical stability and shielding. Results so far indicate that this gage concept has the ability to measure thickness changes in the range and to the resolution required. Hardware power and size requirements do not exceed what would be available on a flight vehicle. Additional applications possibly include measuring the sublimation rate of surface flow-vis chemicals like napthalene and wing ice detection.

Publications resulting from study: None so far

Key words

Ablation measurement, Thin film measurement

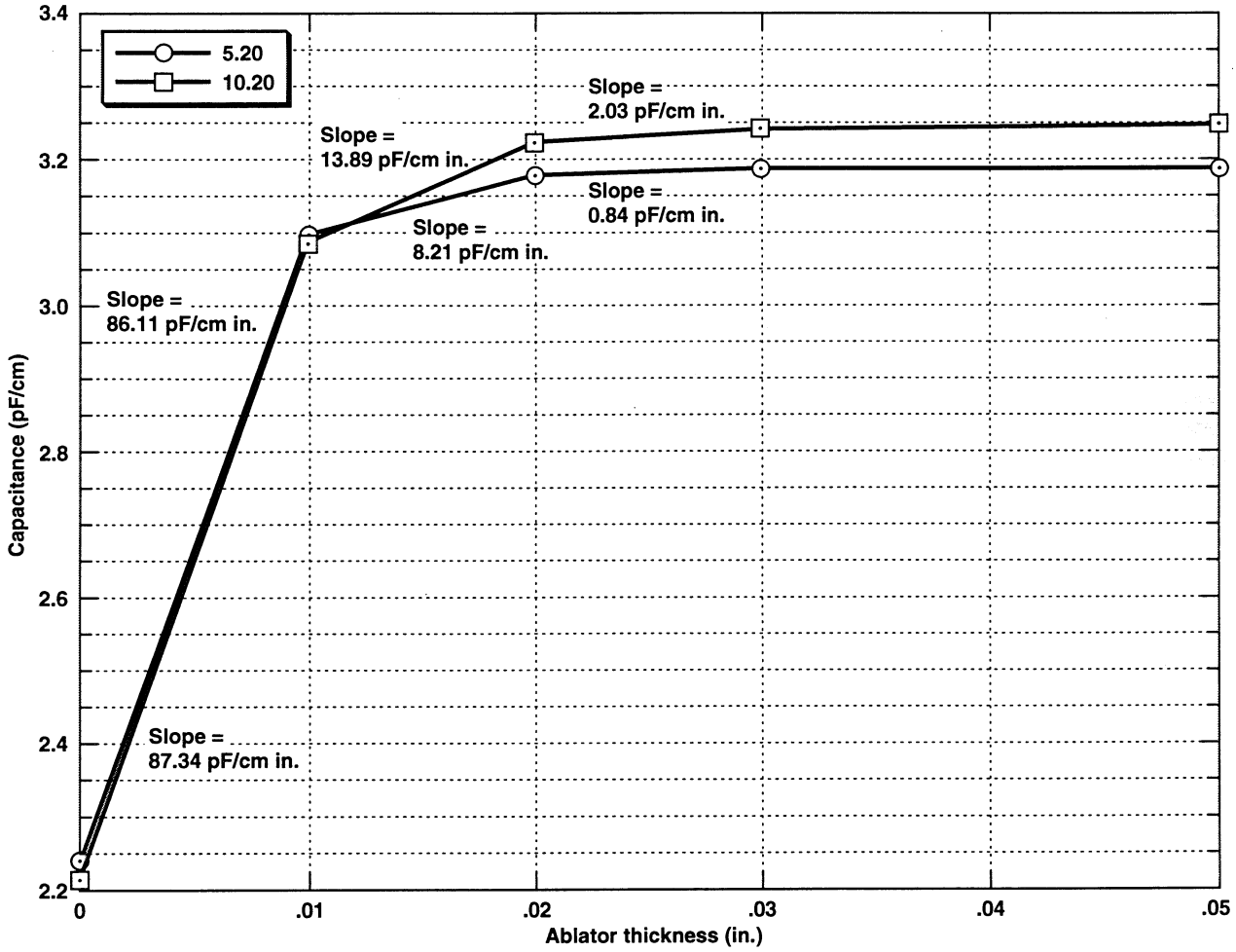


Figure 3. Gage sensitivity for 5.20 and 10.20 geometries.

Crew Decision Making in Aerospace Environments: A Taxonomy of Decision Structures

Investigator(s)
Judith Orasanu, Ames Research Center,
Moffett Field, CA 94035-1000

Other personnel involved
Rick Tarrel, San Jose State University Foundation,
San Jose, CA 95192
Ute Fischer, Ames Research Center,
Moffett Field, CA 94035-1000

Objectives of the study

Of fatal air transport accidents between 1983–1987, 47% involved failures of crew decision making, planning, or communication (National Transportation Safety Board (NTSB), 1991). Scientific research has not provided an adequate basis for training or aiding crews to make decisions in complex dynamic environments such as aviation or space. Before we can hope to improve the safety of aerospace operations, it is essential to understand the nature of decision tasks crews actually face and how they respond to them. The objectives of this project are to:

- Develop a taxonomy of the kinds of decisions crews face in aerospace environments
- Determine the cognitive demands posed by various problem conditions
- Identify vulnerable areas and types of errors crews are likely to make
- Describe effective decision making strategies
- Determine the costs and benefits of various decision strategies.

Progress and results

Three integrated efforts have been initiated this year:

1. Incident and accident reports (Aviation Safety Reporting System (ASRS), NTSB) have been analyzed to identify decision types, which served as input for building a decision taxonomy.
2. Crew performance in full-mission simulators has been analyzed to identify more and less effective decision making strategies.
3. NTSB accident reports have been analyzed to develop hypotheses about types and sources of crew decision errors.

Efforts to date have yielded the following products and preliminary conclusions:

1. Two primary factors define the complexity and difficulty of cockpit decisions: degree of ambiguity in problem specification and degree to which responses are prescribed. Time pressure and risk level function as amplifiers (fig. 1).
2. Different types of operational events make different cognitive demands on the decision maker; different strategies are appropriate to different types of decisions (fig. 2).
3. More effective crews are flexible in their application of decision strategies; they know what information is important; their decisions are sensitive to constraints; they have longer planning horizons and actively manage their "windows of opportunity."
4. Errors frequently result from poor situational awareness (defined by accurate and timely interpretation of cues, especially risk assessment, and appreciation of implications of current situation). Poor decisions result from oversimplifying problems, ignoring constraints, and failure to consider options.

Significance of the results

We are beginning to understand the characteristics of problems that crews face in dynamic complex environments, the features that make problems difficult, and crews' responses to those requirements. This research will yield knowledge of how crews use their expertise to deal with demanding situations, what constitutes "best" performance in ill-structured situations, and where improvements might be made.

Publications resulting from study

Fischer, U.; Orasanu, J.; and Montalvo, M.: Effective Decision Strategies on the Flight Deck. Proceedings of the Seventh International Symposium on Aviation Psychology, R. Jensen, ed., Ohio State University Press, Columbus, Ohio, 1993.

National Transportation Safety Board: Annual Review of Aircraft Accident Data: U.S. Air Carrier Operations Calendar Year 1988. (NTSB/ARC-91/01), Washington, D.C., 1991.

Orasanu, J.: Decision Making in the Cockpit. Cockpit Resource Management, E. L.Wiener, B. G. Kanki, and R. L. Helmreich, eds., Academic Press, San Diego, Calif., 1993, pp. 137–172.

Orasanu, J.: Lessons from Research on Expert Decision Making on the Flight Deck. International Civil Aviation Organization (ICAO) J. (Special issue on Human Factors in Aviation), vol. 48, no. 7, Sept. 1993, pp. 20–22.

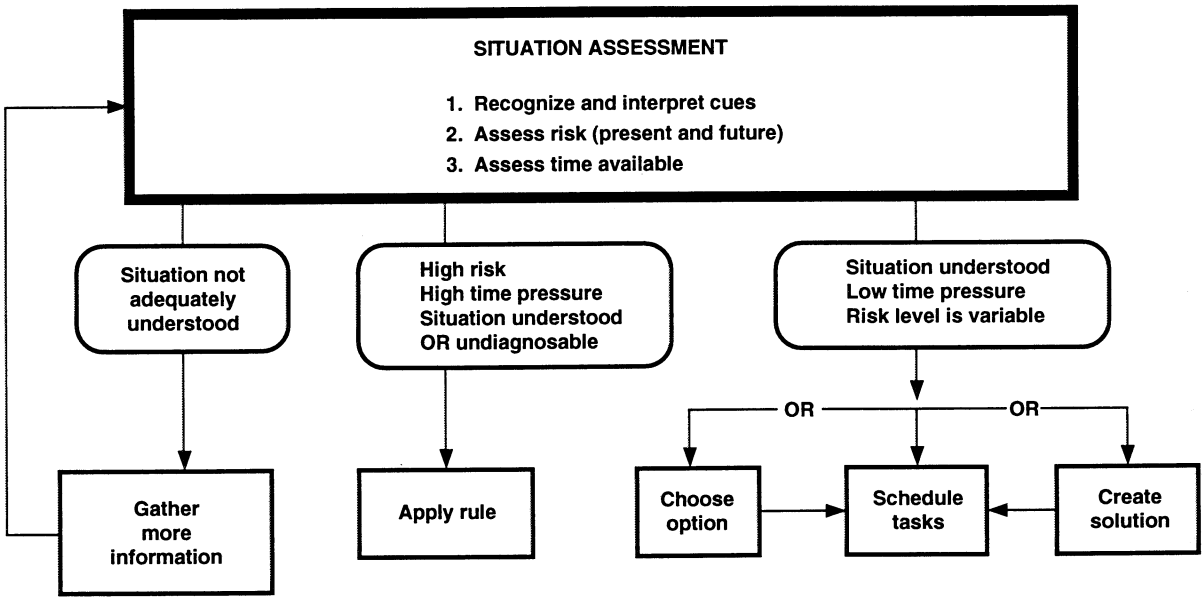


Figure 1. Simplified decision process model.

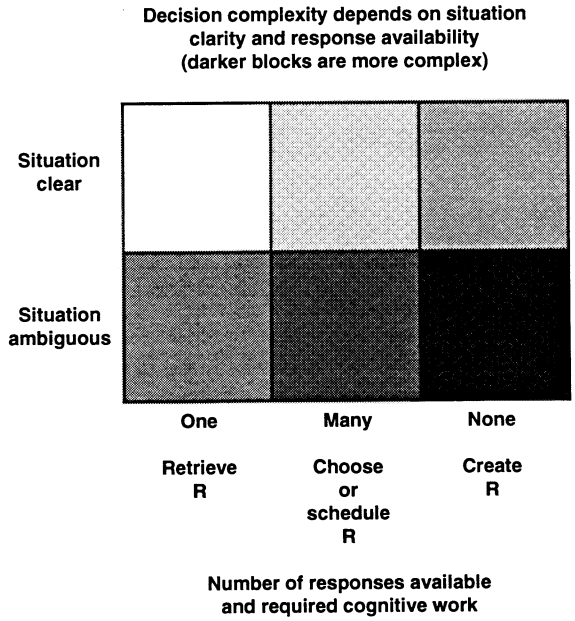


Figure 2. Decision process strategies.

Orasanu, J.; Fischer, U.; and Tarrel, R.: A Taxonomy of Decision Problems on the Flight Deck. Proceedings of the Seventh International Symposium on Aviation Psychology, R. Jensen, ed., Ohio State University Press, Columbus, Ohio, 1993.

Key words
Dynamic decision making, Team decision making, Situation assessment

Analysis of Arc-Jet Wind Tunnel Vacuum Ultraviolet (VUV) Experiment

Investigator(s)
Chul Park, Ames Research Center,
Moffett Field, CA 94035-1000
Dikran S. Babikian, Thermosciences Institute,
Ames Research Center,
Moffett Field, CA 94035-1000

Objectives of the study
The objective of this study is twofold; (1) to refine and validate the code that calculates the radiative heating on a blunt body behind a shock wave, especially in the vacuum ultraviolet (VUV) spectral region, and (2) to improve the arc-jet computational fluid dynamics (CFD) codes to better characterize the flow in the arc-jet wind tunnel. Through the computations we will be able to better identify the thermochemical nonequilibrium processes in the nozzle and behind the shock wave over a blunt body and obtain information on the shape of the far wings of VUV lines.

Progress and results
Radiation from the nitric oxide band systems emitted by the free-stream flow of the 20 MW arc-jet wind tunnel has been computed. A one-dimensional multi-temperature code for use in an expanding flow named NOZNT, which reproduces the nitric oxide data, was developed. Also the flow field and the spectral radiation within the 120 nm to 1000 nm range from the shock layer of a blunt body in the 20 MW arc-jet has been measured and computed. The final calculation awaits calibration of the experimental data, which is in progress.

Significance of results
Using the NOZNT code, the nonequilibrium state in the test section of an arc-jet wind tunnel can be predicted.

Publications resulting from study
1. Measurement and Analysis of Nitric Oxide Radiation in an Arc-Jet Flow. AIAA 28th Thermo-Physics Conference, Orlando, Fla.
2. Validation of Multi-Temperature Nozzle Flow Code NOZNT. AIAA 28th Thermophysics Conference, Orlando, Fla.
3. User's Manual for NOZNT and NOZ1T. Technical note, in review.
4. Calculated and Measured Spectral Radiation from a Blunt Body Shock Layer in an Arc-Jet Wind Tunnel. 32nd Aerospace Sciences Meeting and Exhibit, Reno, Nev.
5. Characterization of Arc-Jet Flows Using Laser-Induced Fluorescence. 32nd Aerospace Sciences Meeting and Exhibit, Reno, Nev.

Key words
Arc-jet wind tunnel, Nonequilibrium expanding flows, Radiative heating of blunt body

A Miniature, Lightweight Ozone Analyzer for Use on Unmanned Stratospheric Research Aircraft

Investigator(s)
Richard Pearson, Jr., Ames Research Center, Moffett Field, CA 94035-1000

Other personnel involved
Dana Lynch, Bill Gunter, Jim Eilers, Pete Lissol, and John Cooney, Ames Research Center, Moffett Field, CA 94035-1000

Objectives of the study

The objective of this study was to design and test the critical measuring components of a small, lightweight, low-power ozone (O_3) analyzer for use on light, unmanned research aircraft such as Perseus. The earliest such high altitude aircraft will be able to carry only light, small instruments that need minimal electric power. But to be effective, the instruments must be reliable, accurate, and automatic.

The essential design goals were to:

- Minimize weight, size, and power requirements so that flights with multiple instruments would be possible.
- Provide accuracy comparable to that of the existing instrument flown on NASA high altitude (ER-2) missions.
- Retain the same analytical method to ensure that the measurements would be traceable to the National Institutes of Standards and Technology.
- Achieve a well defined optical length that doesn't change during flight. Path length uncertainties have caused serious problems in the accuracies of O_3 measurements with a number of multipass optical cells.
- Minimize reflections from the cell walls. Reflections can change the effective optical length of the cell, necessitating frequent calibrations to avoid systematic errors in measurements.
- Work at highest altitudes (lowest pressures) where O_3 losses to the cell walls can be significant.
- Achieve a balance between the signal magnitude, which is directly proportional to optical path length, and compactness and speed of flushing, which require a physically short, compact cell.
- Achieve a high étendue to get the highest light intensity reaching the detector. The term étendue is a specific optical engineering concept related to the speed, or light throughput of an entire optical system. The higher the étendue for this system, the more light reaches the detector from a source of fixed brightness. Generally this permits higher signal-to-noise ratio measurements for a cell of given optical path length. Thus the best signal-to-noise ratio is obtained to maximize measurement precision.

The operating principle used is absorption of ultraviolet (UV) light at 254 nanometers wavelength, which is highly specific for O_3 in ambient air. The basic O_3 photometer consists of a light source, a cell to contain the gas to be analyzed, a light detector, and an embedded controller to operate the unit and record the observations and engineering data. A measurement is made by filling the cell alternately with air to be measured, and air from the same source from which the O_3 alone has been removed with a chemically selective trap. The O_3 concentration then is obtained from the Beer-Lambert Law using the ratio of these two light intensity measurements, the state parameters for the air in the cell, the physical properties of O_3, and the cell length. This is the recognized standard reference method for O_3. Most of the difficulties with it derive from the fact that the light absorption to be measured is small (typically a few parts per million) and the two components must be measured sequentially, *not* simultaneously. This situation allows factors other than O_3 to change the measured light intensity. In addition, reflections internal to the cell can be—and, in many cell designs are—an integral part of the optical path and may change unpredictably during use of the instrument. Such changes have the potential to cause significant systematic errors in the measurements without frequent intercomparisons with a transfer standard.

The most critical design requirements were to keep the conditions for two different light intensity measurements as identical as possible except for the O_3 content of the air, and to measure the individual light intensities to an accuracy approaching one part per million. For best signal-to-noise ratio, it is also advantageous to optimize the use of the existing type of light source, and to fit the instrument into a space in the aircraft compatible with Argus, an instrument designed to measure nitrous oxide and methane. It is nearing completion for use on Perseus.

Progress and results

The main results of this study are: developing the concept for a new type of optical absorption cell particularly well suited for use under these conditions;

carrying out a thorough analysis of a geometric optical model of the complete system for the O_3 photometer; fabricating and testing a working (visible or infrared light) model of the absorption cell as proof of concept and as verification of the accuracy of the complex design calculations with comparatively inexpensive components; and completing an integrated, detailed design for the prototype instrument.

The cell appears to operate precisely as expected; it was photographed in laser light showing the beam following the intended path, exiting through the window. One of the most significant findings of this study was the confirmation of design calculations showing that the mechanical and optical tolerances for the optical components would be relatively loose compared to optical systems generally, which will significantly lower fabrication costs and ease problems of interchangeability of parts.

The complexity of designing some of the UV components and subsystems greatly exceeded our expectations. Small changes in optical components necessitated continual modifications to the mechanical design. As a result of increased design and engineering costs, we were unable to build and bench test a UV prototype as originally intended. But the design is conservative, and extensive consultations have been made with optical producers to be sure that the custom components can be fabricated to the required characteristics and tolerances.

Significance of results

This study has developed a new concept and detailed design for an O_3 photometer small enough to be used with other instruments on light, remotely piloted aircraft, but capable of operating at any altitude below about 40 km so that it is compatible with use on balloons as well as use at sea level. The unique characteristics of the design involve a cell expected to have exceptionally good stability, so that it may find applications in O_3 transfer standards, or in analyzers that must operate for extended times without reference to an O_3 standard. Nothing in the overall concept is specific to O_3, so the photometer or just the cell could be implemented for use at other wavelengths for different gases.

The novel optical absorption cell will also operate effectively at infrared and visible wavelengths, and it can easily be adapted to open path applications at low to moderate windspeeds.

Publications resulting from study: None so far

Key words

Ozone photometer, Trace gas analyzer, Optical absorption cell

Development of a Polarimeter for Astrophysical Applications in the Midinfrared

Investigator(s)
Yvonne Pendleton, Lynne Deutsch, and Thomas Roellig, Ames Research Center, Moffett Field, CA 94035-1000

Introduction

The polarization of light from astrophysical sources is an important indicator of the environment and physical processes at work in the emission region, as well as in the intervening medium. Understanding processes such as the life cycle of stars and the synthesis of interstellar material increases our knowledge of how the material that is the basis of everything around us arrived at the proper point and at the proper time to create the observed universe. Our approach is to combine the imaging capabilities of a midinfrared array camera with an externally mounted polarimeter to obtain geometrical information about astrophysical environments otherwise obscured from view.

Statement of problem

Dust grains associated with a variety of astrophysical settings absorb and reradiate energy at infrared wavelengths. Comparisons of midinfrared (10 μm) and near-infrared (2.2 μm) polarization maps show that observations at these wavelengths probe different regimes and that the polarization produced at these wavelengths arises from very different mechanisms. At 2.2 μm, the high degree of polarization measured is produced by scattered light. At 10 μm, grains cannot scatter efficiently (due to the size of the grain compared to the wavelength of the light) and therefore the polarization is dominated by dichroic absorption due to aligned grains. The mechanism at 2.2 μm reveals information about the illuminating sources because the orientation of the maximum electric vector remains orthogonal to the direction of illumination. The mechanism at 10 μm produces polarization by preferentially absorbing one component of the electric vector over the other. This can only happen if the grains are highly aligned and elongated, so maps of 10 μm polarization provide information about the dust grains and their orientation. The comparison of the polarization maps at those two wavelengths will reveal new information about the geometry and composition of the gas, dust, and stars.

To illustrate the usefulness of this technique, consider the center of our galaxy, which remains hidden from view at optical wavelengths. Infrared studies have provided much of the current information about the galactic center. Polarimetric studies at 2.2 μm have revealed the distribution of dust and some of the illuminating sources. Midinfrared polarimetric studies have revealed information concerning grain alignment and the effect of magnetic fields. Until now, polarization studies in the midinfrared could be done only by using single detector technology. Figure 1 represents the best midinfrared polarization map of the galactic center that exists today. The polarization measurements for that map were painstakingly made one at a time in a separate experiment from the one that provided the underlying photometric map. The infrared sources labeled IRS1, 10, 5, and 8 all have strong intrinsic polarization, which is thought to be due to the alignment of grains surrounding the sources. The position angle of the maximum electric vector and the magnitude of the polarization are consistent with that which would be produced by a strong magnetic field (>10μG) (Aitken, et al., 1986). Such a strong field would have significant impact on the structure and evolution of the galactic center. The change in position angle and the smaller polarization seen in the other sources in figure 1 is attributed to differences in grain composition and alignment in the southern portion of the map. The Ames 10-μm polarimetric imager can simultaneously provide photometric and polarimetric images of a 14- by 14-in. area of the sky and increase the resolution of the map shown in figure 1 to a resolution of 1 in. per pixel (as shown by the box in the upper right hand portion of the figure).

Instrumentation and methods

NASA-ARC 10/20 μm camera: A new infrared camera (AIR Camera) has been developed at NASA Ames Research Center for observations from ground-based telescopes. The heart of the camera is a Hughes 58 × 62 pixel arsenic-doped silicon detector array that has the spectral sensitivity range to allow observations in both the 10- and 20-micron atmospheric windows. Three discrete 8% filters at 18, 20, and 22 microns, a 3% circular variable filter covering the 7.5- to 14-micron atmospheric window, and discrete 10% filters centered at 9.8 and 10.3 microns can be selected to define the spectral resolution. A very flexible optical design and a dedicated guider/mounting box allow camera operation at any major telescope that has a focal ratio of 17 to 45. The camera has been used for observing runs

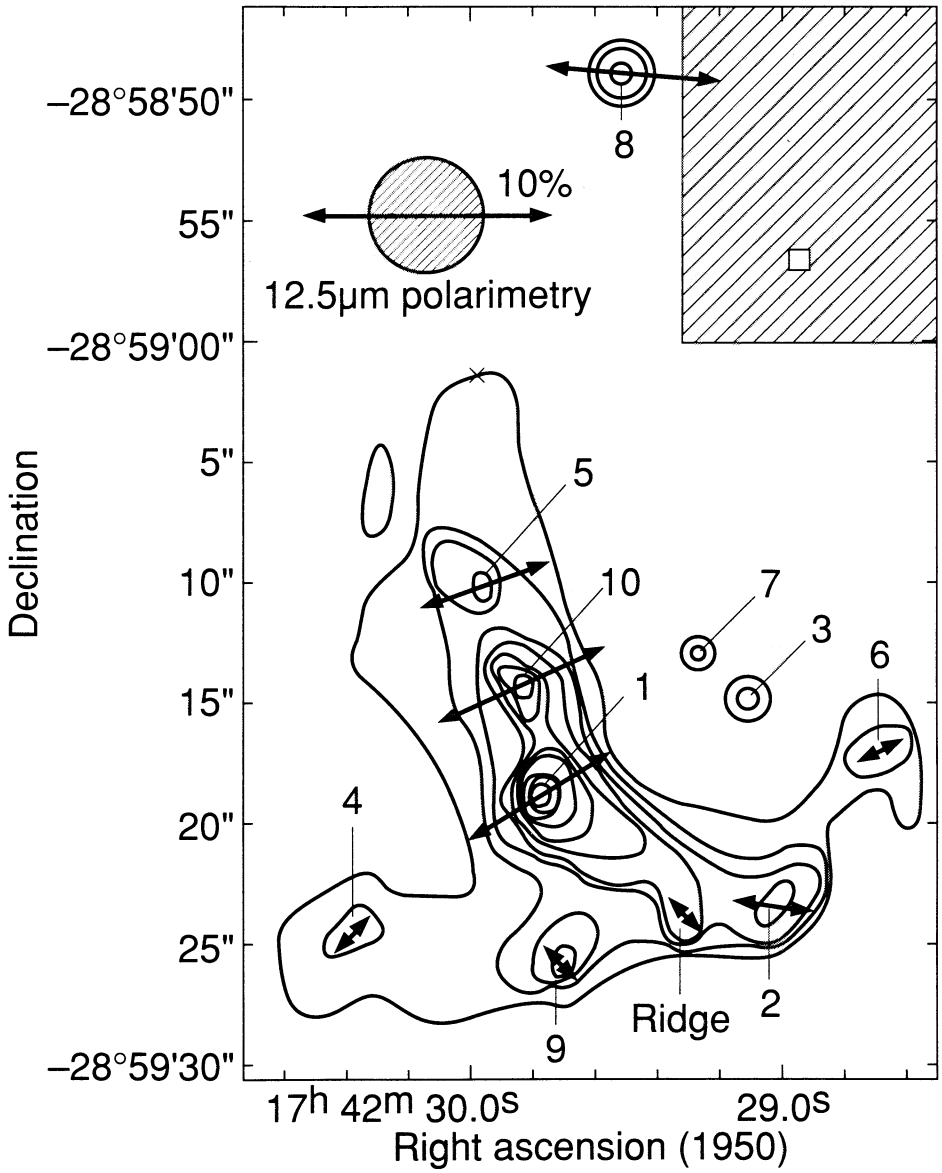


Figure 1. Intrinsic 12.5 μm polarization measurements of the galactic center (Aitken et al., 1986) superposed on the 12.5 μm flux contour map (Becklin et al., 1978). The length of the dark lines indicates the percentage polarization while the orientation of the line shows the position angle. The array size of the 10 μm camera is shown by the cross-hatched box in the upper right corner and the pixel size is drawn in as a 1-inch square.

at the Mt. Lemmon 1.5-m NASA/UA telescope. When using this telescope, each camera pixel corresponded to a square 0.73 arc-seconds wide on the sky, which gave a total camera field-of-view of 42 × 45 arc-seconds. At the NASA Infrared Telescope Facility in Hawaii a smaller pixel scale gives a 14-in. field-of-view.

The optics of the AIR Camera are very simple, consisting of a single lens that simultaneously reimages the sky image formed by the telescope onto the detector array as it images the telescope secondary mirror onto a cold stop at the entrance to the array enclosure. Two filter wheels select from among the available filters, rotating them into positions just in front of the cold stop. The optical design (fig. 2) allows changing between telescopes of different focal ratios by changing the reimaging lens while keeping the filter wheels, cold stop, and array undisturbed.

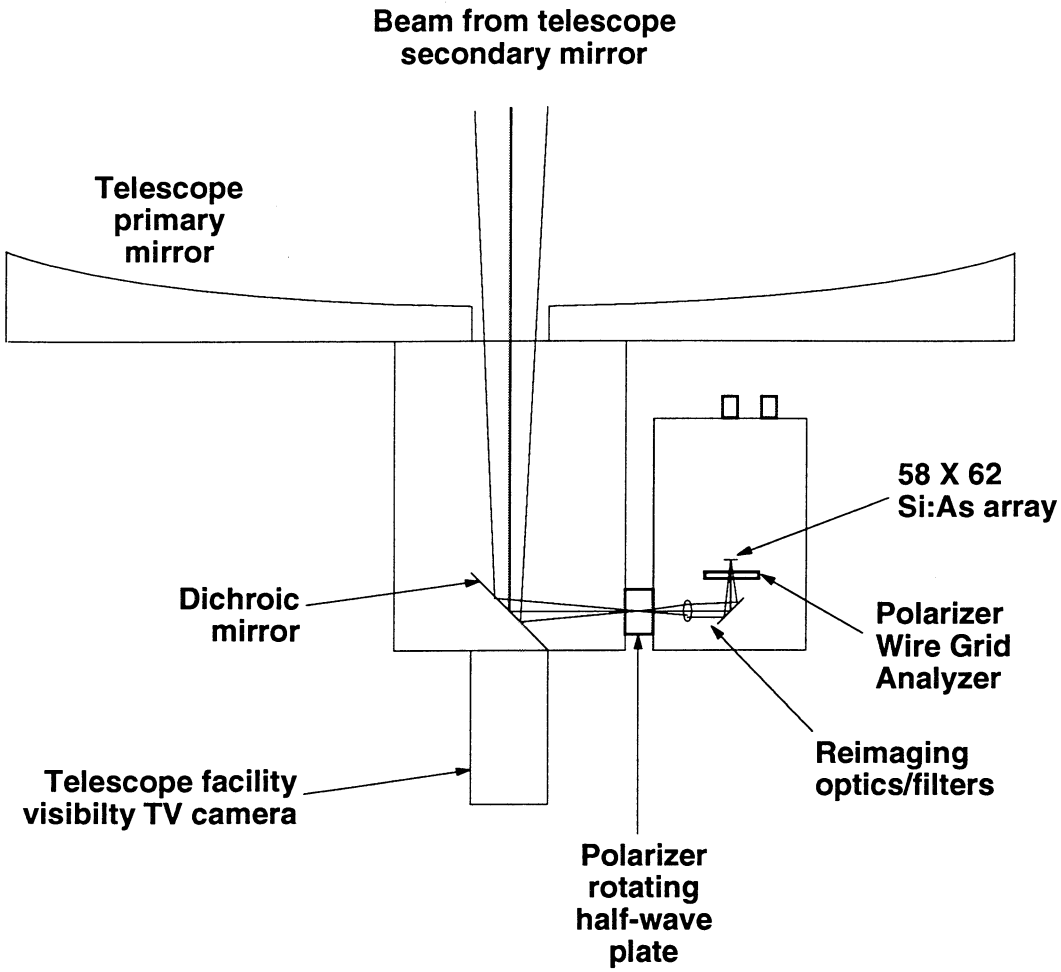


Figure 2. Schematic representation of the polarimeter and midinfrared camera assembly.

Ames midinfrared polarimeter

The design of the near-infrared polarimeter consists of a fixed wiregrid analyzer (which is cryogenically cooled) and a rotating half wave plate. The materials used for the optical components are an Ar coated germanium wiregrid and a cadmium sulfide half wave-plate. These materials were chosen because they provide optimum characteristics for midinfrared polarimetry. The wiregrid analyzer resides in a filter wheel position inside the cryogenically cooled camera. The rotating half wave plate is housed inside a cylindrical mount that is motor driven.

Astronomical results

In figure 3(a–b) we present new astronomical images obtained with the AIR Camera at NASA's Mt. Lemmon telescope. These images show emissions from the young planetary nebula NGC 7027 at two midinfrared wavelengths. Planetary nebulae are the ejected envelopes of evolved stars. The central star of NGC 7027 is totally obscured by dust in the optical, has a temperature of 180,000 to 234,000 K, and is located approximately 1 kpc from our Sun. The mid-infrared images reveal a double lobed structure and a central minimum, which represent a cross-section of a tipped toroid of gas and dust. The dust ejected by planetary nebulae has been enriched with heavy elements created through the star's nucleosynthesis. The nebula also contains large carbon molecules, which may be the building blocks of prebiotic material. This material is ultimately reincorporated into the interstellar medium from which new stars will be formed.

Ongoing research efforts

Now that the AIR Camera has been tested at the telescope, the polarimeter can be used in conjunction with the camera. The next step in this project includes taking the camera/polarimeter to various telescopes to observe objects such as NGC 7027 and the galactic center to further study a variety of astrophysical environments.

References

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Becklin, E. E.; Mathews, K.; Neugebauer, G.; and Willner, S. P.: Infrared Observations of the Galactic Center. IV. The Interstellar Extinction. Astrophys. J., vol. 220, Mar. 15, 1978, pp. 831–835.

Key words

Midinfrared polarimetry, Two-dimensional array camera

Three-Dimensional (3-D) Disturbances Generated by Suction Holes for Laminar Flow Control (LFC)

Investigator(s)
Daniel C. Reda and Jonathan H. Watmuff,
Ames Research Center,
Moffett Field, CA 94035-1000

Other personnel involved
Wes Lord, Pratt & Whitney,
East Hartford, CT 06108

Objectives
The benefits of using suction for delaying transition to turbulence have been known for some time, but only recently has the technology become available to produce large sheets of perforated material for use in aircraft wings at reasonable cost. However there is evidence to suggest that local three-dimensional (3-D) disturbances are generated by the discrete holes, which could defeat the purpose of the suction, i.e., cause premature transition. The objective of this research is to determine the characteristics of these disturbances, whether they decay or amplify with streamwise distance, and whether there are interactions between disturbances generated by different holes.

Progress and results
This initial DDF funding was used to modify an existing facility, which has been completed on schedule. Measurements of the background flow are under way. The test section unsteadiness is 0.08% and the transitional Re = 2.2×10^6 for an impervious flat plate, which is very good for an open-return blower driven tunnel. The mean flow exhibits the Blasius profiles although the data have not been fully analyzed as yet. Disturbances generated by an isolated suction hole will be investigated shortly. The suction will be perturbed harmonically and the data phase-averaged on the basis of the perturbation. Measurements will be made on spatially dense 3-D grids allowing animations of the T-S-like 3-D waves to be studied on a graphics workstation. A scaled-up porous surface consisting of 8,966 holes is ready for testing. This will be used to investigate the interactions between disturbances on a full suction surface typical of those currently being flight tested for future use in airplane wings and engine nacelles.

Significance of the results
The holes have been scaled up by a factor of 20 to allow direct observation of the disturbances. Of special interest is the interaction between disturbances originating from two holes displaced, but aligned in the streamwise direction. There is likely to be some degree of enhancement, or more relevantly, some degree of cancellation of these waves. If cancellation is observed, then it is possible that the streamwise grid spacing of the holes should be designed for a specific flight speed (i.e., T-S wavelength). Current design practice considers only the spanwise grid spacing.

Publications resulting from study

Watmuff, Jonathan H.: Interaction Between Instabilities Originating from Suction Holes. To be presented at the 46th Annual Meeting of the APS Division of Fluid Dynamics, Nov. 1993.

Key words
Laminar flow control, Suction holes

An Ultralow-Temperature Thin-Film Thermometer

Investigator(s)
Pat Roach, Ames Research Center,
Moffett Field, CA 94035-1000

Other personnel involved
Al Spivak and Mic Clark, Ames Research Center,
Moffett Field, CA 94035-1000

Objectives of the study

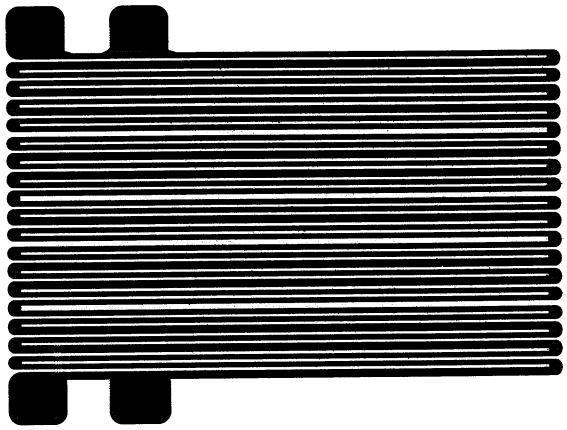
The purpose of this project is to develop a simple, accurate thermometer that will be useful in the temperature range of 0.01-0.38 K for use with cryocoolers that are being developed to operate at 0.10 K and below. There are currently no thermometers operating in this range that are reliable, accurate, and simple enough for unattended operation in an orbiting telescope. We hope to show that a thin-film resistance thermometer can be developed that is both sensitive and reproducible after cycling to room temperature. Because it will be a resistive device, it will be very simple to measure.

The idea behind the thermometer is that certain gold-aluminum alloys have a superconducting transition temperature that depends on the ratio of the two metals. We will create a thin-film serpentine pattern of Au-Al alloy that varies continuously in its composition so that the region of 86%Au-14%Al begins to superconduct at 0.38 K, and more of the pattern becomes superconducting as the temperature decreases until the last region of 96%Au-4%Al becomes superconducting at 0.01 K.

The objectives are:

1. Design the serpentine pattern to maximize the pattern length and area of thermal contact in a small package. Make a corresponding mask.
2. Evaporate the gold and aluminum films in the correct composition gradient.
3. Etch the pattern in the film and diffuse the Au and Al together.
4. Evaluate the thermometer behavior (sensitivity and reproducibility) at low temperatures.
5. Develop solutions for problems that are revealed. Possible problems are sensitivity to air or moisture, sensitivity to the Earth's magnetic field, poor thermal contact, hysteresis in the superconducting transitions, and problems with electrical contacts to the thermometer.

Step 1 has been completed and the mask pattern is shown in the figure. This pattern achieves a length of 40 cm and a width of 0.01 cm in an area of only 1 cm^2. Its surface area is 0.4 cm^2 for good thermal contact.



Serpentine pattern for thin-film thermometer.

Preliminary tests with samples of Au-Al films have revealed that the nearly pure gold alloy is very soft and does not bond well to a sapphire substrate but it can be soldered for lead attachment. The 14% Al alloy is much harder and bonds better to the substrate, but it cannot be soldered for lead attachment. Experiments with several conducting epoxies have produced mixed results. Leads can sometimes be attached to the alloy with good results at low temperatures but at other times the joints develop a high resistance at low temperature.

The results so far indicate that the alloy film will have to be handled carefully to avoid damaging the regions where it is soft and poorly bonded. Methods of improving the bond generally involve layers of other metals below the Au-Al alloy and would not be advisable in this application. We feel that the use of silver epoxy to attach leads can be made to work if sufficient care is taken.

Key words
Resistance thermometer, Low temperature,
Superconducting thin film

Early Warning Blackout Sensor for Pilots and Astronauts

Investigator(s)
S. A. Rositano, Alan Hargens, and
Malcolm Cohen, Ames Research Center,
Moffett Field, CA 94035-1000

Objectives of the study
To develop and evaluate a forehead-mounted impedance measuring patch capable of providing a 4- to 7-second advance warning of impending physiologic limit (blackout) caused by head-to-toe acceleration forces.

Progress and results
Signal processing circuitry has been designed and tested with simplified electrodes. A contract has been awarded to Classic Medical for production of prototype electrodes. The first integrated test was scheduled for November 1993. Preliminary results indicate high probability for detecting the arterial pulse.

Upon successful tests on resting human subjects, tests on the ARC 20-G Centrifuge will be conducted. Refinements in electronics are expected to provide "smart signal processing" for adaptive artifact suppression.

Key words
Biomedical technology, Biomedical electrodes, Pilot safety

The Infrared Spectra of Microsamples of Cosmic Interest: Diamonds, Silicon Carbide, Interplanetary Dust Particles, and Organic Residues

Investigator(s)
Scott A. Sandford, Ames Research Center, Moffett Field, CA 94035-1000

Other personnel involved
Louis Allamandola, Douglas Hudgins, and Robert Walker, Ames Research Center, Moffett Field, CA 94035-1000

Objectives of the study

The purpose of this investigation is to obtain the infrared spectra in the 4000-400 cm^{-1} range of a number of different kinds of microsamples. These samples include, but are not restricted to, (1) diamond and silicon carbon grains that are found in meteorites that are known from isotopic anomalies to have an interstellar origin, (2) individual interplanetary dust particles (IDPs) collected in the stratosphere by NASA high altitude aircraft, and (3) organic residues found in meteorites and produced in laboratory simulation experiments in our low-temperature laboratory.

The spectra from these samples can be used to determine the chemical and mineralogical composition of these samples, thereby allowing us to draw inferences about the environments in which they formed and about subsequent processes they experienced in interstellar and interplanetary space and within their solar system parent bodies (asteroids and comets). The spectra can also be compared directly to telescopic and remote sensing data. Such comparisons help identify these materials in space and allow us to better determine their cosmic distribution and abundance.

Progress and results

The majority of the DDF funds allocated to this study were used in the purchase of an infrared microscope. The infrared microscope, a Nicolet IR-Plan, has now been fully integrated with our Nicolet 740 Fourier transform infrared spectrometer and has been thoroughly tested for performance and compatibility. The system is designed to provide a great deal of flexibility, a key requirement since the spectrometer used with the microscope is also responsible for carrying out other experimental studies on macroscopic samples. It was found that the entire system can be switched from normal operation to microscope operation or vice versa in about an hour. Optimization of the system for difficult samples often requires longer times, with about a half day being typical.

The microscope itself has been found to perform up to expectations. Once the overall spectrometer system is configured for microsample work, it can provide a good quality infrared spectrum of micron-sized samples in as little as 10 minutes. Prior to the installation of the microscope, it would have taken at least 2 days to obtain such a spectrum and it would have resulted in decidedly inferior data. The infrared microscope therefore represents a 300-fold plus improvement in our ability to study microsamples. Spectra obtained from microscopic samples that were previously characterized in larger quantities using more traditional techniques demonstrate that the microscope produces reliable and repeatable results.

Now that the microscope can rapidly measure the spectra of microsamples, the biggest bottleneck in these studies is the preparation and mounting of the samples themselves, which are, not surprisingly, difficult to handle because of their extremely small sizes. We have used our remaining DDF funds to equip a modest microsample preparation bench with an optical microscope and light source. We have also designed and built a specialized adjustable sample holder that can be used to mount a variety of different sample types into the microscope's sampling area.

Significance of results

The work done in the past year demonstrates that the new infrared microscope works well and can be used to routinely measure the infrared spectra of nanogram-sized quantities of material with both rapidity and a high degree of reliability. Based on the results of our tests with standard materials and the work done on cosmic microsamples already characterized using other techniques, we expect the microscope to generate exciting new discoveries.

The successful installation of the infrared microscope opens up a wide variety of possible study areas that were previously impractical to consider. So far, the microscope has been used to study a number of samples from Antarctic meteorites in the ureilite class and to study a variety of polycyclic aromatic hydrocarbon (PAH) species common in the organic portions of meteorites. Plans are presently under way to begin a

collaborative effort with Don Brownlee of the University of Washington to use the microscope to study the organic components in interplanetary dust particles. Dr. Brownlee will provide whole particle samples and ultramicrotomed (ultra-thin) sections of interplanetary dust particles, which we will examine using the microscope. We intend to focus on the organic fraction of the particles. This component is presently the least well understood of all the phases in interplanetary dust particles and is known (from deuterium measurements) to contain an interstellar precursor material whose character is not understood at this time.

Publications Resulting from this Study

No publications resulting *solely* from this study have yet been submitted, although we hope to be able to complete a paper on the organic component of interplanetary dust particles during the upcoming year. However, the microscope has already been used to verify certain key points in two other papers. The first paper is entitled "The Mid-Infrared Transmission Spectra of Antarctic Ureilites" and is presently in press in Meteoritics. The second paper, entitled "Infrared Spectroscopy of Polycyclic Aromatic Hydrocarbon Cations I: Matrix Isolated Naphthalene and Perdeuterated Naphthalene," is presently in press in The Journal of Physical Chemistry.

Key words

Infrared spectroscopy, Microsamples, Extraterrestrial materials

Development of a Direct Measurement Transducer for the Oil Wedge Skin-Friction Technique

Investigator(s)
H. Lee Seegmiller, Ames Research Center,
Moffett Field, CA 94035-1000

Objectives of the study

The objective is to develop a new nonintrusive means of measuring skin friction. The recently developed laser interferometer oil wedge technique is regarded as a reliable and nonintrusive means of obtaining skin-friction measurements in certain flows. In this technique, the thinning rate of a wedge of oil on the model surface is related to the friction force at the oil-gas interface. The oil thickness is determined from alternating constructive and destructive interference between laser beams reflected from the surfaces of the oil and model as the oil wedge thins.

Although reliable results have been obtained with this method, the requirement for optical access prevents its use in the internal flows of nozzles or inlets. The laborious and time-consuming setup of the laser and detector also severely restricts the opportunity to make simultaneous measurements at various model locations, resulting in lengthy and expensive tunnel test programs. Additional limitations of the interferometric method are the presence of tunnel or model vibrations or model or aircraft structural deflection occurring in response to aerodynamic or thermal effects.

A new, rugged, flush-mounted transducer is proposed that may make direct measurement of the oil wedge thickness possible. Unlike the laser interferometric method, the proposed transducer would provide continuous measurement during the thinning of the oil wedge. Furthermore, if a means of exuding the oil through a slit near the transducer can be developed, the method could be used in full-scale flight vehicles or large continuously running wind tunnels.

Progress and results

A new state-of-the-art capacitance bridge has been obtained, and several prototype transducers have been fabricated. Testing of several transducer configurations has resulted in a candidate design for testing in the High Reynolds Pilot Channel. This design is now being fabricated and will include provision for oil injection to permit repeated measurements as required for a continuously running tunnel or for aircraft in flight. During testing of concept configurations to evaluate temperature sensitivity, it was discovered that the transducers were highly sensitive to condensed moisture as they were cooled below the dew point. As spinoff technology, it is believed that this sensitivity to water and ice can be exploited in a very different application. Consequently, tests were conducted to see if a modified transducer could be used as an aircraft ice detector. These tests were successful and a U.S. patent application has been filed. The proposed ice-detector would not only indicate the presence of ice on aircraft surfaces but also advise the flight crew of the need to reapply deicing fluid during ground operations.

Significance of the results: None so far

Key words
Liquid film thickness measurement

Utility of the Experimental Electro-Optical Camera (SPEC-T) for Assessment of Insect/Drought Related Forest Mortality

Investigator(s)
Gary A. Shelton and Vincent G. Ambrosia,
Ames Research Center,
Moffett Field, CA 94035-1000
James McKean, U.S.D.A. Forest Service,
Pleasant Hill, CA 94523

Other personnel involved
John C. Arvesen, Ames Research Center,
Moffett Field, CA 94035-1000
Edward A. Hildum, SVERDRUP,
Ames Research Center,
Moffett Field, CA 94035-1000
Jeffrey S. Myers, ATAC, Inc.,
Ames Research Center,
Moffett Field, CA 94035-1000

Objective of study

Evaluate and test the application of a newly developed, high spatial resolution, electro-optical digital camera (SPEC-T) for use in detecting insect/drought related forest mortality and other environmental assessments that require high spatial/spectral resolution data sets. Test and evaluation of system configuration and utility for inclusion of SPEC-T as part of NASA's supported suite of research and applications aircraft instruments.

Progress and results

An intensively managed study site was located in conjunction with the U.S.D.A. Forest Service with known forest mortality (McCloud, Calif.). An ER-2 mission flight with the SPEC-T system aboard was flown over the area in spring 1993. Analysis of the resultant data indicated an engineering problem with the data recorder and components of the tilting/timing mechanism. The resultant data were unusable for the objectives assessment. The instrument was corrected and deployed to the South Pacific for missions, but again failed. As of September 1993 the instrument is in reconfiguration to allow for reliable data collection. Possible test flights in support of this DDF will occur early in FY94, as well as during the optimum collection period in spring 1994. Funding for aircraft flight time was utilized in FY93, and remaining funds were forwarded for FY94 contract analysis support. Request for FY94 funding is to support engineering benchmark testing and engineering support for furthering operational development of the SPEC-T to preclude further mechanical failures.

Significance of results

During the in-house development and trouble-shooting of the SPEC-T system, the engineering staff are familiarizing themselves with a unique instrument and operation of that instrument. This DDF funding, besides supporting the scientific/ecosystems analysis phase, also assists in furthering the development of a new, unique airborne system built exclusively at Ames. Further, NASA-Johnson Space Center and the U.S. Navy (including the Naval Post-Graduate School, Monterey) are developing and utilizing a similar system on the shuttle. Our cooperation and discussion have led to suggestions on improvements to their system and the utility of the data obtained from a spaceborne instrument. Further discussions are continuing, leading to a potential coordinated shuttle overflight/ER-2 underflight with both systems operational for comparison of imaging characteristics.

Key words
Electro-optical camera, Remote sensing, Ecosystem analysis

A Neural Learning Algorithm for Touch Based Control of Mechanical Manipulation

Investigator(s)
Jay Steele, Ames Research Center,
Moffett Field, CA 94035-1000

Objectives of the study

A fundamental NASA goal is to return an active human presence to the Moon and establish a lunar base. The technological problems facing NASA in this future endeavor to build, maintain, and operate a base in the extremely hostile lunar environment are very challenging. We feel that automating vehicles and manipulators to accomplish tasks in the lunar environment is essential to the successful solution to these problems. Specifically, the ability to safely control the movement of autonomous or semiautonomous guided vehicles and manipulators in a cluttered work space with potentially dynamic obstacles is a critical technology area. The purpose of this study is to develop a new neural learning system capable of handling the control problem of moving these vehicles and manipulators safely around perceived obstacles toward specified goals. The complete system must be capable of learning and storing information about the world in addition to controlling a physical robot with a real time control loop.

Progress and results

During the first year of this research, we experimented with several different learning systems and focused on a reinforcement learning system. This system uses an evaluation function that returns the most appropriate action for a given state that allows the robot to reach its goal safely. This evaluation function gradually improves over time, as the tendency to take appropriate actions is reinforced while the tendency to take inappropriate actions is decreased. Appropriate actions are defined to be actions that produce short or long term success, whereas inappropriate actions produce the opposite results. The evaluation function is structured around the vehicle's possible actions and is developed by the vehicle's interaction with the geometry of its environment.

This reinforcement learning approach worked successfully with vehicles moving in a finite sized, planar world. Applying this approach to controlling articulated robot arms in three dimensions with a consequently larger action space created impossibly high memory requirements for the evaluation function. In order to solve this problem, an evaluation function that is evolved with a better knowledge of the intrinsic geometry of the articulation of the robot arm and vehicular motion is required. In short, the geometry of the evaluation function must match the external geometry of the robot arm.

As a means to creating a better evaluation function for determining robot motions, we turned to the tensor network theory, which describes the internal representation for the cerebellum of the geometries of muscular movement. Furthermore, this theory models the interaction between this representation and the sensory geometry representation, which begins to explain sensorimotor coordination in the brain. We set up a controller for the Puma robot arm based on this tensor theory and it successfully calculated appropriate joint movements to reach toward specified goals after an initial learning phase. More research is required in the next year, however, in order to expand upon this tensor theory to discover mathematics that will emulate the brain's ability to control movements beyond simple reaches and to move around obstacles.

Key words
Neural network, Arm path planning, Learning

Development of a New System for Canopy Architecture Remote Sensing

Investigator(s)
V. C. Vanderbilt, Ames Research Center, Moffett Field, CA 94035-1000
A. W. Sarto and B. J. Van Zeghbroeck, University of Colorado, Boulder, CO 80309

Objectives of the study
This remote sensing project will develop a new theory and measurement method for an emerging remote sensing technology—canopy architecture remote sensing—which will supplement the existing optical and microwave remote sensing technologies.

Progress and results
We are developing a new theory and a new laser based measurement method for remotely sensing canopy architecture. The theoretical development supports development of a proof-of-concept instrument.

Theoretical Development
We divided the theoretical problem of understanding and extracting the information in the laser pulse returned to a lidar from a canopy into two parts.

- During this first year, we have developed a stochastic process model to mathematically describe canopy architecture.
- During the coming year, we will use the results of our architecture model to develop a second model, an engineering interaction model, describing the interaction between a spatially and temporally modulated laser pulse and the architecture of a plant canopy.

In our newly developed stochastic architecture model, the stochastic variable is not time but rather (x,y,z) position and possibly (q,f) direction in the canopy. In the model, the canopy statistical properties are computed from the statistical properties of an ensemble of 'plots' selected from within the canopy. This model supports definition of an autocorrelation function for canopy architecture, providing a fundamental measure of canopy architectural properties. Examples in this report illustrate application of the theory to the problem of quantifying canopy architecture.

Development of a proof-of-concept instrument
Recent research has demonstrated the potential of metal–semiconductor–metal (MSM) photodetectors to attain extremely short response time constants required for use in the canopy architecture measurement system. The research has shown that these extremely fast MSM photodiodes, fabricated as single detectors or as arrays of detectors, perform well in a frequency mixing mode of operation, a fact which we have exploited in the design of the canopy architecture measurement system.

Rather than acquire data at gigahertz (GHz) frequencies, the canopy architecture measurement system we are developing will sample the output of a superfast array of MSM photodetectors with gigahertz bandwidth, allowing data collection at a much lower frequency than the GHz regime. This sampling design takes advantage of the signal mixing capability of the MSM photodiodes and avoids the need to fabricate a GHz transmission line connection to each element of the array.

During the past year, we have designed and fabricated at the University of Colorado extremely high speed, MSM photodetectors—both single detectors and arrays of detectors—for use in the proof-of-concept lidar canopy architecture sensor (fig. 1). The MSM detectors, the critical component in the canopy architecture instrument, are capable of providing an output current proportional to the incident light (fig. 2). The prototype, proof-of-concept lidar sensor uses high-speed galium-arsenide, MSM photodetectors, developed at the University of Colorado (B. J. Van Zeghbroeck et al., 1990), implemented in an optical correlation system. The optical correlation design takes advantage of the signal mixing capabilities of MSM photodetectors, avoiding the need for expensive, often one-of-a-kind electronic components with GHz bandwidths while allowing signal processing of the return laser pulse waveform, its analog-to-digital conversion, and storage of the digital data with the aid of cheap, yet high quality, off-the-shelf hardware. The prototype system will be developed at Ames Research Center during the coming year. In a laboratory test a sample MSM detector exhibited a response time that would allow the architecture of even miniature canopies to be measured (fig. 3).

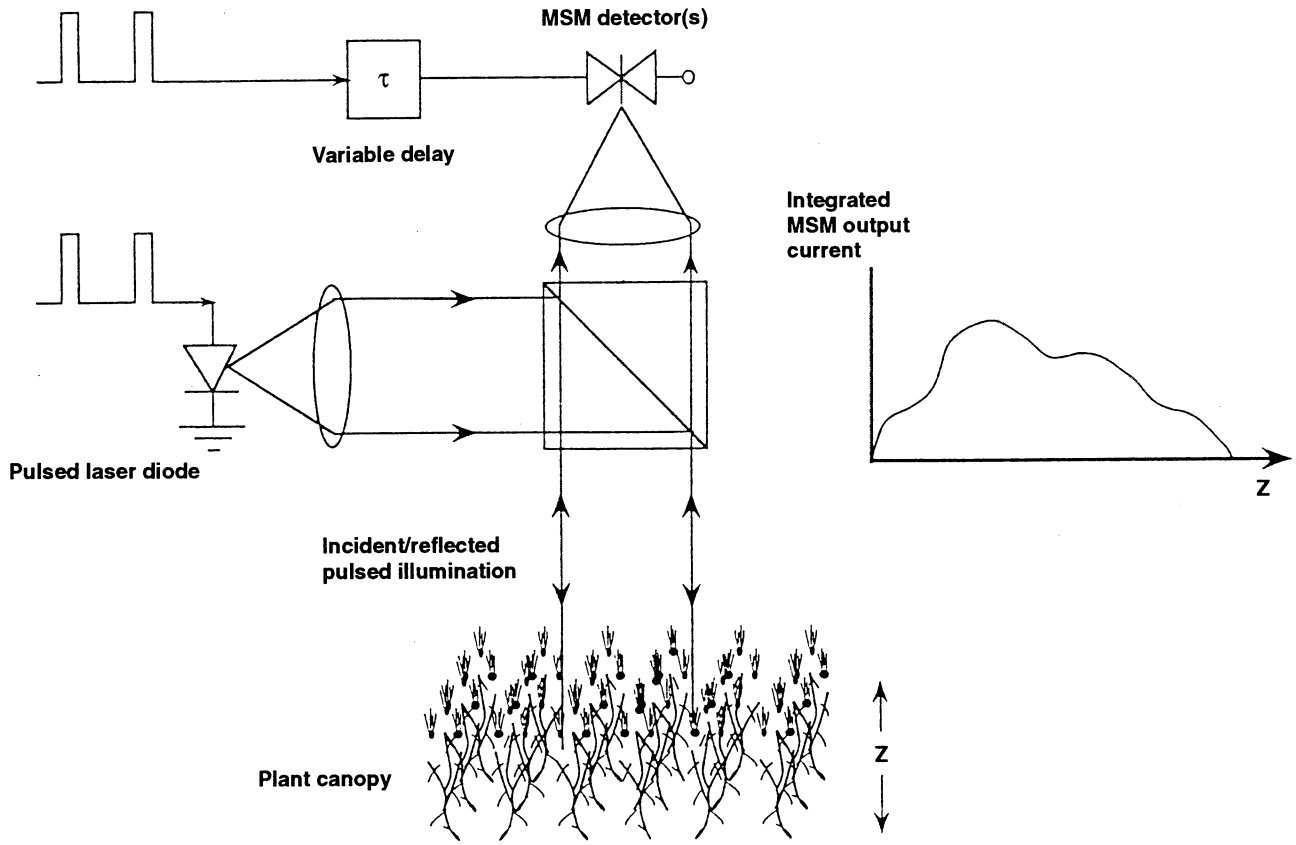


Figure 1. Plant canopy architecture measurement system.

Significance of the results

The progress and results to date lay the foundation for our efforts during the second year of the project. Our new model for canopy architecture provides the needed theoretical structure upon which to develop the engineering model of the instrument operation. The MSM detectors and detector arrays that we have fabricated are essential for developing the prototype instrument during the second year.

Publications resulting from study

A draft report, Stochastic Model of Plant Canopy Architecture, has been written by V. C. Vanderbilt (1993).

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Van Zeghbroeck, B. J. et al.: High-Speed GaAs/AlGaAs Optoelectronic Devices for Computer Applications. IBM J. Research and Development, vol. 34, 1990.

Key words

Canopy architecture, Stochastic model of canopy architecture, Measurement of canopy architecture

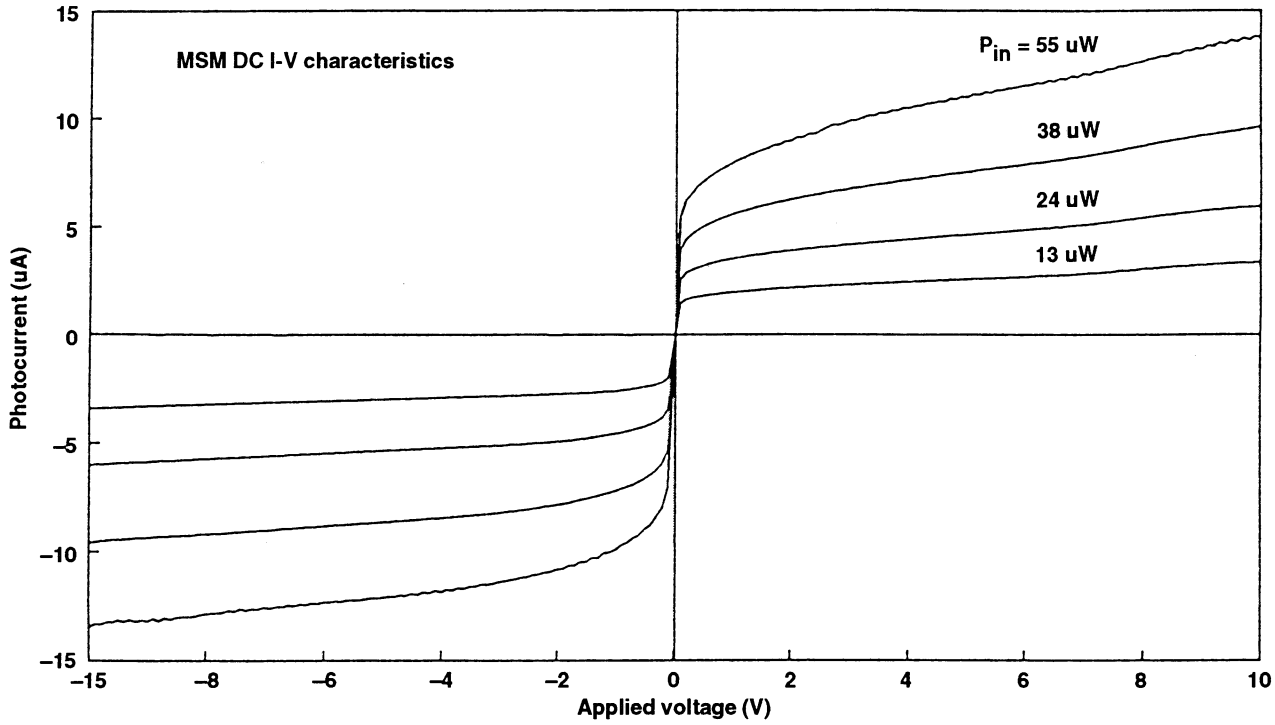

Figure 2. Current (I) and voltage (V) characteristics of the MSM photodetectors fabricated at the University of Colorado for the lidar sensor showing dependence on the incident light intensity.

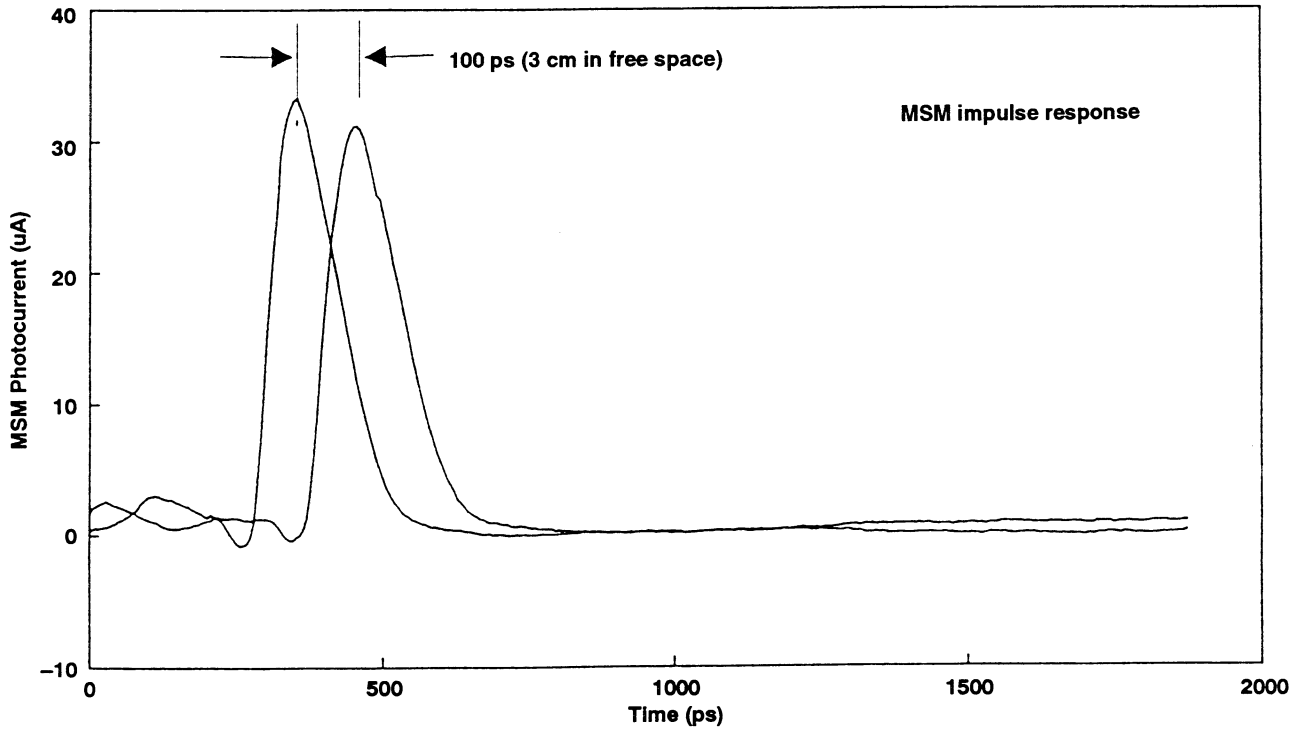

Figure 3. Measurement of beam round-trip travel time to a stationary mirror.

Optimization of Spatial Auditory Displays for Multiple Communication Channel Intelligibility

Investigator(s)
Elizabeth M. Wenzel and Durand R. Begault,
Ames Research Center,
Moffett Field, CA 94035-1000

Objectives of the study
The study seeks to determine the optimal placement of multiple radio communication channels using 3-D sound techniques, so that speech intelligibility in contexts such as NASA-KSC launch operations is improved. A concurrent DDF from Kennedy Space Center (KSC) allowed the development of a prototype, the Ames Spatial Auditory Display (fig. 1). The Ames DDF supports psychoacoustic experiments for determining intelligibility as a function of placement on the virtual acoustic azimuth, with frequency response and launch control environment conditions as additional independent variables.

Figure 1. Ames Spatial Auditory Display.

Progress and results
Figure 2 shows the results of an experiment designed to measure intelligibility of four letter call signs used by KSC personnel as a function of incremented 30-deg virtual azimuths. The solid line represents results for a group of "naive" listeners, and the dotted line represents results from listeners familiar with the call signs. It can be seen that a 6–7 dB improvement results at the optimal positions of 60 and 90 degrees azimuth.

Significance of the results
The 6–7 dB advantage for 60- and 90-deg head-related transfer function (HRTF)-filtered speech represents a minimum halving of the intensity (acoustic power) necessary for correctly identifying four letter call signs typical of those used in communication systems at KSC. This reduction in the likelihood of misinterpreting call signs over communication systems is an important safety improvement for "high stress," human-machine interface contexts. The binaural advantage could also benefit communications personnel because the overall intensity of communications hardware could be reduced without sacrificing intelligibility, and volume adjustment of a desired individual channel can occur less frequency. Lower listening levels over headphones could possibly reduce the risk of threshold shifts, the **Lombard Reflex**

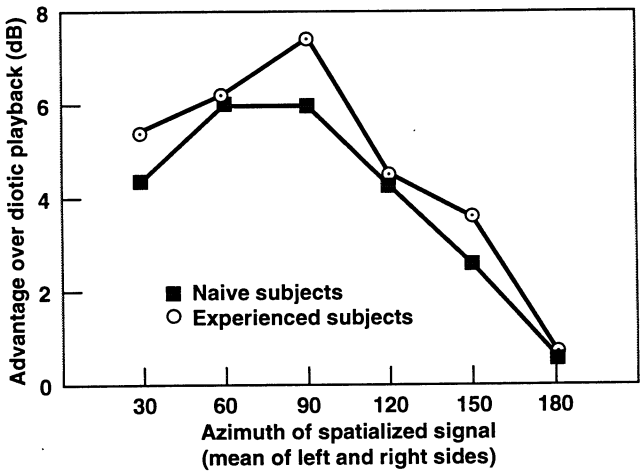

Figure 2. Intelligibility of four letter call signs used by KSC personnel as a function of incremented 30-deg virtual azimuths.

(raising the intensity of one's own voice), and overall fatigue. Overall, the findings here suggest that the use of a spatial auditory display could enhance both occupational and operational safety and efficiency of NASA operations.

Publications resulting from study

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Begault, D. R.: Call Sign Intelligibility Improvement Using a Spatial Auditory Display. NASA TM-104014, 1993.

Begault, D. R.: Call Sign Intelligibility Improvement Using a Spatial Auditory Display: Applications to KSC Speech Communications. In Proceedings of the Space Operations, Applications and Research (SOAR) Conference, Houston, Tex.: NASA Johnson Space Center, 1993.

Begault, D. R.; and Erbe, T. R.: Multichannel Spatial Auditory Display for Speech Communications. In Proceedings of the 95th Audio Engineering Society Convention., Preprint No. 3707, Audio Engineering Society, New York, N.Y., 1993.

Key words

Speech intelligibility, 3-D audio displays, Communication systems

Musculoskeletal Loading or Unloading with Differential Pressure

Investigator(s)
Robert Whalen and Gregory Breit,
Ames Research Center,
Moffett Field, CA 94035-1000
Douglas Schwandt,
Rehabilitation Research and Development (RR&D) Center,
Palo Alto, CA 94304

Other personnel involved
Charles Burgar, RR&D Center,
Palo Alto, CA 94304

Introduction
We have proposed a novel method of using air pressure to apply an external axial force to the body, coincident with the body's center of mass, that has the potential of enabling Earth-equivalent musculoskeletal forces in space [Whalen et al., 1991; Hargens et al., 1991]. Since gait is primarily controlled by gravity acting at the center of mass and only secondarily by its distributed action on limb segments (He et al., 1991; McMahon and Cheng, 1990), we hypothesize that near-normal exercise walking and running are possible in space by combining a treadmill with this method of loading the body. This consideration is important since current exercise devices are not capable of generating skeletal force levels and daily loading histories of sufficient magnitude in space to maintain the musculoskeletal system without lengthy daily exercise periods [Whalen, 1993]. Furthermore, by reversing the direction of the pressure differential, walking and running at musculoskeletal levels below normal one-G walking, i.e., simulated hypogravity locomotion, are possible on Earth. With our DDF research, we have pursued the application of differential pressure as a countermeasure device for use in space and, in collaboration with the Palo Alto Veterans Administration (VA) RR&D Center, as a walking assist device for rehabilitation.

Objectives of the study
The objectives of this research were

- to design and fabricate an air pressure chamber and treadmill assembly,
- to test the hypothesis that Earth-equivalent skeletal forces are achievable in microgravity,
- to simulate hypogravity and hypergravity locomotion on Earth.

Theory
The method of developing a "noncontact" force at the mass center of the body is illustrated in figure 1(a). The upper and lower body are separated

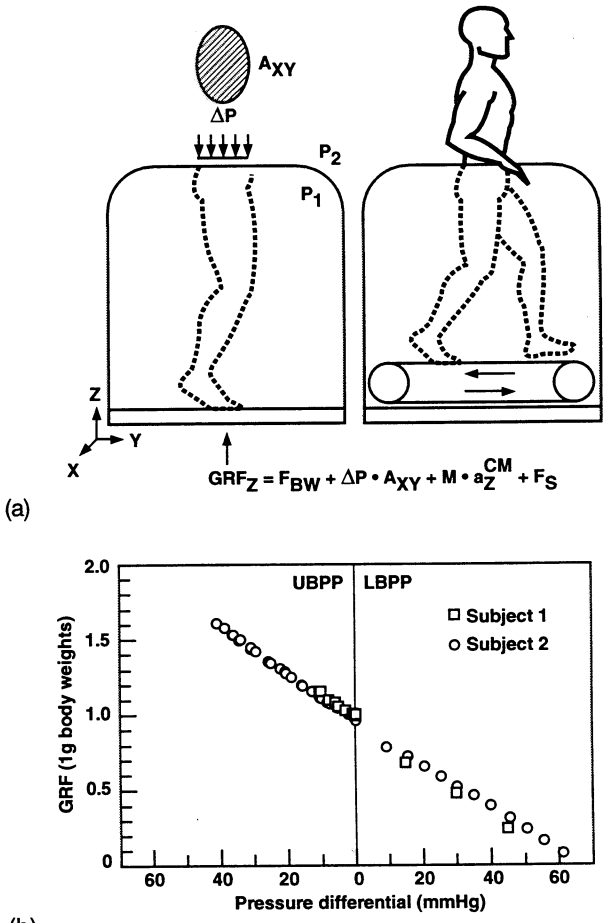


Figure 1. Differential pressure chamber with treadmill and pressure force calibration data. (a) Treadmill walking at 2 m/s and treadmill running at 3 m/s. Note the characteristic ground reaction force profiles, suggesting proportional lower limb musculoskeletal loading. (b) Hypergravity is simulated by a positive lower body pressure.

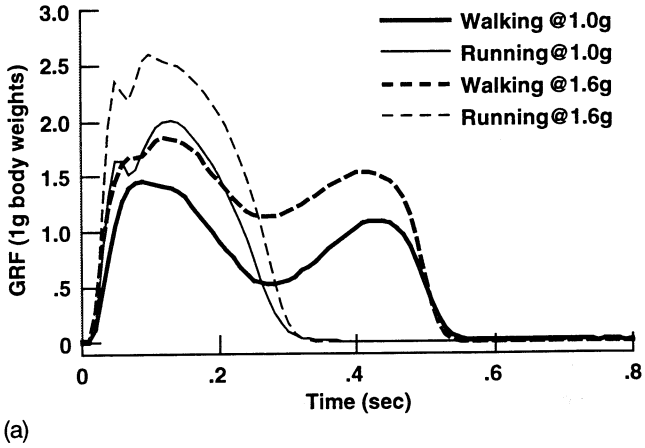
by a flexible airtight seal that permits free lateral and vertical movement. The direction of the pressure difference between the upper and lower body determines the direction of the resultant force. We have used upper body positive pressure (UBPP) to simulate or augment gravity (hypergravity) during locomotion and a lower body positive pressure (LBPP) to simulate hypogravity. The seal can provide an additional shear force whose magnitude depends on the unrestrained exposed area of the seal. Body weight on Earth, the pressure force, seal shear force, and inertia forces all contribute to the resultant ground reaction force (GRF).

Progress and results

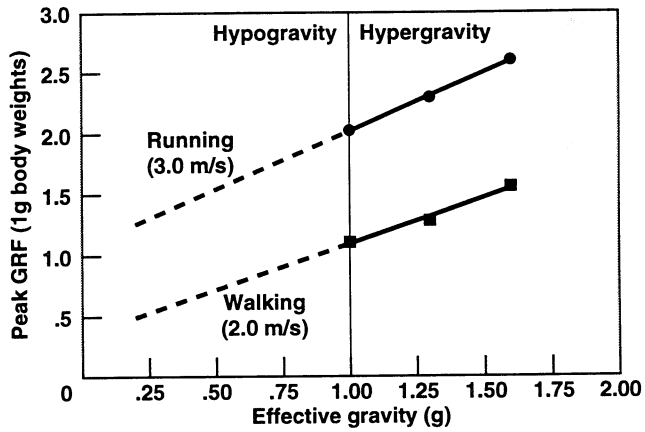
We have built a treadmill and computer-controlled upper body air pressure system capable of imposing high force levels on the body and have used the system to simulate hypergravity locomotion on Earth. With this design a 3-foot-diameter inflatable sphere, constructed from a lightweight coated fabric, encloses the upper body. The sphere is tethered to the treadmill with four tension straps that balance compression forces applied to the body by the pressure, shear, and inertia loading. In collaboration with the VA RR&D Center we have also constructed a LBPP system to investigate subject tolerance to LBPP in order to develop a walking assist device for patients recovering from a stroke, incomplete spinal cord injury, or joint replacement surgery. Lower body positive pressure provides support to patients who need to begin exercise walking on a treadmill with reduced ground reaction and joint forces. The relationship between the pressure differential and the GRF force during a static calibration test is shown in figure 1(b).

Hypergravity and hypogravity simulation

Ground reaction force data while walking and running on the treadmill were collected at 1.0, 1.3, and 1.6 G (0, 20, 40 mm Hg) using a capacitance insole force sensor. Typical gait cycles of treadmill walking at 2 m/s and treadmill running at 3 m/s at 1.0 G and 1.6 G are plotted in figure 2(a). Peak force levels at toe-off increased as expected with increasing "G-level" (see fig. 2(b)). Running data collected at different G-levels were normalized by the stride period (Tstride) and the effective body weight, computed by multiplying Earth body weight by the effective gravity. Normalized peak GRFs decreased with increasing G-level indicating that muscle force generation is a limiting factor to hypergravity gait. Interestingly, ground contact time at a fixed gait speed was constant, i.e., independent of gravity.



(a)



(b)

Figure 2. Ground reaction forces during gait at different effective gravity levels. (a) Treadmill walking at 2 m/s and treadmill running at 3 m/s. Note the characteristic ground reaction force profiles, suggesting proportional lower limb musculoskeletal loading. (b) Hypogravity simulation values are extrapolated. The plots also express the relative change in lower limb musculoskeletal loading since internal forces are scaled approximately by the magnitude of the ground reaction force.

Results extrapolated to hypogravity locomotion in figure 2(b) agree with recent hypogravity locomotion studies (He et al., 1991). In preliminary tests performed at the VA RR&D Center, normal subjects tolerated LBPP without significant effect on the cardiovascular system. In these studies a positive pressure of 45 mm Hg supported approximately 75% of body weight.

Conclusions

We have verified that differential pressure loading is an effective and feasible method of altering GRFs during gait. Furthermore, since the profiles of

the GRFs are similar at different "G-levels," this result suggests that the internal musculoskeletal forces that contribute to the resultant GRF are proportionally changed. We believe Earth-equivalent lower limb musculoskeletal forces can be generated in space with this device.

Significance of results

1. Differential pressure loading with treadmill exercise is a promising method for maintaining the musculoskeletal and cardiovascular systems of humans in space.

2. Lower body positive pressure may be used to assist walking by supporting the body during gait rehabilitation on Earth.

3. The method provides a new tool for studying the effects of different "gravitational" levels on gait and musculoskeletal adaptation.

Publications resulting from study

1. Whalen, R.; Hargens, A.; Schwandt, D.; and Watenpaugh D.: Musculoskeletal Loading or Unloading with Differential Air Pressure. Transactions of the 37th Meeting of the Orthopedic Research Society (ORS), vol. 16, no. 2, 1991, p. 628.
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3. Whalen, R.; and Hargens, A.: Patent 5,113,339: Exercise Method and Apparatus Utilizing Differential Air Pressure, 1992.

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Key words

Exercise countermeasures, Hypergravity locomotion, Hypogravity locomotion, Gait rehabilitation

Aerogel Advanced Material Development

Investigator(s)
Susan White, Ames Research Center,
Moffett Field, CA 94035-1000

Objectives of the study

Aerogels, sometimes called "solid smoke," have the potential for being a breakthrough material because of their extremely light weight. They present two problems: mechanical fragility and very high surface activity. Both of these problems were tackled in this project. The focus of this project was to produce and investigate prototypes of two new classes of materials: fiber-strengthened and chemically altered aerogels, in order to explore their potential for thermal protection system (TPS) use.

This project evolved to investigate different materials in order to take advantage of unique, previously unexploited properties of aerogel composite materials. The focus widened from investigating high-temperature low-density insulation to include other applications, in response to changes in NASA's priorities.

Progress and results

A key question in any new approach is always whether it will work. In the case of these materials, it has been shown that the approach of fiber-loading aerogels does in fact produce a strengthened, toughened, low-density composite material.

System investigated

- Zirconia aerogel/zirconia fiber: The first known samples of fiber-reinforced stabilized zirconia aerogel were successfully produced for this project by TRW's Space and Technology Group. Twenty-five samples were produced by using a test matrix varying the fiber-loading, chemical processing methods and heat-treatment conditions. Fiber loading of 12% by weight minimized the end-product density of the samples, as shown in figure 1. To produce sufficiently strong samples, the required heat treatment temperatures and times have been roughly quantified at 1350°C for 10 hours. Scanning electron microscope (SEM) pictures of the materials showed the microstructure.
- Chemically modified silica aerogel: To solve the problem of the very high surface activity characteristic of aerogels, silica aerogels were used as a testbed because the chemistry of silica is already well understood. The approach involves chemically bonding extra nitrogen atoms to the hydroxyl groups bound to the aerogel structure itself. This is accomplished by oxidizing the material, followed by nitriding aerogel bound to gaseous phase and decomposing it thermally once it has entered the structure. Fifteen different compositions were produced and tested. Results also indicate that this approach did succeed in raising the sintering temperature of the material, reducing the contraction of the material at a given temperature. Results indicate that high-temperature processing is required to optimize the processing. A follow-on phase of this investigation is in progress.
- Silica aerogel/silica fiber (currently in progress): This development benefits from the extensive NASA knowledge base on silica fiber composites. A family of different composite materials is currently being produced with a range of different aerogel and fiber loading fractions.
- Zirconia aerogel/silica fiber (currently in progress): This development includes more sophisticated processing methods than those used in the first phase of the study. Property measurements planned for this final set of samples include compression, Young's modulus, thermal conductivity, and other thermal tests.
- Numerical predictions (currently in progress): This DDF project also continues to benefit from a related but separately funded SBIR Phase 1 project with Applied Sciences Laboratory. In that project, a numerical model was developed to predict the radiative transport properties of fiber/particle composites like these materials. The predicted

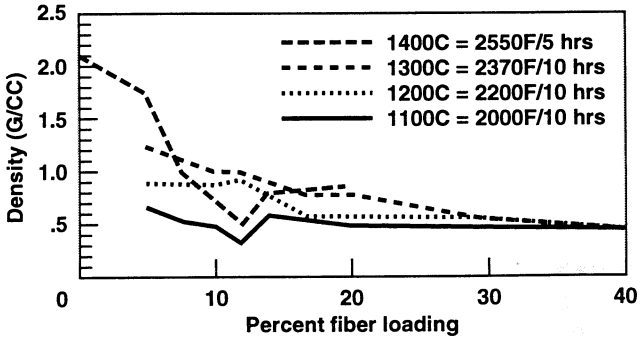

Figure 1. Density of the composite is minimized by optimization.

trends show a clear advantage to having the small aerogel particles contribute a strong short-wavelength reflectance property to the material.

Significance of the results

The goal of this project was to create and investigate a new class of lightweight, mechanically strong insulation materials. These extremely lightweight, low conductivity materials offer significant potential for thermal protection system applications. Fiber-loading aerogels successfully produce a strengthened, toughened, low-density composite material. Chemical modification did succeed in raising the sintering temperature of a representative aerogel. The unique physical properties and nanostructure of this novel material offer new solutions to several insulation problems of concern to NASA.

Publications resulting from study

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Hrubesh, L.: Enhanced Thermal Capacity Aerogels. Summary Report for Contract No. A-26310D/L-1342, Lawrence Livermore National Laboratory, Livermore, Calif.

White, Susan; Lee, Siu-Chun; and Grzesik, Jan: Advanced Particulate Fibrous Composite for Thermal Control of Re-entry Vehicles. AIAA 93-2824, AIAA 28th Thermophysics Conference, Orlando, Fla., 1993. Submitted to: J. Quant. Spectros. Radiat. Trans.

Lee, Siu-Chun; White, Susan; and Grzesik, Jan: Effect of Particle Size in Composite Materials on Radiative Properties. AIAA 93-2729, AIAA 28th Thermophysics Conference, Orlando, Fla., 1993. Submitted to AIAA J. Thermophysics.

Key words

Aerogel, Thermal protection materials, Composites

Effects of Low Energy Impact of Atomic Oxygen and Nitrogen on Advanced Materials

Investigator(s)
Susan White, Joan Pallix, and Les Barnes,
Ames Research Center,
Moffett Field, CA 94035-1000

Objectives of the study

The objective of this research is to develop experimental and computational methods that will aid in understanding the fundamental physical processes involved in surface catalysis on thermal protection materials. Little data have been collected on the interactions of oxygen and nitrogen atoms with the surfaces of advanced thermal protection materials. Catalysis data would aid in understanding the relationships between surface mediated atom recombination and surface heating during vehicle reentry into the Earth's atmosphere. This is essential in the development of higher performance and lighter weight thermal protection systems. During the past year, research has been carried out in three areas including (1) Fourier transform infrared (FTIR) spectroscopy, (2) laser induced fluorescence and ionization spectroscopy and (3) computational modeling of gas-surface interactions.

Progress and results

FTIR spectroscopy– Infrared measurements will track and quantify the low-pressure temperature-controlled desorption of surface adsorbed species including O_2 on a silica substrate. These experiments will simulate the more complex surface interactions on a reentry vehicle surface. A porous substrate, made by chemically etching crystalline silica, has been successfully used in related desorption experiments reported in the literature. However, the interacting surface area can be maximized by using an amorphous silica aerogel substrate to significantly enhance the signal-to-noise ratio. In these experiments, the silica aerogel substrate will be heated to 500°C for heat cleaning, then cooled to –125°C in a low-pressure chamber. The adsorbing/desorbing species will be introduced and allowed to react with the extended surface of the substrate. The temperature will then be increased to the maximum following a programmed profile. During this phase of the project, the experimental requirements were established and the necessary apparatus was designed and partly procured. In the second year of the project, the remainder of the necessary equipment will be procured and the infrared spectroscopy experiments will be carried out.

Laser spectroscopy– A number of spectroscopic measurements have been made at SRI International (in collaboration with R. Copeland) in order to design experiments which will detect O and N atoms as well as their recombination products N_2, O_2, and NO. Current experiments include room temperature detection of O atoms as well as O_2 molecules formed from surface recombination. The experimental apparatus was designed for versatility in that it allows for either fluorescence detection or detection of ions. Laser induced fluorescence and ionization methods can be used to probe the internal energy (vibrational or rotational) of the product molecules. This information will aid in determination of energy accommodation coefficients and atom recombination probabilities at the surface of interest. Quartz was chosen for the initial measurements to determine the viability of the detection methods because the surface is fairly well defined and O atom recombination on quartz has been well studied. Recombination on Cu and Ni was also briefly investigated. Through this work we have established a method of generating O atoms with minimal O_2 background that will simplify interpretation of surface mediated atom recombination data. All sources of spectral interference and background interference have been identified and minimized or eliminated for detection of ground state O_2. This experimental setup will be useful for studies involving surface reactions that produce O_2; in addition, studies involving N_2 and NO production at the surface are also possible with few modifications to the procedures. A final report on this work entitled "Oxygen Atom Scattering and Recombination Experiments" has been submitted.

Computational chemistry– An examination of the available literature on the alpha-quartz surface has given insight into the complicated nature of the problem of the interaction of molecules with the surface. From both an experimental and theoretical viewpoint, the structure of the surface of alpha-quartz and amorphous silica is important. The level of hydroxylation (from available water molecules) of the surface will affect adsorption significantly. Thus the current theoretical calculations are aimed at modeling the interaction of water with small silica clusters, to study interaction energies and possibly vibrational spectra of the adsorbed water molecules. These calculations are

ongoing, currently applied to different adsorption geometries for water on an Si(2)O(7)H(6) cluster, which may be compared with other theoretical work on smaller clusters and also experimental work surface studies. This work was summarized in a report entitled "Methods for Studying the Alpha-Quartz Surface" by Lynn Amon of the University of Michigan.

Key words
Catalysis, Atom recombination, Energy accommodation

Application of Digital Signal Processing (DSP) to Near Real-Time Compensation of Attenuated Acoustical and Unsteady Pressure Measurements

Investigator(s)
Stephen A. Whitmore,
Dryden Flight Research Facility,
Edwards, CA 93523-0273

Objectives of the study

The measurement of high frequency acoustical/unsteady pressure data is a difficult sensing task. The primary difficulty in obtaining these high fidelity measurements is pneumatic distortion in the tubing used to transmit pressure impulses from the surface to the measurement transducer. To avoid pneumatic distortion, experiment designers seek to mount the sensor at the measurement surface. In some cases this offers a viable measurement solution; however, in most cases, as when many pressures must be measured in a small surface area or when pressure is sensed in a hostile environment, pneumatic tubing is required to transmit pressure from the surface to the transducer. This tubing distorts the pressure impulses and causes a magnitude amplification (resonance) or attenuation and a phase delay (Berg and Tijdeman, 1965; Iberall, 1950; Lamb, 1957; Rayleigh, 1894; and Schuder and Binder, 1959).

This research attempts to develop methods for numerical compensation of pressure measurement distortion induced by pneumatic tubing, which cannot be mitigated in the instrumentation design, i.e., the goal is to take the acoustically distorted pressure measurements and perform inverse modeling to compensate for the effects of the distortion using analytical models. The research proposes to apply the compensation methods in real time using digital signal processing (DSP) technology.

Progress and results

The physics of pneumatic distortion have been analyzed using one-dimensional (1-D) unsteady Navier-Stokes relationships. The energy equation has been decoupled from momentum and continuity assuming a polytropic relationship between pressure, density, and temperature. This decoupling allows the boundary value problem to be reduced to a simple model, which can be solved in closed form in the frequency domain. The model has been experimentally verified for simple geometric configurations (figs. 1(a–b)).

Although numerical techniques for highly damped complex configurations have been developed previously (Whitmore, 1988), closed form solutions have not existed.

Deconvolution algorithms to perform the compensation have been analytically developed and verified off line (nonreal time). Conceptually, it is a trivial matter to compensate for the effects of the acoustical distortion by simply inverting the transfer function and performing the inverse transform, a method referred to as spectral deconvolution.

In practice, however, the problem is not as easy. At high frequencies where the measured signal is attenuated considerably, the inverse of the transfer function acts as an amplifier and will amplify both the attenuated signal and the noise introduced into the measurement by the transducer and its associated electronics. This amplification tends to produce a very noisy reconstructed signal at high frequencies.

An inversion algorithm based on the Wiener Filter (Mendel, 1983) has been developed to circumvent this problem. The algorithm basically weights the inverse transfer function as a function of the signal-to-noise power ratio of the measured pressure data. Hardware necessary to implement the developed filtering algorithm has been procured.

Significance of the results

The closed form analytical model allows the compensation to be performed directly using Fourier transform methods, and it does not require the solution of partial differential equations—a time consuming process that cannot be performed in real time. The development of the filtering algorithm circumvents noise amplification problems and will allow even heavily attenuated signals to be faithfully reconstructed up to the noise threshold of the measurement system.

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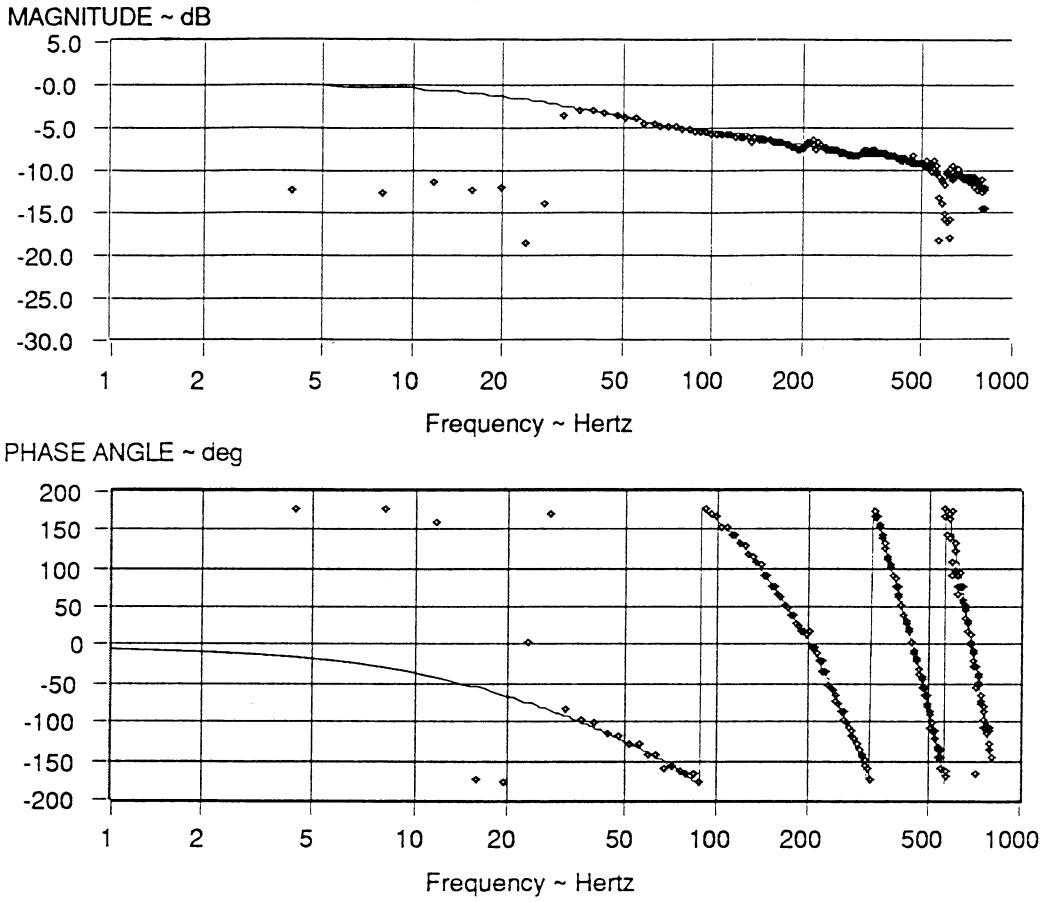
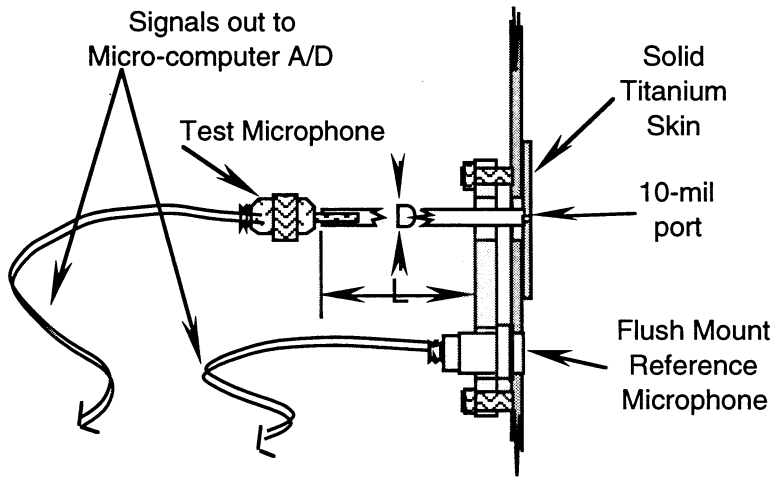


(a)



(b)

Figure 1. (a) Empirical validation of closed form model, (b) test configuration 0.03 in. diameter steel line with 0.010-in. diameter port (F-16XL wing glove).

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Key words
Pressure sensor, Deconvolution, Digital signal processing (DSP), Pneumatic compensation

Technology Development for Selective Recovery of Urea from Urine and Its Subsequent Decomposition to Ammonia with Application in the Controlled Ecological Life Support Systems (CELSS)

Investigator(s)
Richard Wisniewski, Ames Research Center, Moffett Field, CA 94035-1000

Other personnel involved
Jeff Chamberlain, University of California, Berkeley, CA 94720

Objectives of the study
Develop a technology for separation of urea and salts from urine. Urea will be a major component of the nitrogen balance loop and will be used as fertilizer for plants in CELSS.

Progress and results
The applied separation principle is based on the fact that in the aqueous solution salt molecules dissociate completely into ions and urea molecules dissociate very little. Application of an electric field would cause a movement of the salt ions and might have only a limited effect on the urea molecules. Diffusional effects may not affect this separation in a significant way since the diffusion coefficient of a urea molecule is of similar magnitude to salts. The electric field is a dominant separation driving force, and a transport flux in an electric field can be several hundred times that due to diffusion. In a free-flow electrophoresis apparatus, a thin layer of flowing liquid is subject to a perpendicular electric field. After injecting a sample in the center of a stream, urea will be collected from the outlet central area, and salt ions that migrate toward the electrodes will be collected on both sides. The urea molecule H_2NCONH_2 forms hydrogen bonds with the surrounding water molecules. Ions have their own hydration shells that are dragged during ion movement. Movement of ions in an electric field may affect the urea molecules and their associated water. Positive and negative ions would have hydration shells with differently oriented water molecules and might interact differently with the urea hydration shell. These assumptions might be confirmed experimentally by showing how the moving ions with different mobilities and hydration shells could affect the distribution of urea molecules originally introduced as a narrow band.

Methods for urea detection and ion determination in aqueous solutions have been developed. The urea detection method employs enzyme urease that converts urea to ammonia. The same enzyme will be used to convert a stream of separated urea into ammonia in a controlled manner. Electrophoretic power supplies, a multichannel peristaltic pump with extended head and cassettes, and a recirculating cooler have been selected and purchased. Two small batch electrophoretic cells were designed and tested. An in-house design of a continuous flow electrophoretic chamber has been built. A precision free-flow electrophoresis chamber has been purchased from Dr. Weber GmbH. It arrived in August 1993. Some originally missing components arrived in September 1993. A capillary flow electrophoresis apparatus has been purchased from Isco and arrived in September 1993.

The first stage of this study involved testing the separation process and possible intermolecular effects during electrophoresis in a free solution. Nine experiments were performed using the batch electrophoretic chamber (fig. 1) with manual sample injection and withdrawal. After each experiment, the separation weirs were lowered to divide liquid volume prior to sampling. The observed increase of electric current during each run has been an indication of ionic migration. Figure 2 shows the distribution of urea and ions (a) and the distribution of pH (b) when a sample containing urea and high concentration salts was injected into a buffer with low salt concentration. Figure 3 shows the urea distribution when urea only was injected into the same buffer. Initial and final levels of the electric current are shown as Io and If. Analytical grade urea and sodium phosphate were used for preparation of solutions.

Significance of the results
Results indicate that there may be a molecular interaction involved among the urea molecules, ions migrating in an electric field, and hydrating water molecules. The final urea band is wider in the case of higher salt concentration (fig. 2(a)). At higher salt concentrations more ions move through the bulk water and widening of the urea band occurs because of their apparent interaction with urea molecules.

At high electric currents the phenomena of thermal convection and electroosmotic flow may also contribute to band spreading. Use of the manual sampling technique may result in some minute back flows of liquid during sampling, further spreading the urea band. In the free-flow electrophoresis with

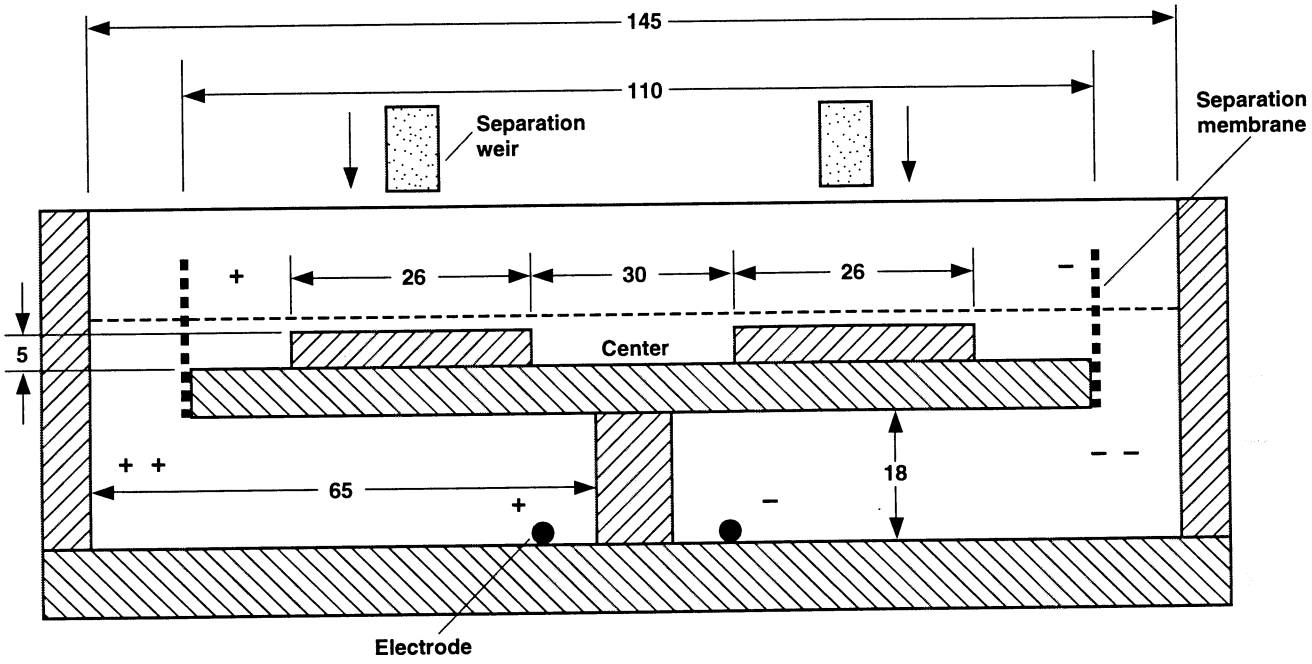

Figure 1. The cross section of batch electrophoretic chamber (width = 100 mm; all dimensions in mm).

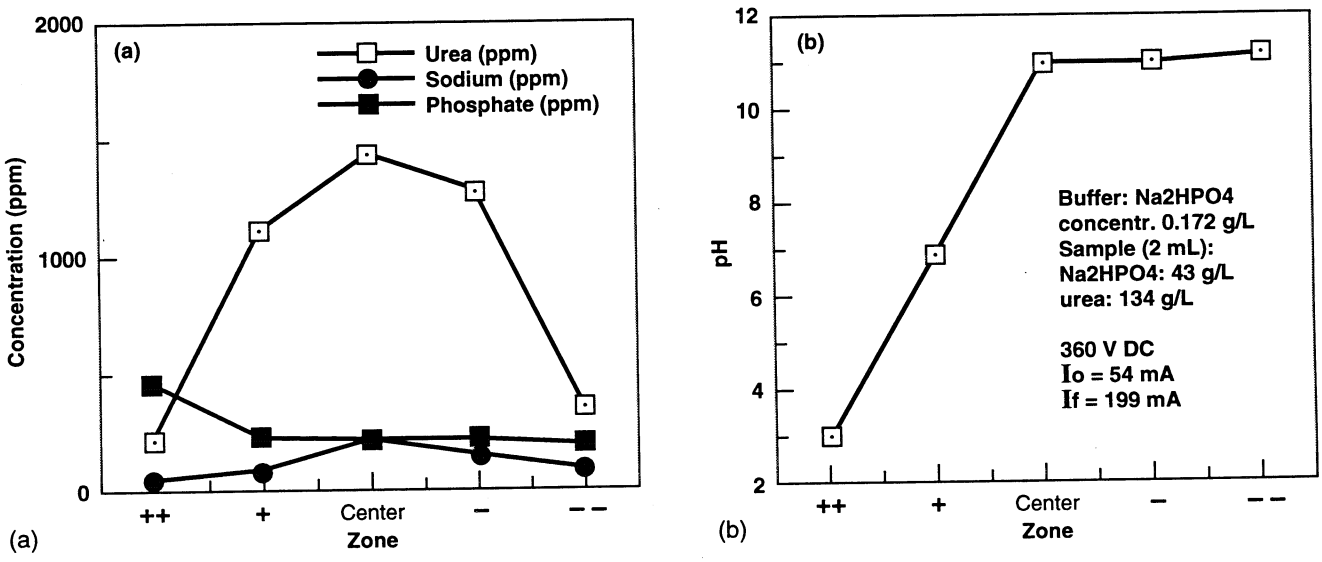

Figure 2. (a) Urea and ion distribution, (b) pH distribution.

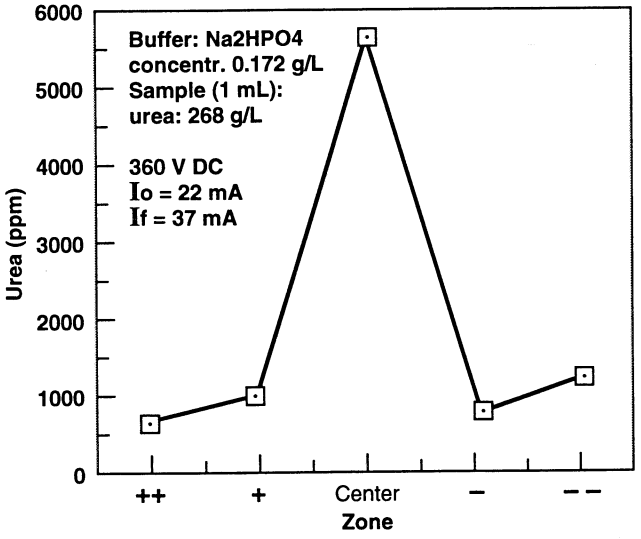

Figure 3. Distribution of urea with low salt buffer.

well-controlled laminar flow, a continuous sampling and wall cooling would eliminate some of these problems. In the free-flow electrophoresis process, salt concentration in a carrier buffer and a sample would be optimized for best separation. Lower concentration of salt had a positive effect on separation resolution (fig. 3).

There is a pH distribution phenomenon across the chamber (fig. 2(b)) caused by reactions near electrodes. The pH distribution may be controlled by adjustments in a main buffer composition. The electrode zones can be separated from the main chamber by various membranes (ultrafiltration, microfiltration, or dialysis type) to further minimize the electrode effects.

A molecular modeling approach may be tried for modeling the urea molecule with its hydrating shell and the ions (salts) with their hydrating shells to aid in better understanding how those shells might interact.

A longer batch chamber with more partitions to be used for detailed investigations of urea band spreading effect is in a design stage. Electrophoretic separation phenomena will be further studied using the free-flow and capillary electrophoresis systems. A process of enzymatic hydrolysis of separated urea would complete the project.

Publications resulting from study: None so far

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Key words

Separation in electric field, Free-flow electrophoresis, Salt-urea separation.

MIR Study of Disks Around Young Stellar Objects

Investigator(s)
Fred Witteborn, Ames Research Center,
Moffett Field, CA 94035-1000
Harold M. Butner, DTM-Carnegie Institute,
Washington, D.C. 20015

Other personnel involved
Lynne Deutsch, University of Massachusetts,
Amherst, MA 01002
Diane Wooden, Ames Research Center,
Moffett Field, CA 94035-1000
Antonella Natta, Osservatorio di Arcetri,
Firenze, Italy

Objectives of the study

Understanding the circumstellar environment of young stars is one of the major areas of research in star formation today. Current theories suggest that disks, which might serve as sites for planet formation, are quite common. However, our understanding of disk properties, and how the disk is related to the more extended young stellar object environment, is quite limited. We had two major objectives. The first was to develop a radiative transport code that would allow us to model both the disk and the more extended envelope around a young star. In particular, we wanted to have a code that allowed us to vary the disk properties and explore a range of physical conditions. Second, we planned to obtain midinfrared spectral data using the Ames Hi-Resolution Faint Object Spectragraph for a variety of sources. These data would be combined with far-infrared, submillimeter and millimeter data. The data would be used to constrain source models.

From these source models, we would then test current ideas of star formation. For example, are all sources consistent with the idea of a simple infalling zone? Are more complex density gradients found, and under what conditions? Is there a correlation between the young stellar mass and the disk properties? Only by building up a large sample of source models can these questions be addressed. Studies of so few objects leave open the possibility that the particular source is somehow unique.

Progress and results

1. Disk code: We have produced a very flexible, simple disk code for use with our radiative transport code. The disk portion of the radiative transfer is not self-consistent, but it does conserve luminosity. It assumes a power law temperature distribution, and it handles the reprocessing of the central star's radiation field. The output from this code can be directly input into the spherical envelope radiative transport code. By adopting the average radiation field from the disk, we can estimate the disk's effects on the envelope. By an iteration process, we have also included the envelope's heating on the disk. The backwarming of the disk by the envelope has important consequences for estimates of the total disk mass because the disk mass is most easily estimated from the total millimeter flux. However, backwarming allows a disk to become warmer than expected at its outer portions, and thus to require a smaller disk to produce the same millimeter flux.

2. MIDIR Observations: We have obtained some spectra of T Tauri stars, and some preliminary observations of Vega-like stars. T Tauri systems are low mass young stars, similar to our own Sun in mass. Vega-like stars are stars that are on the main sequence but seem to have debris disks around them. The debris might be failed planets or just material that never condensed. Both systems have implications for our understanding of star formation. We have only just begun studying the data, but it is quite promising. In addition, we have an active program to obtain more spectra using the Ames Hi-Resolution Faint Object Spectragraph (HIFOGS). We will be observing at Mount Lemmon in February 1994 and at the Infrared Telescope Facility (IRTF) in June 1994.

We have also expanded the program to include midinfrared imaging. By studying the midinfrared spatial distribution and comparing it with far-infrared maps, we can estimate the envelope structure much more precisely. In addition, by careful mapping at selected wavelengths, we can deduce the dust properties in the envelopes and look for possible variations between different stars. Such changes would reflect different heating histories and evolutionary paths.

3. The program has now received support from the NASA Origins of the Solar System program. Costs of observing will be supported primarily by that program in the future.

Significance of results

We have modeled several sources in detail and have demonstrated that our technique can place strong constraints on the disk and envelope properties. We will be able to provide a large sample of source models in the next two to three years. This large sample offers

the opportunity to directly compare star formation models with actual sources in a statistically meaningful way. In addition, our results are already revealing a systematic difference between low mass stars forming in relative isolation and higher mass stars. The low mass stars seem to have envelopes whose properties are in agreement with current expections from theoretical considerations. The higher mass stars have much shallower density gradients and would appear to require additional physical processes to explain the observations.

Publications resulting from study

A number of papers have resulted from the work thus far, and more are anticipated over the next year or so. The initial project has greatly expanded as a result to include a large range of young stellar objects.

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Key words

Disks, Star formation, Midinfrared observations

Predicting Lyme Disease Risk: A Remote Sensing Model Based on Landscape Epidemiology

Investigator(s)
Byron L. Wood, James G. Lawless,
Louisa R. Beck, and Sheri W. Dister,
Ames Research Center,
Moffett Field, CA 94035-1000
Durland Fish, New York Medical College,
Valhalla, NY 10595

Objectives of the study

Lyme disease is one of the most prevalent and rapidly increasing vector-borne diseases affecting humans in the United States and northern temperate regions of the globe. In 1991, 9,465 cases were reported in the U.S. Field studies by investigators at the Medical Entomology Laboratory (MEL) in Westchester County, New York, have shown that tick populations and canine seroprevalence rates (CSR, a measure of Lyme disease exposure) vary along an urban-to-rural gradient. This gradient can be described in terms of landscape features, such as woodlands and residential developments with high-, medium-, and low-density vegetation, which are likely locations for contact between humans and infected ticks. The goal of this research is to develop a remote sensing-based spatial model to describe key landscape features associated with the vector and hosts of Lyme disease, and therefore predict areas where humans are at greatest risk of getting the disease.

Progress and results

The results of the 1992 comparison between CSR, landscape composition, and the ratio of deciduous to residential-dense vegetation properties were used to create a Lyme disease risk map of Westchester County. During 1993, previously acquired Landsat Thematic Mapper (TM) data were reprocessed to create an improved map of the landscape composition along the urban-to-rural gradient in the study area. In 1993, research also focused on (1) the use of additional field datasets to refine this risk map to the property level, and (2) the extension of the techniques developed in Westchester County to a regional scale. Raw TM data (with 30-m spatial resolution) were spatially and spectrally degraded to simulate 80- and 1,100-m data for use at regional scales. The three datasets (30-, 80-, and 1,100-m) were then used to generate a vegetation index map of the urban-to-rural gradient. It was found that the relationship between CSR and the ratio of deciduous forest and residential-dense vegetation properties was maintained at all scales. Additional field datasets on human cases, tick populations, and residential landscape composition have been integrated into the geographic information system (GIS) database for spatial analysis and correlated with CSR and landscape composition.

Significance of the results

The results of the remote sensing and GIS studies indicate that it is possible to generate a Lyme disease risk map at the municipality, county, and regional level. The dataset on tick abundance data will be used to study the size, shape, and spatial context of landscape elements that influence disease transmission risk.

FY94 research

Funding for this DDF investigation ended on September 30, 1993. Work will, however, continue for approximately two more months in order to complete all tasks outlined in the initial proposal. A follow-on proposal has already been submitted to the U.S. Agency for International Development and work has begun on a second collaborative proposal between NASA and the National Institutes of Health and Centers for Disease Control.

Publications resulting from study

Dister, S. W.; Beck, L. R.; Wood, B. L. ; Falco, R.; and Fish, D.: The Use of GIS and Remote Sensing Technologies in a Landscape Approach to the Study of Lyme Disease Transmission Risk. Proceedings, Seventh Annual Symposium on Geographic Information Systems in Forestry, Environmental, and Natural Resource Management, Vancouver, B.C., Feb. 15–18, 1993.

References: None so far

Key words

Remote sensing, Geographic information systems, Risk map

APPENDIX

For each of 48 projects sponsored in FY 1993, a brief description and the financial distribution and status follow. The reports are arranged alphabetically by the last name of the first investigator.

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: Laboratory Investigation of the Growth, Structure, and Apparent Phase Equilibria of Polar Stratospheric Clouds

Investigator(s) (show affiliation): David F. Blake, Ames Research Center, Moffett Field, CA 94035-1000

Funding — Year Initiated: FY93 — Expected completion date: FY94

Total prior to FY93: 0 — Authorized in FY93: $40,000

Total expended in FY93: $40,000 (Estimated) — Requested for FY94, if any: $37,000

- In-house: $40,000
- Contracts (identify):
- Grants (identify):

Status of study: ☐ Completed in FY93 ☒ Continued in FY94

If continued in FY94: ☐ with funds remaining? ☒ with FY94 funds?

If transitioned to other funding, to RTOP (number?): _____

to Program (name?): _____ to Other (identify): _____

Purpose of investigation

The chlorofluorocarbon (CFC)-induced depletion of ozone in the polar stratosphere is known to involve heterogeneous chemical reactions on polar stratospheric cloud particles. The purpose in this investigation is to identify the phases that exist within polar stratospheric cloud ice particles by forming analog ices under the same conditions and studying their structure. We hope that the results will help to clarify important issues such as the reason for the expansion of the Antarctic ozone hole, the likelihood of an Arctic ozone hole, or the possibility that observed ozone depletions above the midlatitudes will persist or become widespread.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

None

Planned future work

The first year has been spent building an apparatus to deposit polar stratospheric cloud analog ices onto electron microscope grids for analysis. The apparatus is nearly complete. In the second year of the project, a series of experiments will be conducted to identify the phases present by analyzing the analog materials in an electron microscope.

Prepared by: David F. Blake — Org. Code: SSX — MS: 239-4 — Phone: (415) 604-4816

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: The Preservation of Organic Matter in Hot Spring Deposits: Developing Search Strategies for a Fossil Record on Mars

Investigator(s) (show affiliation): David F. Blake, Ames Research Center, Moffett Field, CA 94035-1000;
Jack Farmer, SETI Institute, Mountain View, CA

Funding — Year Initiated: FY93 — Expected completion date: FY94

Total prior to FY93: 0 — Authorized in FY93: $40,000

Total expended in FY93: $40,000 (Estimated) — Requested for FY94, if any: $40,000
- In-house: $40,000
- Contracts (identify):
- Grants (identify):

Status of study: ☐ Completed in FY93 ☒ Continued in FY94

If continued in FY94: ☐ with funds remaining? ☒ with FY94 funds?

If transitioned to other funding, to RTOP (number?): _____

to Program (name?): _____ to Other (identify): _____

Purpose of investigation

Images of Mars show morphological features that are thought to be due to the flow of liquid water. This observation, along with theoretical considerations, has led scientists to conclude that Mars had an early wet and warm period, similar to that of Earth. During this period, life may have developed on Mars just as it did on the Earth. One environment that could have harbored early life on Mars (and also could have preserved fossil evidence of it) is silica-depositing hot springs. However, there are very few if any macroscopic clues to the biogenicity of the materials preserved within ancient hot spring sinter.

We are using state-of-the-art electronic microscopic techniques to characterize the style and extent of preservation (e.g., taphonomy) of biological materials within hot spring deposits on Earth. Materials collected for study include complete suites of samples from modern, near-recent, and ancient hot springs sinters. The results from this study will be used to devise a strategy for searching for fossil evidence of early life on Mars.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

None

Planned future work

We anticipate that an ion-thinner, which as been in the procurement process for some time, will be in the lab by mid-December. We have practiced the sample preparation and analysis techniques by doing some limited ion-thinning off-site. In the next year we will be able to perform analyses of real materials and identification of biogenic features within fossilized materials. A mineralogy student from the University of California at Berkeley will be arriving in early 1994 to begin an NRC postdoctoral fellowship associated with this project.

Prepared by: David F. Blake — Org. Code: SSX — MS: 239-4 — Phone: (415) 604-4816

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: Human Exploration Demonstration Project (HEDP)

Investigator(s) (show affiliation): Edward Chevers and David Korsmeyer, Ames Research Center, Moffett Field, CA 94035-1000

Funding — Year Initiated: FY91 — Expected completion date: FY94

Total prior to FY93: $467,000 — Authorized in FY93: $310,000

Total expended in FY93: $310,000 (Estimated) — Requested for FY94, if any: $140,000

- In-house: $267,000
- Contracts (identify): $43,000 (Bionetics)
- Grants (identify):

Status of study: ☐ Completed in FY93 ☒ Continued in FY94

If continued in FY94: ☐ with funds remaining? ☒ with FY94 funds?

If transitioned to other funding, to RTOP (number?):

to Program (name?): to Other (identify):

Purpose of investigation

To develop a technology testbed based on ARC-specific systems and capabilities relating to planetary exploration. The implementation is a series of demonstrations showing the synergism between technologies and emphasizing collaborative systems development.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

None

Planned future work

None

Prepared by: David Korsmeyer — Org. Code: FI — MS: 269-1 — Phone: (415) 604-3114

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: Development of Fiber-Optic Acoustic Sensors for Wind Tunnel Applications

Investigator(s) (show affiliation): Young C. Cho and Paul T. Soderman, Ames Research Center, Moffett Field, CA 94035-1000

Funding — Year Initiated: FY92 — Expected completion date: FY94

Total prior to FY93: $60,000 — Authorized in FY93: $20,000

Total expended in FY93: $20,000 (Estimated) — Requested for FY94, if any:
- In-house
- Contracts (identify)
- Grants (identify)

Status of study: ☐ Completed in FY93 ☒ Continued in FY94

If continued in FY94: ☒ with funds remaining? ☐ with FY94 funds?

If transitioned to other funding, to RTOP (number?):

to Program (name?): to Other (identify):

Purpose of investigation

To develop advanced acoustic sensors for wind tunnel applications, with minimized interference noises such as flow-sensor interaction noise, flow induced sensor vibration, wind noise, etc. These interference noises strongly affect currently existing acoustic sensor techniques.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

NASA's first fiber-optic microphone was developed and fabricated in a breadboard form. This sensor is multiplexed with two sensor heads, each made of single mode fiber wrapped around a circular cylinder of styrofoam or a torpedo-shaped aluminum body. Extensive laboratory tests are in progress for evaluation of its acoustic characteristics including acoustic sensitivity, dynamic range, frequency response, etc. Preliminary test results demonstrated successfully its feasibility for aeroacoustic measurements. Two papers were produced:

1. Cho, Young C.: Fiber-optic Interferometric Acoustic Sensors for Wind Tunnel Applications. SPIE Proc., vol. 1795, 1992, pp. 16–27.
2. Cho, Young C.; and Soderman, Paul T.: Fiber-optic Interferometric Sensors for Measurements of Pressure Fluctuations: Experimental Evaluation. AIAA Paper 93-0738, 31st Aerospace Sciences Meeting, Reno, Nev, Jan. 11–14, 1993.

Planned future work

Laboratory calibration is being performed to study and quantify environmental effects on the fiber-optic microphone. New fiber-optic sensor heads will be designed and fabricated for more vigorous tests in anechoic chambers and wind tunnels. Successful completion of the wind tunnel tests will be followed by the development of a dual sensor for simultaneous measurements of pressure and temperature.

Prepared by: Young C. Cho — Org. Code: FIC — MS: 269-3 — Phone: (415) 604-4139

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation A Prototype Infrared Gas Analyzer for Characterizing Plant Growth During Space Flight

Investigator(s) (show affiliation) James Connolly, Ames Research Center, Moffett Field, CA 94035-1000

Funding Year Initiated FY92 Expected completion date FY93

Total prior to FY93 $40,000 Authorized in FY93 $40,000

Total expended in FY93: (Estimated) Requested for FY94, if any

In-house $40,000

Contracts (identify)

Grants (identify)

Status of study ☒ Completed in FY93 ☐ Continued in FY94

If continued in FY94 ☐ with funds remaining? ☐ with FY94 funds?

If transitioned to other funding, to RTOP (number?)

to Program (name?) to Other (identify)

Purpose of investigation

Accurate and reliable measurement of CO_2 and water vapor is critical for characterizing photosynthesis and transpiration of green plants in space. All food production, air revitalization, and water purification functions of plants depend on proper function of photosynthesis and transpiration. Current CO_2 analysis technologies used in ground-based laboratories have several characteristics that would severely restrict and limit their reliable and safe use in space flight. The analyzer design developed here utilizes alternative component technologies and the operation approaches to address each of the limitations and safety problems present in current instrumentation.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

The efforts of the past year resulted in the identification of various subsystems and the design and construction of a breadboard CO_2 analyzer unit to allow experimentation with different components and analyzer configurations. Feasibility studies indicated that a miniature infrared (IR) laser as well as a special type of high energy flash bulb may be used as alternate IR radiation sources in CO_2 gas analyzers. The project studies also identified specific miniature diode requirements to allow their development. Also project efforts have initiated process for a joint effort between NASA and commercial companies to develop technology that is mutually beneficial. Successful implementation of either of the alternate IR radiation sources will eliminate the use of traditional mechanical choppers or beam splitters.

The characteristics and performance of the IR radiation sensing subsystem, currently designed, will meet design requirements. Digital signal processing (DSP) methods may also allow simultaneous multiple gas concentration measures.

Planned future work

To encourage the development of the IR laser diode, the gas filled flash bulb, and unique radiation measurement approaches, efforts were placed in the area of technology transfer. The goal is to use commercial funds in exchange for marketable technology developed by NASA. To accomplish our goal a Joint Sponsored Research Program (JSRP) has been initiated. The JSRP is currently being managed by the American Technology Institute (ATI). ATI is responsible for researching the industry and assisting with the transfer technology to commercial companies in exchange for development funds. A JSRP proposal has been completed and will be released to selected companies by ATI.

Prepared by David Bubenheim Org. Code SAR MS 239-11 Phone (415) 604-3209

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: Origins of Planetary Systems: Observations and Analysis

Investigator(s) (show affiliation):
Kent Cullers, Ames Research Center, Moffett Field, CA 94035-1000
Laurance Doyle, SETI Institute, Ames Research Center, Moffett Field, CA 94035-1000

Funding — Year Initiated: FY92 — Expected completion date: FY93

Total prior to FY93: 0 — Authorized in FY93:

Total expended in FY93: $38,000 (Estimated) — Requested for FY94, if any: 0
- In-house
- Contracts (identify)
- Grants (identify)

Status of study: ☒ Completed in FY93 ☐ Continued in FY94

If continued in FY94: ☐ with funds remaining? ☐ with FY94 funds?

If transitioned to other funding, to RTOP (number?):

to Program (name?): to Other (identify):

Purpose of investigation

Pave the way for extra solar-planetary detection from Earth-based medium-sized telescopes.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

None

Planned future work

Continue with program if funding can be found.

Prepared by: Laurance Doyle — Org. Code: SI — MS: 244-11 — Phone: (415) 604-1372

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: Monitoring Global Change During the Last 10,000 Years

Investigator(s) (show affiliation): Hector L. D'Antoni, Ames Research Center, Moffett Field, CA 94035-1000

Funding — Year Initiated: FY93 — Expected completion date: FY94

Total prior to FY93: _____ — Authorized in FY93: $30,000

Total expended in FY93: $30,000 (Estimated) — Requested for FY94, if any: $40,000

- In-house: $30,000
- Contracts (identify)
- Grants (identify)

Status of study: ☐ Completed in FY93 ☒ Continued in FY94

If continued in FY94: ☐ with funds remaining? ☒ with FY94 funds?

If transitioned to other funding, to RTOP (number?) _____

to Program (name?) _____ to Other (identify) _____

Purpose of investigation

To link modern pollen data and remote sensing data of vegetation to calibrate environmental data as monitored by satellite remote sensing. Use resulting models in hindcasting past climate change and provide a larger window for predictive models of climate change.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Communication and poster at the 26th meeting of the American Association of Stratigraphic Palynologiests, 1993.

D'Antoni, H.; and Spanner, M.: Remote Sensing and Modern Pollen Dispersal in Southern Patagonia and Tierra del Fuego (Argentina): Models for Palaeoecology. Grana, vol. 32, Stockholm, 1993, pp. 29–39.

D'Antoni, H.: Paleotemperatures of La Malinche: A Palynological Hypothesis. Grana, Stockholm (in press).

Planned future work

Continuation of the research plan. Extension of the study of effects of increased UV-B radiation on vegetation.

Prepared by: Hector L. D'Antoni Org. Code: SGE MS: 239-20 Phone: (415) 604-5149

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: Schmidt-Cassegrain Long-Range Laser Velocimeter

Investigator(s) (show affiliation): Stephen E. Dunagan, Ames Research Center, Moffett Field, CA 94035-1000

Funding — Year Initiated: FY93 — Expected completion date: FY94

Total prior to FY93: 0 — Authorized in FY93: $37,000

Total expended in FY93: $37,000 (Estimated) — Requested for FY94, if any: $38,000

- In-house: $37,000
- Contracts (identify):
- Grants (identify):

Status of study: ☐ Completed in FY93 ☒ Continued in FY94

If continued in FY94: ☐ with funds remaining? ☒ with FY94 funds?

If transitioned to other funding, to RTOP (number?): _____

to Program (name?): _____ to Other (identify): _____

Purpose of investigation

This investigation is designed to develop a new long-range laser velocimeter instrument that will provide multi-application support to aerodynamic wind tunnel studies conducted in the NFAC 40 × 80 wind tunnel. The instrument incorporates new technologies including high acuity telescope optics, fiber optics for both laser beam and signal transmission, and digital signal processing to enhance data rate and accuracy.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

The study has resulted in a viable instrument design utilizing the above mentioned technologies. A proof-of-concept demonstrator configuration has been assembled and tested in the optics laboratory. A prototype instrument for the wind tunnel is presently being fabricated, with the intention of deploying it on the High Speed Research Test in November, 1993. A meeting paper is being prepared that describes the instrument design and operation with completion dependent on wind tunnel test results.

Planned future work

Additional tasks remaining in the instrument assembly plan include: upgrading optical and signal processing components to provide two-component measurement, designing and fabricating a two-dimensional traverse to provide full two test section access, and investigating the potential for improved signal processing using digital autocorrelation techniques.

Prepared by: Barbara Rench — Org. Code: FFR — MS: T-042 — Phone: (415) 604-4023

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: Investigation of the Scales of Turbulence in Hypersonic Rarefied Flow

Investigator(s) (show affiliation): William J. Feiereisen, Ames Research Center, Moffett Field, CA 94035-1000
Donald Baganoff and Sanjiva Lele, Stanford University, Stanford, CA 94305

Funding — Year Initiated: FY92 — Expected completion date: FY94

Total prior to FY93: $40,000 — Authorized in FY93: $40,000

Total expended in FY93: $40,000 (Estimated) — Requested for FY94, if any: ____

In-house:
Contracts (identify):
Grants (identify): $40,000 Stanford

Status of study: ☐ Completed in FY93 ☒ Continued in FY94

If continued in FY94: ☒ with funds remaining? ☐ with FY94 funds?

If transitioned to other funding, to RTOP (number?): ____

to Program (name?): ____ to Other (identify): ____

Purpose of investigation

To determine, for the case of intense turbulence in a rarefied flow, whether the predictions of the Navier–Stokes equations agree with the predictions of a particle simulation; and, if they differ, how they differ and what impact it has on the process of modeling turbulence by use of the Navier–Stokes equations. Three questions are being investigated: (1) Can turbulence exist under conditions corresponding to high speed flight in the upper atmosphere? (2) Do the dissipation length scales become of the same order of magnitude as the mean free path and what implication would this have for the modeling of these scales? (3) Can a Monte-Carlo simulation method be used to produce a direct simulation of turbulent flow under rarefied conditions?

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Goswami, A.; Baganoff, D.; Lele, S.; and Feiereisen, W.: A Comparative Study of Turbulent Decay Using Navier–Stokes and Discrete Particle Simulations. 45th Annual Meeting, Fluid Dynamics Division, American Physical Society, Florida State University, Nov. 22–24, 1992.

Planned future work

None

Prepared by: William J. Feiereisen — Org. Code: RTA — MS: 230-2 — Phone: (415) 604-4225

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: Analytical and Experimental Studies of Rotorcraft Vertical Climb Performance

Investigator(s) (show affiliation): Fort F. Felker, Ames Research Center, Moffett Field, CA 94035-1000;
Robert M. McKillip, Continuum Dynamics, Inc., Princeton, NJ 08543

Funding — Year Initiated: FY92 — Expected completion date: FY94

Total prior to FY93: $40,000 — Authorized in FY93: $40,000

Total expended in FY93: $28,500 (Estimated) — Requested for FY94, if any: $40,000
- In-house: $28,500
- Contracts (identify):
- Grants (identify):

Status of study: ☐ Completed in FY93 ☒ Continued in FY94

If continued in FY94: ☒ with funds remaining? ☐ with FY94 funds?

If transitioned to other funding, to RTOP (number?) _____

to Program (name?) _____ to Other (identify) _____

Purpose of investigation

Develop accurate analytical methods for the prediction of rotorcraft performance in vertical climb. An accurate set of experimental data was acquired to support the analysis development.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

None. A paper describing the research results will be presented at the 1994 Forum of the American Helicopter Society.

Planned future work

Complete the paper documenting the research results and present the paper at the 1994 Forum of the American Helicopter Society.

Prepared by: Fort F. Felker — Org. Code: FFR — MS: T-12B — Phone: (415) 604-6096

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: Continuous-Flow Apparatus for Studies of Gas- and Liquid-Phase Adsorption Dynamics

Investigator(s) (show affiliation): John E. Finn and Sanford S. Davis, Ames Research Center, Moffett Field, CA 94035-1000

Funding — Year Initiated: FY92 — Expected completion date: FY93

Total prior to FY93: $40,000 — Authorized in FY93: $40,000

Total expended in FY93: $40,000 (Estimated) — Requested for FY94, if any: ____

- In-house: $40,000
- Contracts (identify):
- Grants (identify):

Status of study: ☒ Completed in FY93 ☐ Continued in FY94

If continued in FY94: ☐ with funds remaining? ☐ with FY94 funds?

If transitioned to other funding, to RTOP (number?): ____

to Program (name?): ____ to Other (identify): ____

Purpose of investigation

Design, assemble, and test an apparatus for validating theory and simulation cost for gas- and liquid-phase adsorption column models for life support system applications.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Apparatus currently applied to issues in carbon dioxide removal from cabin air.

Planned future work

Continued work on validation of computer models, and publication of results.

Prepared by: John E. Finn Org. Code: SAR MS: 239-11 Phone: (415) 604-1028

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: Development of Modal Filtering Techniques for Online Estimation of Structural Vibration Parameters

Investigator(s) (show affiliation): Lawrence C. Freudinger, Dryden Flight Research Facility, Edwards, CA 93523-0273

Funding — Year Initiated: FY92 — Expected completion date: _____

Total prior to FY93: $40,000 — Authorized in FY93: _____

Total expended in FY93: $40,000 (Estimated) — Requested for FY94, if any: _____

- In-house: $15,000
- Contracts (identify): $25,000
- Grants (identify):

Status of study: ☒ Completed in FY93 ☐ Continued in FY94

If continued in FY94: ☐ with funds remaining? ☐ with FY94 funds?

If transitioned to other funding, to RTOP (number?): 505-68

to Program (name?): Flight Test Techniques — to Other (identify): _____

Purpose of investigation

To develop a theory known as discrete modal filtering for the purpose of observing the vibration characteristics of mechanical systems.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Computer upgrades were made to allow the research to proceed without hindering other computer users. Software was purchased, including data acquisition control libraries. Boeing has contracted with the University of Cincinnati to investigate the performance of modal filters during the ground vibration tests of the B-777. Successful results will subsequently lead to flight test application. Teledyne Ryan has expressed interest in using an online estimation tool concept that was proposed by the principal investigator. This interest resulted in an unsolicited proposal from Structural Dynamics Research Corporation to implement modal filtering as an option in their currently available software for data acquisition. Funding procedures for the unsolicited proposal have been initiated.

Planned future work

Modal filtering is a data condensation tool that will aid in the development of online tools for data processing. Sufficient interest has been generated to make non-DDF funding sources available. These other sources will be pursued.

Future work will include development of test methodologies that use modally filtered data. Theoretical aspects will continue to be investigated. In addition, several individuals in academia have begun to incorporate modal filters into their efforts. It is hoped that well-conceived algorithm development combined with appropriate commercialization efforts will eventually result in a panacea for health monitoring of certain vibrating mechanical systems such as aircraft.

Prepared by: Lawrence C. Freudinger — Org. Code: XRDV — MS: 4840D — Phone: (805) 258-3542

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: Computational Modeling of Femtosecond All-Optical Switches Directly from Maxwell's Equations

Investigator(s) (show affiliation): Peter M. Goorjian, Ames Research Center, Moffett Field, CA 94035-1000
Allen Taflove, Northwestern University, Evanston, IL 60208

Funding — Year Initiated: FY91 — Expected completion date: FY93

Total prior to FY93: $40,000 — Authorized in FY93: $40,000

Total expended in FY93: $40,000 (Estimated) — Requested for FY94, if any: 0

- In-house: $15,000
- Contracts (identify):
- Grants (identify): $25,000 NCA2-827

Status of study: ☐ Completed in FY93 ☒ Continued in FY94

If continued in FY94: ☒ with funds remaining? ☐ with FY94 funds?

If transitioned to other funding, to RTOP (number?): _____

to Program (name?): _____ to Other (identify): _____

Purpose of investigation

Develop algorithms and computer codes for modeling all-optical switches and semiconductor lasers with the full-vector nonlinear Maxwell's equations

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Planned future work

1. Continue code development for all-optical switches
2. Develop code for semiconductor lasers

Prepared by: Peter Goorjian — Org. Code: RFC — MS: T047-1 — Phone: (415) 604-5547

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: Tension and Compression Effects of Cell Behavior

Investigator(s) (show affiliation): Rosalind A. Grymes and Christine Sawyer, Ames Research Center, Moffett Field, CA 94035-1000

Funding — Year Initiated: FY92 — Expected completion date: FY93

Total prior to FY93: $40,000 — Authorized in FY93: $40,000

Total expended in FY93: $40,000 (Estimated) — Requested for FY94, if any: ____

- In-house: $40,000
- Contracts (identify):
- Grants (identify):

Status of study: ☐ Completed in FY93 ☒ Continued in FY94

If continued in FY94: ☐ with funds remaining? ☒ with FY94 funds?

If transitioned to other funding, to RTOP (number?): 199-40-22-01

to Program (name?): Space Biology — to Other (identify): ____

Purpose of investigation

This investigation was designed to:

- acquire and instantiate the use of an instrument that provides a mechanically active environment of uniaxial tension and/or biaxial compression on growing cultures of mammalian cells
- demonstrate the effect of applied uniaxial tension on the growth patterns of normal dermal fibroblasts representing various chronologic ages
- observe the progress of simulated wound healing in the mechanically active environment
- study the response of dermal fibroblasts to the soluble growth factor platelet-derived growth factor (PDGF)

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

1. Studies of Senescent Cell Behavior in Response to PDGF Under Conditions of Varying Stress. Abstract presentation, American Society of Biochemistry and Molecular Biology, Apr. 1993.
2. Dermal Fibroblasts in a Mechanically Active Environment. Paper presented at the American Society for Gravitational and Space Biology, Oct. 1993.
3. Human Dermal Fibroblasts Orient in Response to Applied Stretch. Abstract submitted to Western Regional Society for Investigative Dermatology Meeting, Feb. 1994.
4. Dermal and Corneal Fibroblasts 'Orienteer' in Response to Applied Mechanical Stretch: A Mechanistic Approach. Abstract submitted to American Society for Cell Biology, Dec. 1993.

Authorship

1,2 Rosalind A. Grymes and Christine Sawyer, Ames
3 Christine Sawyer and Rosalind A. Grymes
4 Christine Sawyer, Barbara Johnson-Wint, and Rosalind A. Grymes

Planned future work

We have revealed several highly significant effects of the mechanically active environment on our cellular system. By surveying various regimens of cyclic and static stretch, at different strain levels, we determined that dermal fibroblasts can be studied under all these conditions without indications of deterioration. Cellular behaviors do change, however, and exhibit adaptation. This adaptation phenomenon reverses the genetic defect observed in one cell strain, allowing the cultures to respond to the soluble growth factor PDGF only when grown on the flexible membranes. These findings are unique, and they will be followed up in an intramural grant proposal to the Space Biology Program.

Prepared by: Rose Grymes — Org. Code: SL — MS: 239-11 — Phone: (415) 604-3239

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: The Deuterium Abundance in the Interstellar Medium

Investigator(s) (show affiliation): Michael R. Haas and Alexander G. G. M. Tielens,
Ames Research Center, Moffett Field, CA 94035-1000

Funding — Year Initiated: FY92 — Expected completion date: FY94

Total prior to FY93: $40,0000 — Authorized in FY93: $40,000

Total expended in FY93: $40,000 (Estimated) — Requested for FY94, if any: 0

- In-house: $ 9,000
- Contracts (identify): $31,000 NAS2-13605
- Grants (identify):

Status of study: ☐ Completed in FY93 ☒ Continued in FY94

If continued in FY94: ☒ with funds remaining? ☐ with FY94 funds?

If transitioned to other funding, to RTOP (number?): 352

to Program (name?): _____ to Other (identify): _____

Purpose of investigation

To determine the deuterium abundance in the interstellar medium by observing several rotational lines of HD and H_2 in shocked interstellar gas.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

None

Planned future work

Install Si:As back-illuminated, blocked impurity band (BIBIB) detectors in the Cooled Grating Spectrometer for flights aboard the Kuiper Airborne Observatory (KAO) in late November 1993. Continue procurement and development of Si:Sb BIBIBs to extend the observations to longer wavelengths. Analyze the resulting flight data and use the measured line intensities to deduce the deuterium abundance in the Orion molecular cloud. Write up the results for publication in a scientific journal.

Prepared by: Michael R. Haas Org. Code: SSA MS: 245-6 Phone: (415) 604-5511

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: Determination of Polar Stratospheric Cloud Onset Over Antarctica Using Cloud Top Temperature Retrievals from the NOAA Advanced Very High Resolution Radiometer (AVHRR) Satellite Imagery

Investigator(s) (show affiliation): Steve Hipskind, Ames Research Center, Moffett Field, CA 94035-1000
Kathy Pagan, Oswaldo Garcia, and Patricia Foschi, San Francisco State University, San Francisco, CA 94132
Steve Gaines, Sterling Software, Ames Research Center, Moffett Field, CA 94035-1000

Funding — Year Initiated: FY93 — Expected completion date: FY94

Total prior to FY93: 0 — Authorized in FY93: $33,000

Total expended in FY93: $33,000 (Estimated) — Requested for FY94, if any: $40,000

- In-house: $13,000
- Contracts (identify):
- Grants (identify): $20,000 SFSU JRI

Status of study: ☐ Completed in FY93 ☒ Continued in FY94

If continued in FY94: ☐ with funds remaining? ☒ with FY94 funds?

If transitioned to other funding, to RTOP (number?): _____

to Program (name?): _____ to Other (identify): _____

Purpose of investigation

Determine whether AVHRR imagery can be used to detect PSCs (polar stratospheric clouds) over Antarctica. If so, determine date of PSC onset and develop climatology of duration and geographical extent of PSCs.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Results presented in a poster at the annual high speed research program/atmospheric effects of stratospheric aircraft (HSRP/AESA) meeting in Virginia Beach, Va., June 15, 1993.

Planned future work

Conduct intercomparisons with other datasets (surface temperature, upper air, UARS). Develop detection algorithms for optically thin PSCs.

Prepared by: Steve Hipskind Org. Code: SGA MS: 245-5 Phone: (415) 604-5076

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: Real-Time Automated Diagnosis System for the Ames Research Animal Holding Facility

Investigator(s) (show affiliation): David L. Iverson and Stephanie Herrin, Ames Research Center, Moffett Field, CA 94035-1000

Funding — Year Initiated: FY92 — Expected completion date: FY94

Total prior to FY93: $40,000 — Authorized in FY93: $40,000

Total expended in FY93: $38,500 (Estimated) — Requested for FY94, if any: 0

- In-house: $34,000
- Contracts (identify): $4,500 – RECOM contract, consultant short term hire
- Grants (identify):

Status of study: ☒ Completed in FY93 ☐ Continued in FY94

If continued in FY94: ☐ with funds remaining? ☐ with FY94 funds?

If transitioned to other funding, to RTOP (number?): _____

to Program (name?): _____ to Other (identify): Possible funding through Code SP

Purpose of investigation

Improve knowledge engineering and automated monitoring and diagnosis technology by developing general techniques for constructing automated diagnosis systems using information from reliability analysis models.

Develop a tool for monitoring and diagnosis of the Research Animal Holding Facilities (RAHF) payload.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Results of this research were used to build the RAD (Real-Time Automated Diagnosis) system, which was used by payload controllers and engineers during the SLS-2 Space Shuttle mission to monitor the two RAHFs onboard Columbia.

The work was published in the Proceedings of the Sixth International Conference on Industrial and Engineering Applications of Artificial Intelligence. The conference was held in Edinburgh, Scotland, on June 1–4, 1993.

Planned future work

Investigate techniques to use reliability models in conjunction with functional models to develop more powerful monitoring and diagnosis systems.

Prepared by: David Iverson — Org. Code: FIS — MS: 269-4 — Phone: (415) 604-3115

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: Stratospheric Aerosol Particulates: Simulation of Their Morphology, Physical Properties, and Chemistry

Investigator(s) (show affiliation): Richard L. Jaffe, Ames Research Center, Moffett Field, CA 94035-1000

Funding — Year Initiated: FY92 — Expected completion date: FY94

Total prior to FY93: $40,000 — Authorized in FY93: $40,000

Total expended in FY93: $40,000 (Estimated) — Requested for FY94, if any: 0

In-house

Contracts (identify)

Grants (identify)

Status of study: ☐ Completed in FY93 ☒ Continued in FY94

If continued in FY94: ☒ with funds remaining? ☐ with FY94 funds?

If transitioned to other funding, to RTOP (number?) _____

to Program (name?) _____ to Other (identify) _____

Purpose of investigation

Simulations of nitric acid-water ice particles and droplets representative of conditions found in polar stratospheric clouds. In addition, calculations of HCl interacting with these particles were planned.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

None

Planned future work

Completion of project as originally proposed.

Prepared by: Richard Jaffe Org. Code: RTC MS: 230-3 Phone: (415) 604-6458

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: The Use of Molecular Fossils for the Interpretation of Paleoenvironments

Investigator(s) (show affiliation): Linda L. Jahnke, Ames Research Center, Moffett Field, CA 94035-1000

Funding — Year Initiated: FY92 — Expected completion date: FY93

Total prior to FY93: $35,300 — Authorized in FY93: $37,300

Total expended in FY93: $37,300 (Estimated) — Requested for FY94, if any: 0

- In-house: $1,500
- Contracts (identify):
- Grants (identify): $35,810/NCC2-695

Status of study: ☒ Completed in FY93 ☐ Continued in FY94

If continued in FY94: ☐ with funds remaining? ☐ with FY94 funds?

If transitioned to other funding, to RTOP (number?) _____

to Program (name?) _____ to Other (identify) _____

Purpose of investigation

To understand the synthesis of hopane biomarkers in photosynthetic bacteria and any relationship the presence of these biomarker molecules might have to the evolution of oxygenic photosynthesis.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Jahnke, L. L.; and Munoz, E.: Characterization of Two Facultatively Anoxygenic Cyanobacteria Isolated from a Hypersaline Microbial Mat. Abstracts of the 93rd General Meeting of the American Society for Microbiology, 1993, p. 253.

Planned future work

Publication of peer reviewed journal article on facultative anoxygenic cyanobacteria and application of information gained to analysis of microbial mat material.

Prepared by: Linda Jahnke Org. Code: SSX MS: 239-4 Phone: (415) 604-3221

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: Flight Measured Wall Pressure Fluctuations Beneath Swept Shock/Boundary-Layer Interactions

Investigator(s) (show affiliation): Steven A. Johnson, Dryden Flight Research Facility, Edwards, CA 93523-0273

Funding — Year Initiated: FY93 — Expected completion date: FY94

Total prior to FY93: 0 — Authorized in FY93: $40,000

Total expended in FY93: $40,000 (Estimated) — Requested for FY94, if any: $40,000

- In-house: $35,000
- Contracts (identify): $5,000 C&T Machining
- Grants (identify):

Status of study: ☐ Completed in FY93 ☒ Continued in FY94

If continued in FY94: ☐ with funds remaining? ☒ with FY94 funds?

If transitioned to other funding, to RTOP (number?): _____

to Program (name?): _____ to Other (identify): _____

Purpose of investigation

The goal of the proposed study is to assess the acoustical loads generated by a swept shock/boundary-layer interaction in a flight environment (free of wind tunnel turbulence) and to gain a better understanding of the physical mechanisms involved in their generation. Such an understanding is the first step in any attempt to control or limit acoustical loading on flight vehicles. Also, more fundamentally, the interaction unsteadiness is critical in formulating accurate flow models.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

The flight hardware has been designed and constructed.
A prototype signal conditioning card has been designed and constructed.
Pressure transducers have been procured.

Planned future work

A benchtop checkout of the integrated system will be initiated.
A series of four flights will occur.
The data will be analyzed and presented.

Prepared by: Steven A. Johnson Org. Code: XRP MS: D-2033 Phone: (805) 258-3096

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: Pyrosensors for the Detection of Chemical Compounds in Planetary Environments

Investigator(s) (show affiliation): Dan Kojiro and Thomas C. Shen, Ames Research Center, Moffett Field, CA 94035-1000

Funding — Year Initiated: FY92 — Expected completion date: FY93

Total prior to FY93: $40,000 — Authorized in FY93: $40,000

Total expended in FY93: $40,000 (Estimated) — Requested for FY94, if any: 0

- In-house: $2,000
- Contracts (identify): $38,000 (cooperative agreement NCC2-650)
- Grants (identify):

Status of study: ☒ Completed in FY93 ☐ Continued in FY94

If continued in FY94: ☐ with funds remaining? ☐ with FY94 funds?

If transitioned to other funding, to RTOP (number?): _____

to Program (name?): _____ to Other (identify): _____

Purpose of investigation

Developing pyrosensors for Martian soil oxidants analysis.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Shen, Thomas; and Kojiro, Dan: Pyrosensors for Analyzing Oxidants on Martian Soil. ACS Meeting in Denver, Colo., 1993.

Planned future work

Summit Planetary Instrument Definition Development Proposal to NASA Headquarters.

Prepared by: Thomas Shen — Org. Code: SSS — MS: 239-12 — Phone: (415) 604-5769

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: Practical Evaluation of a New Method to Reduce Helicopter Rotor Hub Loads

Investigator(s) (show affiliation): Sesi Kottapalli, Ames Research Center, Moffett Field, CA 94035-1000

Funding — Year Initiated: FY93 — Expected completion date: FY95

Total prior to FY93: 0 — Authorized in FY93: $11,500

Total expended in FY93: $11,500 (Estimated) — Requested for FY94, if any: $28,500

In-house

Contracts (identify)

Grants (identify): University of Maryland at College Park

Status of study: ☐ Completed in FY93 ☒ Continued in FY94

If continued in FY94: ☐ with funds remaining? ☒ with FY94 funds?

If transitioned to other funding, to RTOP (number?) _____

to Program (name?) _____ to Other (identify) _____

Purpose of investigation

Experimental (bench) testing of a new concept, blade root torsional damping, which has been analytically found to reduce helicopter hub loads.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

None.

Planned future work

Initiate design and fabrication of root torsional dampers.

Prepared by: Sesi Kottapalli — Org. Code: FFR — MS: T-042 — Phone: (415) 604-3092

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: Stanford-NASA Ames Cooperative Program in Global Change

Investigator(s) (show affiliation): James G. Lawless and Philip B. Russell, Ames Research Center, Moffett Field, CA 94035-1000
Gary Ernst, Stanford University, Stanford, CA 94305

Funding — Year Initiated: FY91 — Expected completion date: FY94

Total prior to FY93: $42,500 — Authorized in FY93: $4,000

Total expended in FY93: $60,000 (Estimated) — Requested for FY94, if any: 0

- In-house: $31,611
- Contracts (identify):
- Grants (identify): $28,389 (Joint Research Interchange NCA2-768)

Status of study: ☐ Completed in FY93 ☒ Continued in FY94

If continued in FY94: ☐ with funds remaining? ☐ with FY94 funds?

If transitioned to other funding, to RTOP (number?): _____

to Program (name?): _____ to Other (identify): _____

Purpose of investigation

The purpose of the Stanford-NASA Ames Cooperative Program in Global Change is to bring together the unique skills and facilities available at Stanford and Ames to answer key questions about the functioning of the Earth's atmosphere and ecosystems, especially as impacted by human activities. Most of the DDF funds have been used to support a variety of research tasks carried out by students under the joint advisorship of Stanford and Ames scientists. The remainder of the funds helped support a joint seminar series conducted at Stanford and Ames.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Townsend, Alan R.: Influence of Temperature on Soil Carbon Pools. Ph.D. Thesis, Stanford University, 1993.
Imhoff, Marc L.: Remote Estimation of Vegetation Biomass Using AIRSAR. Ph.D. Thesis, Stanford University, 1993.

Planned future work

Several of the student research tasks are still in progress using the funding in Joint Research Interchange (JRI) NCA2-768. This work will be completed in FY94 and described in the JRI Final Report, which is due in December 1994.

Prepared by: Philip B. Russell — Org. Code: SGG — MS: 245-5 — Phone: (415) 604-5404

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: The Study of Ozone Depletion Chemistry Using Ab Initio Quantum Mechanical Methods

Investigator(s) (show affiliation): Timothy J. Lee, Ames Research Center, Moffett Field, CA 94035-1000

Funding — Year Initiated: FY92 — Expected completion date: FY93

Total prior to FY93: $40,000 — Authorized in FY93: $40,000

Total expended in FY93: $40,000 (Estimated) — Requested for FY94, if any: 0

In-house

Contracts (identify)

Grants (identify)

Status of study: ☐ Completed in FY93 ☒ Continued in FY94

If continued in FY94: ☐ with funds remaining? ☐ with FY94 funds?

If transitioned to other funding, to RTOP (number?) _____

to Program (name?) _____ to Other (identify) _____

Purpose of investigation

1. To demonstrate the applicability and usefulness of ab initio quantum mechanical methodology to the study of atmospheric chemistry.
2. To study important molecules and reactions with regards to ozone depletion.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Five journal articles have been completed; the summary of these studies and their significance is given in the DDF final report.

Planned future work

To continue the study of atmospheric chemistry, including the determination of molecular structures, vibrational and electronic spectra, and other molecular properties, using ab initio quantum mechanical methodology.

Proposals to be submitted to Upper Atmosphere Research Program among others.

Prepared by: T. J. Lee Org. Code: RTC MS: 230-3 Phone: (415) 604-5208

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: Surface Shear Stress Measurement Using Liquid Crystal Polymers

Investigator(s) (show affiliation): B. G. McLachlan and J. H. Bell, Ames Research Center, Moffett Field, CA 94035-1000
M. L. Brandes and M. Gouterman, University of Washington, Seattle, WA 98195

Funding — Year Initiated: FY93 — Expected completion date: FY94

Total prior to FY93: 0 — Authorized in FY93: $40,000

Total expended in FY93: $40,000 (Estimated) — Requested for FY94, if any: $40,000
- In-house: $40,000
- Contracts (identify)
- Grants (identify)

Status of study: ☐ Completed in FY93 ☒ Continued in FY94

If continued in FY94: ☐ with funds remaining? ☒ with FY94 funds?

If transitioned to other funding, to RTOP (number?) _____

to Program (name?) _____ to Other (identify) _____

Purpose of investigation

Assess the feasibility of liquid crystal polymer film coatings for surface shear stress field measurement in aerodynamic testing.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

None

Planned future work

Set up an advanced flow apparatus to produce accurate aerodynamic shear stress levels. Evaluate method in tests conducted in RAC small scale wind tunnel using airfoil surfaces.

Prepared by: B. G. McLachlan Org. Code: RAC MS: 227-2 Phone: (415) 604-4142

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: Investigations of Supersonic Combustion Using Unique NASA Ames Facilities

Investigator(s) (show affiliation): Gene P. Menees, Ames Research Center, Moffett Field, CA 94035-1000
Jean-Luc Cambier and Henry G. Adelman, Thermosciences Institute, Ames Research Center, Moffett Field, CA 94035-1000

Funding — Year Initiated: FY92 — Expected completion date: FY93

Total prior to FY93: $40,000 — Authorized in FY93: $40,000

Total expended in FY93: $40,000 (Estimated) — Requested for FY94, if any: 0

- In-house
- Contracts (identify)
- Grants (identify): $40,000 NCC2-487

Status of study: ☐ Completed in FY93 ☒ Continued in FY94

If continued in FY94: ☒ with funds remaining? ☐ with FY94 funds?

If transitioned to other funding, to RTOP (number?): _____

to Program (name?): _____ to Other (identify): _____

Purpose of investigation

To investigate ways to utilize the Direct Connect Arc-Jet Facility (DCAF) for Ames hypersonic propulsion experiments. This involves the design of unique combustion experiments and diagnostic procedures along with the use of Ames CFD tools for flow prediction and analysis.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

The new CFD code developed in FY 92 has been upgraded by including grid embedding techniques and K-E turbulence models. This will allow the study of complex injector shapes such as the bifurcated strut. In preparation for injector studies, a simulation of the flowfield from the nozzle throat to the injectors has been completed. Boundary layer thickness and heat transfer to the combustor walls have been predicted.

Planned future work

Predictions of pitot pressures at the injector location will be compared to experimental data from the DCAF facility to validate the flowfield simulations.

Prepared by: Gene Menees — Org. Code: RTA — MS: 230-2 — Phone: (415) 604-3465

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: Mixing, Combustion, and Thrust Enhancement by a Pulsed Detonation Wave Augmentor

Investigator(s) (show affiliation): Gene P. Menees, Ames Research Center, Moffett Field, CA 94035-1000
Jean-Luc Cambier and Henry G. Adelman, Thermosciences Institute, Ames Research Center, Moffett Field, CA 94035-1000

Funding — Year Initiated: FY92 — Expected completion date: FY93

Total prior to FY93: $40,000 — Authorized in FY93: $40,000

Total expended in FY93: $40,000 (Estimated) — Requested for FY94, if any: 0

In-house

Contracts (identify)

Grants (identify): $40,000 NCC2-487

Status of study: ☒ Completed in FY93 ☐ Continued in FY94

If continued in FY94: ☐ with funds remaining? ☐ with FY94 funds?

If transitioned to other funding, to RTOP (number?) _____

to Program (name?) _____ to Other (identify) _____

Purpose of investigation

Focus on applications of an innovative concept called the pulsed detonation wave augmentor (PDWA), which uses detonation waves to solve problems facing a supersonic combustion engine (i.e., mixing, combustion efficiency, thrust enhancement, and lightweight packaging).

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Numerical results show that for our configuration (axial mode) achieving strong mixing enhancement with minimal losses in stagnation pressure is possible. Combustion is also increased by shock heating of the mixing layer. Three-dimensional (3-D) effects should lead to even better performance.

Planned future work

Determine effectiveness of concept for external combustion. Perform 3-D simulations.

Prepared by: Gene Menees Org. Code: RTA MS: 230-2 Phone: (415) 604-3465

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: Ablating Surface Heat Transfer Estimation for Flight Application

Investigator(s) (show affiliation): Greg Noffz and Mike Bowman, Dryden Flight Research Facility, Edwards, CA 93523-0273

Funding — Year Initiated: FY92 — Expected completion date: FY93

Total prior to FY93: $40,000 — Authorized in FY93: $40,000

Total expended in FY93: $40,000 (Estimated) — Requested for FY94, if any: $40,000

- In-house: $35,000
- Contracts (identify): $5,000 (San Jose State University Student)
- Grants (identify):

Status of study: ☐ Completed in FY93 ☒ Continued in FY94

If continued in FY94: ☒ with funds remaining? ☐ with FY94 funds?

If transitioned to other funding, to RTOP (number?): _____

to Program (name?): _____ to Other (identify): _____

Purpose of investigation

To develop a capacitive gage capable of measuring the recession of thin layered ablators, thus quantifying the energy component leaving the surface with ablation products. This type of instrumentation may also be used to measure the sublimation rate of certain chemicals used in flow visualization experiments.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

None

Planned future work

1. Continue evaluation of the candidate gages already fabricated.
2. Construct some third generation gages incorporating lessons learned.
3. Obtain calibration data using the actual materials of interest.
4. Complete a system capable of multiplexing and recording data from multiple gages.
5. Conduct a "hot" test using the materials of interest.

Prepared by: Greg Noffz — Org. Code: XRA — MS: D-2033 — Phone: (805) 258-2417

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: Crew Decision Making in Aerospace Environments: A Taxonomy of Decision Structures

Investigator(s) (show affiliation): Judith Orasanu, Ames Research Center, Moffett Field, CA 94035-1000

Funding — Year Initiated: FY93 — Expected completion date: FY94

Total prior to FY93: 0 — Authorized in FY93: $40,000

Total expended in FY93: $40,000 (Estimated) — Requested for FY94, if any: $40,000

In-house: $40,000 (through San Jose State University Foundation)

Contracts (identify)

Grants (identify)

Status of study: ☐ Completed in FY93 ☒ Continued in FY94

If continued in FY94: ☐ with funds remaining? ☒ with FY94 funds?

If transitioned to other funding, to RTOP (number?) _____

to Program (name?) _____ to Other (identify) _____

Purpose of investigation

This project is motivated by two factors: the signficant role of crew judgment and decision errors in aviation accidents and the absence of guidance from the traditional decision making literature. Its purpose is to develop a taxonomy of the types of decisions crews face in aerospace environments, and then for each decision type to determine the cognitive demands, to identify vulnerable points and types of errors, and to describe effective coping strategies. This knowledge will establish a basis for training standards, crew procedures, and decision aids.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

- Research findings from this project are being used by the following airlines in their crew resource management training courses: Delta, Northwest, Alaska, TWA, Horizon, Aer Lingus, and SAS. Other industries that are using our finding, methods, and concepts include hospital emergency shock/trauma centers, nuclear power, offshore oil drilling, and merchant marine.
- Six presentations at professional meetings and four publications have resulted from this project, including an invited address at the IATA Conference on Human Factors in Aviation and an invited contribution to a special Human Factors issue of the ICAO Journal.

Planned future work

- Validate dimensions that define decision structures and difficulty.
- Conduct experiments to test hypotheses about sources of judgement and decision error (especially poor situation assessment, including time and risk assessment).
- Test validity of effective decision strategies through training studies in collaboration with several airlines.
- Examine shuttle tapes (STS-21) to identify problem solving episodes and assess the structure of the problems and crew strategies.

Prepared by: Judith Orasanu — Org. Code: FLR — MS: 262-3 — Phone: (415) 604-3404

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: Analysis of Arc-Jet Wind Tunnel Vacuum Ultraviolet (VUV) Experiment

Investigator(s) (show affiliation): Chul Park, Ames Research Center, Moffett Field, CA 94035-1000
Dikran S. Babikian, Thermosciences Institute, Ames Research Center, Moffett Field, CA 94035-1000

Funding — Year Initiated: FY93 — Expected completion date: FY94

Total prior to FY93: 0 — Authorized in FY93: $40,000

Total expended in FY93: $40,000 (Estimated) — Requested for FY94, if any: $50,000

In-house

Contracts (identify)

Grants (identify): NASA Grant NCC2-42D

Status of study: ☐ Completed in FY93 ☒ Continued in FY94

If continued in FY94: ☐ with funds remaining? ☒ with FY94 funds?

If transitioned to other funding, to RTOP (number?) _____

to Program (name?) _____ to Other (identify) _____

Purpose of investigation

- Refine and validate our codes to calculate the radiative heating of our Aeroassisted Space Transfer Vehicle (ASTV)
- Improve the arc-jet CFD codes to better characterize the flow in arc-jet wind tunnels.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Measurement and Analysis of Nitric Oxide Radiation in an Arc-Jet Flow. AIAA 28th Thermophysics Conference, Orlando, Fla.

Validation of Multi-Temperature Nozzle Flow Code NOZNT. AIAA 28th Thermophysics Conference, Orlando, Fla.

User's Manual for NOZNT and NOZ1T. Technical note, in review.

Calculated and Measured Spectral Radiation from a Blunt Body Shock Layer in an Arc-Jet Wind Tunnel. 32nd Aerospace Sciences Meeting and Exhibit, Reno, Nev.

Characterization of Arc-Jet Flows Using Laser-Induced Fluorescence. 32nd Aerospace Sciences Meeting and Exhibit, Reno, Nev.

Planned future work

Continue the analysis of the available experimental data and the spectroscopic investigation of thermochemical processes in a blunt body shock layer in an arc-jet.

Papers in Preparation:

Spectroscopic Investigation of Thermochemical Processes in a Blunt Body Shock Layer in an Arc-Jet. 29th Thermophysics Conference. Prediction and Measurements of VUV Radiation from a Blunt Body Shock layer in an Arc-Jet Wind Tunnel, for a limited distribution TM.

Prepared by: Dikran S. Babikian — Org. Code: RTA — MS: 230-2 — Phone: (415) 604-1144

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation A Miniature, Lightweight Ozone Analyzer for Use on Unmanned Stratospheric Research Aircraft

Investigator(s) (show affiliation) Richard Pearson, Jr., Ames Research Center, Moffett Field, CA 94035-1000

Funding Year Initiated FY92 Expected completion date FY93

Total prior to FY93 $40,000 Authorized in FY93 0

Total expended in FY93: $40,000 (Estimated) Requested for FY94, if any 0
In-house $40,000
Contracts (identify)
Grants (identify)

Status of study ☒ Completed in FY93 ☐ Continued in FY94

If continued in FY94 ☐ with funds remaining? ☐ with FY94 funds?

If transitioned to other funding, to RTOP (number?) _____

to Program (name?) _____ to Other (identify) _____

Purpose of investigation

Our objective was to design and test the critical measuring components for a small, lightweight, low-power ozone (O_3) analyzer for use on unmanned research aircraft such as Perseus. Performance goals were to preserve a measurement accuracy comparable to the standard ER-2 instrument, while resolving problems of O_3 losses at highest altitudes and certain critical deficiencies in some other instruments currently in use thought to be due to uncertainties in optical path length.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

We significantly extended the geometric optic model of the system in this second year. A working (visible or infrared light) model of the absorption cell was built and tested as proof of concept, and to verify the accuracy of the complex design calculations with comparatively inexpensive components. The cell appears to operate precisely as expected, and it was photographed in laser light showing the beam following the intended path of eight passes through the cell, and exiting through the window. The final design of the ultraviolet (UV) elements for the cell and interactions between optical and mechanical parts proved far more difficult than anticipated. As a result, a detailed design is complete, but a prototype UV instrument has not yet been built.

Planned future work

The proposal developed from this work was turned down under extremely tight funding conditions. We plan to re-submit as new equipment funds are available in stratospheric chemistry.

Prepared by Richard Pearson, Jr. Org. Code SGG MS 245-5 Phone (415) 604-4388

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: Development of a Polarimeter for Astrophysical Applications in the Midinfrared

Investigator(s) (show affiliation): Yvonne Pendleton, Lynne Deutsch, and Thomas Roellig, Ames Research Center, Moffett Field, CA 94035-1000

Funding — Year Initiated: FY92 — Expected completion date: FY93

Total prior to FY93: $10,000 — Authorized in FY93: $30,000

Total expended in FY93: $30,000 (Estimated) — Requested for FY94, if any: 0

- In-house: $30,000
- Contracts (identify):
- Grants (identify):

Status of study: ☐ Completed in FY93 ☒ Continued in FY94

If continued in FY94: ☐ with funds remaining? ☒ with FY94 funds?

If transitioned to other funding, to RTOP (number?): _____

to Program (name?): _____ to Other (identify): _____

Purpose of investigation

Until now, polarimetric observations in the midinfrared have been limited to single dectector measurements. In particular, such observations of the center of our galaxy have shown that there is a wealth of information waiting to be gathered by a more sensitive and less time consuming method. We proposed to investigate the galactic center region in just such a manner through the use of two-dimensional polarimetric imaging in the midinfrared.

Our purpose was to investigate the inner few parsec region of the galactic center and other astronomical regions through high spatial resolution polarimetric imaging. These observations could provide answers to questions about the number and geometry of the luminosity sources present as well as information regarding grain alignment and the strength of the galactic magnetic field.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

New astronomical images have been obtained with a new infrared camera (AIR Camera) at NASA's Mt. Lemmon telescope. These images show emission from the young planetary nebula NGC 7027 at two midinfrared wavelengths. Planetary nebulae are the ejected envelopes of evolved stars. The central star of NGC 7027 is totally obscured by dust in the optical, has a temperature of 180,000 to 234,000 K, and is located approximately 1 kpc from our Sun. The midinfrared images reveal a double lobed structure and a central minimum, which represent a cross-section of a tipped toroid of gas and dust. The dust ejected by planetary nebulae has been enriched with heavy elements created through the star's nucleosynthesis. The nebula also contains large carbon molecules, which may be the building blocks of prebiotic material. This material is ultimately reincorporated into the interstellar medium from which new stars will be formed.

Planned future work

Now that the AIR Camera has been tested out at the telescope, the polarimeter can be used in conjunction with the camera. The next step in this project includes taking the camera/polarimeter to various telescopes to observe objects such as NGC 7027 and the galactic center to further study a variety of astrophysical environments.

Prepared by: Yvonne Pendleton Org. Code: SSA MS: 245-3 Phone: (415) 604-4391

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: Three-Dimensional (3-D) Disturbances Generated by Suction Holes for Laminar Flow Control (LFC)

Investigator(s) (show affiliation): Daniel C. Reda and Jonathan H. Watmuff, Ames Research Center, Moffett Field, CA 94035-1000

Funding — Year Initiated: FY93 — Expected completion date: FY94

Total prior to FY93: 0 — Authorized in FY93: $40,000

Total expended in FY93: $40,000 (Estimated) — Requested for FY94, if any: $40,000

- In-house: $40,000
- Contracts (identify)
- Grants (identify)

Status of study: ☐ Completed in FY93 ☒ Continued in FY94

If continued in FY94: ☐ with funds remaining? ☒ with FY94 funds?

If transitioned to other funding, to RTOP (number?) _____

to Program (name?) _____ to Other (identify) _____

Purpose of investigation

To investigate characteristics of boundary layer disturbances in the vicinity of suction holes and to explore the conditions under which the disturbances decay or amplify as they propagate downstream.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Interaction Between Instabilities Originating from Suction Holes. Paper to be presented at 46th Annual Meeting of Division of Fluid Dynamics (APS).

Planned future work

The initial $40,000 funding was used to modify an existing facility, and modification has been completed on schedule. The second year funding was originally estimated at $25,000 but was increased to $40,000 to include purchase of a new wind tunnel fan motor. An additional $5,000 is requested for a coprocessor that will reduce experiment run time by a factor of 10 (e.g., 2 days instead of 20 days).

Measurements of the background flow are under way. The test section unsteadiness is 0.08% and the transitional $Re = 2.2 \times 10^6$ for an impervious flat plate, which is very good for an open return blower driven tunnel. The mean flow exhibits the Blasius profiles, although the data have not yet been fully analyzed.

Disturbances generated by an isolated suction hole will be investigated shortly. The suction will be perturbed harmonically and the data phase-averaged on the basis of the perturbation. Measurements will be made on spatially dense 3-D grids allowing animations of the T-S-like 3-D waves to be studied on a graphics workstation. Of special interest is the interaction between disturbances originating from two holes displaced, but aligned in the streamwise direction. The same techniques will be used to examine possible enhancement, or more significantly, some degree of cancellation of these waves.

A scaled-up porous surface consisting of 8,966 holes will be used to investigate the interactions between disturbances on a full suction surface typical of those currently being flight tested for future use in airplane wings and engine nacelles.

Prepared by: Jonathan H. Watmuff Org. Code: RFR MS: 260-1 Phone: (415) 604-4150

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation An Ultralow-Temperature Thin-Film Thermometer

Investigator(s) (show affiliation) Pat Roach, Ames Research Center, Moffett Field, CA 94035-1000

Funding Year Initiated FY93 Expected completion date FY94

Total prior to FY93 0 Authorized in FY93 $38,000

Total expended in FY93: $35,000 (Estimated) Requested for FY94, if any $38,000

In-house $5,000

Contracts (identify) $30,000 to TransBay Electronics for support service personnel

Grants (identify)

Status of study ☐ Completed in FY93 ☒ Continued in FY94

If continued in FY94 ☐ with funds remaining? ☒ with FY94 funds?

If transitioned to other funding, to RTOP (number?) _____

to Program (name?) _____ to Other (identify) _____

Purpose of investigation

The purpose of this project is to develop a simple, accurate thermometer that will be useful in the temperature range of 0.01–0.38 K for use with cryocoolers that are being developed to be operated at 0.10 K and below.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

None

Planned future work

In FY94 an example of the actual thermometer will be fabricated and tested. The problem of lead attachment will be resolved and low-temperature tests will be carried out to evaluate the sensitivity and reproducibility of the thermometer. Problems that develop will be solved.

Prepared by Pat Roach Org. Code SFO MS 244-10 Phone (415) 604-3191

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: Early Warning Blackout Sensor for Pilots and Astronauts

Investigator(s) (show affiliation): S. A. Rositano, Alan Hargens, and Malcolm Cohen,
Ames Research Center, Moffett Field, CA 94035-1000

Funding — Year Initiated: FY93 — Expected completion date: FY94

Total prior to FY93: 0 — Authorized in FY93: $39,000

Total expended in FY93: $38,000 (Estimated) — Requested for FY94, if any: $20,000

- In-house: $18,000
- Contracts (identify): $20,000 (Classic Medical Products, Inc. – Prototype Electrodes/L&M Electronics – Electronic Circuits)
- Grants (identify):

Status of study: ☐ Completed in FY93 ☒ Continued in FY94

If continued in FY94: ☐ with funds remaining? ☒ with FY94 funds?

If transitioned to other funding, to RTOP (number?): _____

to Program (name?): _____ to Other (identify): _____

Purpose of investigation

Develop and evaluate a forehead-mounted impedance measuring patch capable of providing a 4- to 7-second advance warning of impending physiologic limit (blackout) caused by head-to-toe acceleration forces.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Signal processing circuitry has been designed and tested with simplified electrodes. A contract has been awarded to Classic Medical for production of prototype electrodes. The first integrated test is scheduled for November 93. Preliminary results indicate high probability for detecting the arterial pulse.

Planned future work

Upon successful tests on resting human subjects, tests on the ARC 20-G Centrifuge will be conducted. Refinements in electronics are expected to provide "smart signal processing" for adaptive artifact suppression.

Prepared by: S. A. Rositano — Org. Code: EES — MS: 213-2 — Phone: (415) 604-5480

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: The Infrared Spectra of Microsamples of Cosmic Interest: Diamonds, Silicon Carbide, Interplanetary Dust Particles, and Organic Residues

Investigator(s) (show affiliation): Scott A. Sandford, Ames Research Center, Moffett Field, CA 94035-1000

Funding — Year Initiated: FY92 — Expected completion date: FY93

Total prior to FY93: $30,000 — Authorized in FY93: $20,000

Total expended in FY93: $20,000 (Estimated) — Requested for FY94, if any: 0

- In-house: $20,000
- Contracts (identify):
- Grants (identify):

Status of study: ☒ Completed in FY93 ☐ Continued in FY94

If continued in FY94: ☐ with funds remaining? ☐ with FY94 funds?

If transitioned to other funding, to RTOP (number?): _____

to Program (name?): _____ to Other (identify): _____

Purpose of investigation

Obtain the 4000-400 cm^{-1} infrared spectra of a variety of microsamples for use in astrophysical studies.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

The microscope was used to verify portions of the data in two papers that are presently in press, one in Meteoritics and one in The Journal of Physical Chemistry.

Planned future work

The present DDF grant ends in September 1993, but the microscope will continue to be used to supplement other ongoing studies and will be used heavily if a proposal currently submitted to the Origins of Solar Systems Program is funded. The microscope will be used primarily for studying interplanetary dust particles and organic residues.

Prepared by: Scott Sandford Org. Code: SSA MS: 245-6 Phone: (415) 604-6849

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: Development of a Direct Measurement Transducer for the Oil Wedge Skin-Friction Technique

Investigator(s) (show affiliation): H. Lee Seegmiller, Ames Research Center, Moffett Field, CA 94035-1000

Funding — Year Initiated: FY92 — Expected completion date: FY94

Total prior to FY93: 0 — Authorized in FY93: $23,000

Total expended in FY93: $3,500 (Estimated) — Requested for FY94, if any: $20,000

- In-house: $3,500
- Contracts (identify)
- Grants (identify)

Status of study: ☐ Completed in FY93 ☒ Continued in FY94

If continued in FY94: ☐ with funds remaining? ☒ with FY94 funds?

If transitioned to other funding, to RTOP (number?) _____

to Program (name?) _____ to Other (identify) _____

Purpose of investigation

To develop a transducer and techniques for measurement of skin friction on model surfaces and aircraft by directly measuring the thickness of an applied oil film.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

A U.S. Patent application was filed for an aircraft ice detector developed as a spinoff of this investigation.

Planned future work

Complete fabrication of a wind tunnel model and conduct exploratory tests.

Prepared by: H. Lee Seegmiller Org. Code: RFE MS: 229-1 Phone: (415) 604-6211

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: Utility of the Experimental Electro-Optical Camera (SPEC-T) for Assessment of Insect/Drought Related Forest Mortality

Investigator(s) (show affiliation): Gary A. Shelton and Vincent G. Ambrosia, Ames Research Center, Moffett Field, CA 94035-1000
James McKean, U.S.D.A. Forest Service, Pleasant Hill, CA 94523

Funding — Year Initiated: FY93 — Expected completion date: FY95

Total prior to FY93: 0 — Authorized in FY93: $40,000

Total expended in FY93: $12,000 + $28,000 (estimated) — Requested for FY94, if any: $40,000

In-house

Contracts (identify): NAS-2-13500 + NAS2-13712

Grants (identify)

Status of study: ☐ Completed in FY93 ☒ Continued in FY94

If continued in FY94: ☒ with funds remaining? ☒ with FY94 funds?

If transitioned to other funding, to RTOP (number?) _____

to Program (name?) _____ to Other (identify) _____

Purpose of investigation

Evalute the application of a newly developed, high spatial resolution, electro-optical (EO) digital camera system for use in detecting and mapping insect/drought related forest mortality and other environmental assessments. Test and evaluate system configuration and utility for inclusion of SPEC-T in NASA supported suite of research and applications aircraft instruments.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

No reports or publications to date. Application assessments of feasibility of an electronic, adjustable focus ring to facilitate image collection in the electromagnetic visible and the infrared.

Planned future work

Reconstruct EO camera to operational status following unsuccessful 1993 assessment flights. More test flights planned for early FY94. Funds for 1993 were forward funded for 1994 work. Alignment and image collection timing for off-nadir viewing are currently in progress.

Prepared by: Vincent G. Ambrosia Org. Code: SGE MS: 242-4 Phone: (415) 604-6565

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation A Neural Learning Algorithm for Touch Based Control of Mechanical Manipulation

Investigator(s) (show affiliation) Jay Steele, Ames Research Center, Moffett Field, CA 94035-1000

Funding Year Initiated FY92 Expected completion date FY93

Total prior to FY93 $40,000 Authorized in FY93 $40,000

Total expended in FY93: $40,000 (Estimated) Requested for FY94, if any

In-house $40,000
Contracts (identify)
Grants (identify)

Status of study ☒ Completed in FY93 ☐ Continued in FY94

If continued in FY94 ☐ with funds remaining? ☐ with FY94 funds?

If transitioned to other funding, to RTOP (number?)

to Program (name?) to Other (identify)

Purpose of investigation

To develop a new neural learning system capable of directing the movement of autonomous vehicles and manipulators safely around perceived obstacles toward specified goals.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

None

Planned future work

None

Prepared by Jay Steele Org. Code FIC MS 269-3 Phone (415) 604-0158

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: Development of a New System for Canopy Architecture Remote Sensing

Investigator(s) (show affiliation): V. C. Vanderbilt, Ames Research Center, Moffett Field, CA 94035-1000
A. W. Sarto and B. J. Van Zeghbroeck, University of Colorado, Boulder, CO 80309

Funding — Year Initiated: FY93 — Expected completion date: FY95

Total prior to FY93: 0 — Authorized in FY93: $40,000

Total expended in FY93: $40,000 (Estimated) — Requested for FY94, if any: $40,000

- In-house: $25,000
- Contracts (identify): $15,000 with University of Colorado
- Grants (identify):

Status of study: ☐ Completed in FY93 ☒ Continued in FY94

If continued in FY94: ☐ with funds remaining? ☒ with FY94 funds?

If transitioned to other funding, to RTOP (number?):

to Program (name?): to Other (identify):

Purpose of investigation

We are developing a new theory and new laser based measurement method for remotely sensing canopy architecture. The theoretical development supports development of a proof-of-concept instrument.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

None.

Planned future work

Engineering interaction model: During the coming year we will develop the engineering interaction model, which will allow us to predict the properties of—as well as the information contained in—the return lidar beam for possible spatial and temporal modulations of the incident beam. The engineering interaction model will be designed to provide better insight into the engineering tradeoffs in the design of the lidar sensor.

Proof-of-concept lidar sensor: The information obtained from the theoretical analysis will aid in development of a ground based, proof-of-concept lidar sensor to be undertaken this coming year.

Prepared by: Vern Vanderbilt — Org. Code: SGE — MS: 242-4 — Phone: (415) 604-4254

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: Optimization of Spatial Auditory Displays for Multiple Communication Channel Intelligibility

Investigator(s) (show affiliation): Elizabeth M. Wenzel and Durand R. Begault, Ames Research Center, Moffett Field, CA 94035-1000

Funding — Year Initiated: FY92 — Expected completion date: FY94

Total prior to FY93: $30,374 — Authorized in FY93: $37,971

Total expended in FY93: $37,971 (Estimated) — Requested for FY94, if any: ____

- In-house: $9,000
- Contracts (identify): $22,981 (SJSU Foundation) $5,990 (Sterling Software)
- Grants (identify)

Status of study: ☐ Completed in FY93 ☐ Continued in FY94

If continued in FY94: ☒ with funds remaining? ☐ with FY94 funds?

If transitioned to other funding, to RTOP (number?) ____

to Program (name?) ____ to Other (identify) ____

Purpose of investigation

Improve intelligibility of multiple communication channels for KSC launch personnel.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Results: 6–7 dB improvement with prototype device, Ames Spatial Auditory Display
Patent: ARC 12013-1-CU submitted to U.S. Patent Office, Sept. 1993
Demo Prototype: At Kennedy Space Center Aug. 1993
Award: Patent application considered for Space Act Award 1993
Publications:

1. Begault, D. R.: Call Sign Intelligibility Improvement Using a Spatial Auditory Display. NASA TM-104014, 1993.
2. Begault, D. R.; and Erbe, T. R.: Multichannel Spatial Auditory Display for Speech Communications. In Proceedings of the 95th Audio Engineering Society Convention, Preprint No. 3707, Audio Engineering Society, New York, N.Y., 1993.

Planned future work

Complete psychoacoustic evaluation for "telephone grade" stimuli and multiple sources.

Prepared by: Durand Begault — Org. Code: FLM — MS: 262-2 — Phone: (415) 604-3920

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: Musculoskeletal Loading or Unloading with Differential Pressure

Investigator(s) (show affiliation): Robert Whalen and Gregory Breit, Ames Research Center, Moffett Field, CA 94035-1000
Douglas Schwandt, Rehabilitation Research and Development (RR&D) Center, Palo Alto, CA 94304

Funding — Year Initiated: FY92 — Expected completion date: FY93

Total prior to FY93: $40,000 — Authorized in FY93: $40,000

Total expended in FY93: $40,000 (Estimated) — Requested for FY94, if any:
- In-house: $40,000
- Contracts (identify):
- Grants (identify):

Status of study: ☒ Completed in FY93 ☐ Continued in FY94

If continued in FY94: ☐ with funds remaining? ☐ with FY94 funds?

If transitioned to other funding, to RTOP (number?):

to Program (name?): to Other (identify):

Purpose of investigation

- to design and fabricate an air pressure chamber and treadmill assembly
- to test the hypothesis that Earth-equivalent skeletal forces are achievable in microgravity
- to simulate hypogravity and hypergravity locomotion on Earth

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

- Hypergravity locomotion to 1.6 G was simulated.
- Differential pressure loading is an effective and feasible method of altering skeletal forces during gait.
- Earth-equivalent lower limb musculoskeletal forces can be generated in space.
- Results may be used to assist walking by supporting the body during gait rehabilitation.

1. Whalen, R.; Hargens, A.; Schwandt, D.; and Watenpaugh, D.: Musculoskeletal Loading or Unloading with Differential Air Pressure. Transactions of the 37th Meeting of the ORS, vol. 16, no. 2, 1991, p. 628.
2. Whalen, R.: Musculoskeletal Adaptation to Mechanical Forces on Earth and in Space. The Physiologist, vol. 36, suppl. 1, 1993, pp. 127–130.
3. Hargens, A.; Whalen, R.; Watenpaugh, D.; and Schwandt, D.: LBNP to Provide Load Bearing in Space. Aviation Space Environ. Med., vol. 62, 1991, pp. 934–937.
4. Patent 5,113,339: Exercise Method and Apparatus Utilizing Differential Air Pressure.

Planned future work

- Test the assembly on KC-135 flights
- Veterans' Administration RR&D Center collaboration to develop walking assist device
- Develop flight unit

Prepared by: Robert Whalen — Org. Code: SL — MS: 239-11 — Phone: (415) 604-3280

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: Aerogel Advanced Material Development

Investigator(s) (show affiliation): Susan White, Ames Research Center, Moffett Field, CA 94035-1000

Funding — Year Initiated: FY92 — Expected completion date: FY93

Total prior to FY93: $40,000 — Authorized in FY93: $40,000

Total expended in FY93: $40,000 (Estimated) — Requested for FY94, if any: 0

In-house

Contracts (identify): $24,000 (CF Technologies, Inc.)

Grants (identify): $16,000 (Department of Energy, Lawrence Livermore National Laboratories)

Status of study: ☐ Completed in FY93 ☒ Continued in FY94

If continued in FY94: ☒ with funds remaining? ☐ with FY94 funds?

If transitioned to other funding, to RTOP (number?): 232-01-04

to Program (name?): Base Materials Funding — to Other (identify):

Purpose of investigation

The purpose of this investigation was twofold: The first goal was to produce samples of a novel aerogel—fiber composite material, and to investigate its potential as a next-generation thermal production material. The second purpose of this project was to investigate the use of chemical processing to modify the surface chemistry of an aerogel, to increase its sintering temperature.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

- Aerogel Materials, Final Report for A24127D, TRW Space and Technology Group, Redondo Beach, Calif.
- Hrubesh, L.: Enhanced Thermal Capacity Aerogels, Summary Report for Contract No. A-26310D/L-1342, Lawrence Livermore National Laboratory, Livermore, Calif.
- White, Susan; Lee, Siu-Chun; and Grzesik, Jan: Advanced Particulate Fibrous Composite for Thermal Control of Re-entry Vehicles. AIAA Paper 93-2824, AIAA 28th Thermophysics Conference, Orlando, Fla. Submitted to J. Quant. Spectros. Radiat. Trans., 1993.
- Lee, Siu-Chun; White, Susan; and Grzesik, Jan: Effect of Particle Size in Composite Materials on Radiative Properties. AIAA Paper 93-2729, AIAA 28th Thermophysics Conference, Orlando, Fla. Submitted to AIAA J. Thermophysics, 1993.
- Submitted to International Symposium on Aerogels (ISA4)
- Patent applied for:
  1. Aerogel-loaded Tile Composite Material
  2. Fiber-reinforced Silica Aerogels

Planned future work

Complete current work on developing optimized composites.
Test material properties (mechanical properties, thermal conductivity).
Test materials in intended application.
Write and publish final results.

Prepared by: Susan White — Org. Code: RTM — MS: 234-1 — Phone: (415) 604-6617

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: Effects of Low Energy Impact of Atomic Oxygen and Nitrogen on Advanced Materials

Investigator(s) (show affiliation): Susan White, Joan Pallix, and Les Barnes, Ames Research Center, Moffett Field, CA 94035-1000

Funding — Year Initiated: FY93 — Expected completion date: FY94

Total prior to FY93: — Authorized in FY93: $40,000

Total expended in FY93: $40,000 (Estimated) — Requested for FY94, if any:
- In-house: $20,000
- Contracts (identify): $20,000
- Grants (identify):

Status of study: ☐ Completed in FY93 ☒ Continued in FY94

If continued in FY94: ☐ with funds remaining? ☒ with FY94 funds?

If transitioned to other funding, to RTOP (number?):

to Program (name?): to Other (identify):

Purpose of investigation

To understand the fundamental physical processes responsible for atom recombination and subsequent heating of thermal protection materials.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Final reports for work completed in FY93 include:

Copeland, R.; and Pallix, J.: Oxygen Atom Scattering and Recombination Experiments.

Amon, L.; and Barnes, L.: Methods for Studying the Alpha-Quartz Surface.

To be published when the FY94 work is complete.

Planned future work

Complete spectroscopic measurements of recombination product formation on reaction controlled glass (RCG) and silica surfaces.

Use infrared (IR) spectroscopy to measure surface binding energies.

Use computational methods studied in FY93 to model gas-surface interactions.

Prepared by: Joan Pallix — Org. Code: RTM — MS: 234-1 — Phone: (415) 604-0332

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: Application of Digital Signal Processing (DSP) to Near Real-Time Compensation of Attenuated Acoustical and Unsteady Pressure Measurements

Investigator(s) (show affiliation): Stephen A. Whitmore, Dryden Flight Research Facility, Edwards, CA 93523-0273

Funding — Year Initiated: FY93 — Expected completion date: FY95

Total prior to FY93: — Authorized in FY93: $40,000

Total expended in FY93: $40,000 (Estimated) — Requested for FY94, if any: $40,000

- In-house: $30,500
- Contracts (identify): $9,500 (San Jose State University Students)
- Grants (identify):

Status of study: ☐ Completed in FY93 ☒ Continued in FY94

If continued in FY94: ☐ with funds remaining? ☒ with FY94 funds?

If transitioned to other funding, to RTOP (number?):

to Program (name?): — to Other (identify):

Purpose of investigation

To develop methods for numerical compensation of pressure measurement distortion induced by pneumatic tubing, which cannot be mitigated in the instrumentation design. The compensation will be performed in real time using digital signal processing (DSP) technology.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

None

Planned future work

Miniaturization and packaging of the developed hardware and algorithms for use in wind tunnel and flight tests.

Prepared by: Stephen A. Whitmore — Org. Code: XRA — MS: D-2033 — Phone: (805) 258-2002

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: Technology Development for Selective Recovery of Urea from Urine and Its Subsequent Decomposition to Ammonia with Application in the Controlled Ecological Life Support Systems (CELSS)

Investigator(s) (show affiliation): Richard Wisniewski, Ames Research Center, Moffett Field, CA 94035-1000

Funding — Year Initiated: FY93 — Expected completion date: FY94

Total prior to FY93: 0 — Authorized in FY93: $40,000

Total expended in FY93: $40,000 (Estimated) — Requested for FY94, if any: $40,000

- In-house: $40,000
- Contracts (identify)
- Grants (identify)

Status of study: ☐ Completed in FY93 ☒ Continued in FY94

If continued in FY94: ☐ with funds remaining? ☒ with FY94 funds?

If transitioned to other funding, to RTOP (number?) _____

to Program (name?) _____ to Other (identify) _____

Purpose of investigation

The objective of this study is to develop a technology for separation of urea and salts from urine. Urea will be a major component of the nitrogen balance loop and will be used as fertilizer for plants in CELSS.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Results not yet published but have been reported in monthly reports.

Planned future work

Design longer batch electrophoretic chamber and continue experiments on diffusion. Begin urea separation experiments with free-flow and capillary electrophoresis systems. Develop method of decomposition of urea into ammonia.

Prepared by: Richard Wisniewski Org. Code: SAR MS: 239-11 Phone: (415) 604-1024

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation MIR Study of Disks Around Young Stellar Objects

Investigator(s) (show affiliation) Fred Witteborn, Ames Research Center, Moffett Field, CA 94035-1000
Harold M. Butner, DTM-Carnegie Institute, Washington, DC 20015

Funding Year Initiated FY92 Expected completion date FY93

Total prior to FY93 $25,000 Authorized in FY93 $28,000

Total expended in FY93: $28,000 (Estimated) Requested for FY94, if any 0

In-house

Contracts (identify) $28,000 (Center for Star Formation)

Grants (identify)

Status of study ☐ Completed in FY93 ☒ Continued in FY94

If continued in FY94 ☐ with funds remaining? ☐ with FY94 funds?

If transitioned to other funding, to RTOP (number?) _____

to Program (name?) _____ to Other (identify) _____

Purpose of investigation

To develop more realistic models for the physical conditions in disk models, and to extend high resolution mid-infrared (MIR) observations to a uniform sample of stars that are thought to have disks surrounding them. By combining the disk models and the midinfrared observations with radiative transport models of the circumstellar envelopes and existing far-infrared data, we can develop a more complete source model for young stars.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

A number of papers have resulted from the work thus far, and more are anticipated over the next year or so. As a result the initial project has greatly expanded to include a large range of young stellar objects.

Planned future work

Over the next two to three years, we plan to obtain a large sample of midinfrared spectra from young stars. We have also begun a program to obtain spatial resolved midinfrared data on the brighter sources. We are in the process of building up a large set of data on young stellar objects for which we have detailed source models of the disks and the surrounding envelope. The project has received support from the NASA Origins of the Solar System program.

Prepared by Harold M. Butner Org. Code SSA MS 245-6 Phone (415) 604-5520

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1993

Title of Investigation: Predicting Lyme Disease Risk: A Remote Sensing Model Based on Landscape Epidemiology

Investigator(s) (show affiliation): Byron L. Wood, James G. Lawless, Louisa R. Beck, and Sheri W. Dister,
Ames Research Center, Moffett Field, CA 94035-1000
Durland Fish, New York Medical College, Valhalla, NY 10595

Funding — Year Initiated: FY92 — Expected completion date: FY93

Total prior to FY93: $36,000 — Authorized in FY93: $36,000

Total expended in FY93: $36,000 (Estimated) — Requested for FY94, if any: 0

- In-house: $36,000
- Contracts (identify):
- Grants (identify):

Status of study: ☒ Completed in FY93 ☐ Continued in FY94

If continued in FY94: ☐ with funds remaining? ☐ with FY94 funds?

If transitioned to other funding, to RTOP (number?) _____

to Program (name?) _____ to Other (identify) _____

Purpose of investigation

The goal of this research was to develop a remote sensing-based spatial model (geographic information system, GIS) to describe key landscape features and predict areas where humans are at greatest risk of acquiring Lyme disease. This model was used to generate a Lyme disease risk map of the Westchester County, New York, study area.

FY93 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Development of a landscape level model to predict Lyme disease risk.

Dister, Sheri W.; Beck, Louisa R.; Wood, Byron L.; Falco, R.; and Fish, Durland: The Use of GIS and Remote Sensing Techniques in a Landscape Approach to the Study of Lyme Disease Transmission Risk. Proceedings, Seventh Annual Symposium on Geographic Information Systems in Forestry, Environmental and Natural Resource Management, Vancouver, B.C., Feb. 15–18, 1993.

Four conference presentations of the results of the DDF research.

Planned future work

Completion of all tasks included in the initial DDF proposal.
Submission of collaborative NASA, National Insitutes of Health, and Centers for Disease Control research proposal.
Submission of paper summarizing the final results of the DDF research.

Prepared by: Byron L. Wood Org. Code: SGE MS: 242-4 Phone: (415) 604-4187

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Ames-Moffett and Ames-Dryden Investigators

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Ames Research Center
Moffett Field, CA 94035-1000

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Washington, DC 20546-0001

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11. SUPPLEMENTARY NOTES

Point of Contact: John T. Howe, Ames Research Center, MS 200-16, Moffett Field, CA 94035-1000
(415) 604-5500

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12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This technical memorandum contains brief technical papers describing research and technology development programs sponsored by the Ames Research Center Director's Discretionary Fund during fiscal year 1993 (October 1992 through September 1993). An appendix provides administrative information for each of the sponsored research programs.

14. SUBJECT TERMS

Director's Discretionary Fund, Space science, Life science, Aeronautics, Space and terrestrial applications

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