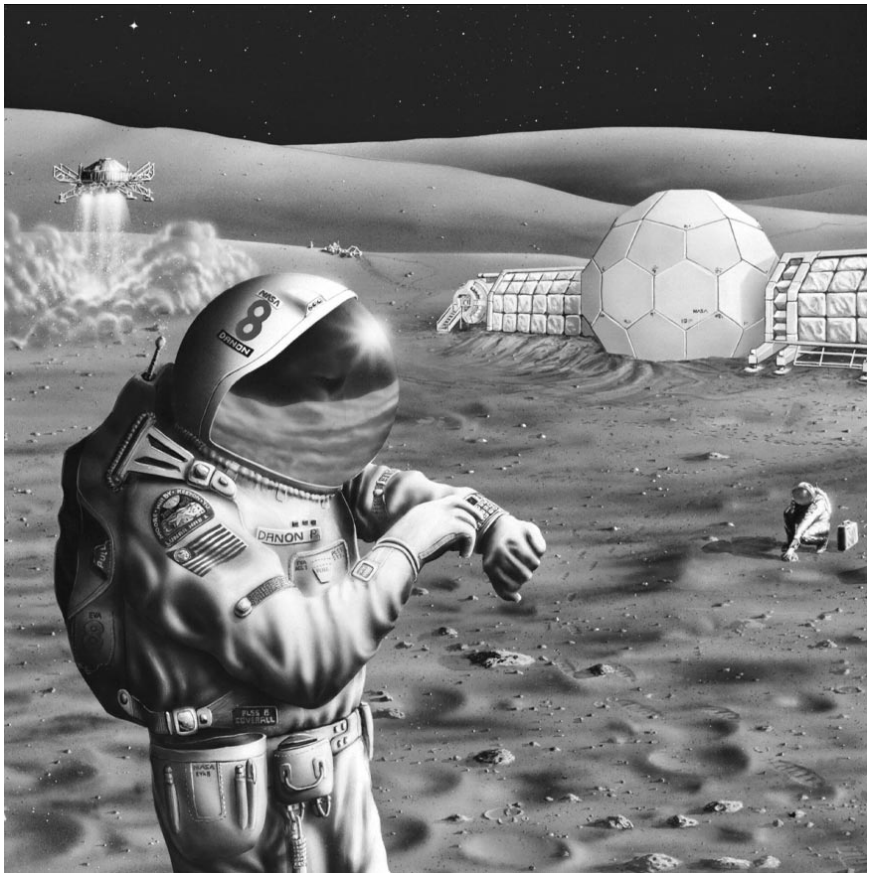
NASA/TM–2000-209583

Director's Discretionary Fund Report for Fiscal Year 1999

Ames Research Center



January 2000

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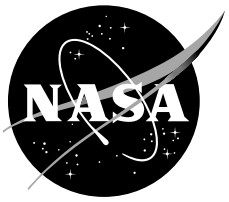

Director's Discretionary Fund Report for Fiscal Year 1999

Ames Research Center, Moffett Field, California

National Aeronautics and
Space Administration

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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 16 final and 26 ongoing projects in Fiscal Year 1999.

The contents are listed alphabetically according to the last name of the primary investigator in two sections (final and ongoing reports). Following the narrative reports, two appendixes (for final and ongoing reports) contain brief descriptions with the financial distribution and status of each of the projects.

Any questions can be addressed to an investigator directly.

Section 1
Final Reports

Where Are the Hidden Supernovae?

Investigators
J. Bregman, D. Wooden, and T. Roellig,
Ames Research Center, Moffett Field, CA 94035-1000

Objectives of the study
To determine whether there are supernovae hidden from view at optical wavelengths in the cores of starburst galaxies and to measure how often they occur.

Progress and results
A science-grade 256- × 256-long wavelength HgCdTe array was purchased, and an engineering-grade array is in the camera dewar and has been tested with preexisting electronics. New electronics were purchased and interfaced to a control computer; cabling between the new electronics and the dewar is in progress. A long delay in delivery of the electronics has delayed our initial observations by more than a year.

Significance of the results
Tests of the engineering-grade array show it to be extremely sensitive and with sufficiently low dark current to be usable from ground-based telescopes. Its performance should be two to four times better than our previous detectors.

Keywords
Infrared rays, Supernovae

Graphics Software Architectures for True Three-Dimensional High-Resolution Volumetric Displays

Investigators

Steve Bryson,
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Moffett Field, CA 94035-1000

Chris Henze, MRJ, Inc., Ames Research Center

Objectives of the study

Inherently three-dimensional displays ("volume displays"), which fill physical three-dimensional space with truly three-dimensional images, recently have been developed. These volume displays use a variety of technologies ranging from moving arrays of lights to intersecting lasers. Volume displays present truly three-dimensional images, which contain all the correct depth cues simultaneously for multiple viewers. By providing high-quality three-dimensional images to multiple viewers, volume displays support collaborative computer-based design and engineering. Such collaboration is critical in several NASA missions such as spacecraft and aircraft design, operations, and the visualization of scientific data.

Current approaches to computer graphics, based on raster methods and frame buffers, are not well suited for volume displays. The purpose of the research is to develop a hybrid raster and vector graphics approach, which we refer to as "sparse raster." In this approach, graphical primitives such as polygons embedded in three dimensions would be converted into points and lines using three-dimensional generalizations of conventional raster, which would then be rendered in the volume display using three-dimensional vector techniques. The sparse raster approach sends to the volume display only the data to be drawn rather than a frame buffer that may be mostly empty. The research will result in a simple graphics library that renders three-dimensional graphical primitives using the sparse raster approach. This graphics library would support points, lines, and polygonal surfaces, and would allow simple monochromatic shading algorithms such as Gouraud shading and simple lighting. This library would be used to implement simple demonstration programs using a volume display, including an interactive scientific visualization application.

Progress and results

Preliminary design of the sparse raster approach has been done. Discussions have occurred with the vendor to integrate this research with the vendor's underlying architectures. Hardware development is expected to be completed in FY00.

The architecture described above will be developed in close cooperation with the hardware vendor in FY00. Formal vehicles such as memoranda of understanding (MOUs) will be explored to increase the cooperation between the vendor and NASA. We are currently projecting joint patents and research publications to result from this work.

Keywords

Three-dimensional display, Virtual reality, Scientific visualization

Self-Contained Oculomotor Tracking System (SCOTS) to Study Gaze Control in Humans during Self-Locomotion

Investigators

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Geoffrey Bush, Lockheed Martin Space Operations,
Ames Research Center

Eric Sabelman, Rehabilitation Research & Development Center, Department of Veterans Affairs Medical Center, Palo Alto, CA 94304

Objectives of the study

To fabricate and test a portable, first-generation Self-Contained Oculomotor Tracking System (SCOTS). The system will be designed to measure the horizontal and vertical movements of both eyes as well as accelerations of the head during a variety of behavioral situations such as walking, running, standing up, and bending over.

Progress and results

The development of the SCOTS has proceeded in two phases. Activity in Phase 1 produced an alpha-generation device that is a working bench-top prototype. Work during the initial phase included component procurement, fabrication of hardware as required, assembly of the infrared oculography components and the digital accelerometry components, and finally integration of the various components with the Advanced Micro Devices (AMD) microprocessor. Component selection has been governed by design objectives that included minimizing power consumption and reducing form factor. During Phase 2, components of the bench-top prototype have been reproduced as miniature versions of the original circuits, resulting in a compact portable system. In addition to hardware assembly, a portion of the SCOTS development effort has involved programming the various devices that interface to the microprocessor and writing software that enables the user to easily acquire and download the data. The SCOTS development has made use of currently available technologies to minimize costs.

The core of the system is the nC52™ 5_x86 Processor Module (AMD 5_x86 chip) configured with 32 megabytes (MB) of DRAM. The processor runs at 133 megahertz (MHz) to give a 105.6-megabyte-per-second (MBps) burst bus at 33 MHz. The carrier board provides for system management, VGA control, and input/output (I/O), and, therefore, is equipped with industry-standard connections for a mouse (PS2 or serial), keyboard, VGA port, parallel port, COM1 and COM2 ports, IDE connector for a hard drive, a connection for a 3 1/2-inch floppy drive, and a PCMCIA module based on the Cirrus Logic CL-PD6722 Host Adapter, which provides for two PCMCIA sockets.

To facilitate system development, a monitor, PS2 mouse, keyboard, 3 1/2-inch floppy drive, and a 540-MB hard drive were connected to the carrier board and the Basic Input/Output System (BIOS) was configured appropriately. A regulated power supply was set up to provide 12 volts (V) and sufficient current to power the board, a fixed drive, and the floppy drive. The serial and parallel ports were tested for proper functioning.

The PCMCIA bus serves as the route of data input through two separate means. Socket A contains a data-acquisition system (Keithley 16AIAO Type II PCMCIA card) with eight single-ended analog input channels. The analog-to-digital (A/D) card supports sampling rates up to 100 kilohertz (kHz) with 16-bit resolution. Input to this card comes from the infrared oculography device. The four analog input channels used are 1) right eye horizontal position, 2) right eye vertical eye position, 3) left eye horizontal position, and 4) left eye vertical position. The infrared oculography device consists of an array of infrared light-emitting diodes (LEDs) and infrared sensitive phototransducers mounted onto goggles worn by the subject. The infrared light is reflected from the surface of the eye and converted into a voltage. Voltages arising from phototransducers in different locations in each array are passed to separate horizontal and vertical differential amplifiers. The output of these amplifiers represents the horizontal and vertical position of the eye. The signal is then low-pass filtered before it is acquired by the A/D circuitry. The position of the LED array in front of each eye is adjustable to maximize the infrared (IR) reflectance detection from the cornea.

Socket B contains the Altera chip (EPF10K70RC240-3 Flex 10K chip). The primary function of the Altera chip is to provide the interface between the six digital accelerometers and the Adaptive System's embedded computer system through the PCMCIA bus. The PCMCIA bus is controlled by a Cirrus Logic CL-PD6722 ISA to PC-Card Host Adapter that uses an index register method to access internal registers. The Altera chip can be programmed to provide access to the read and write registers. During the initial development, the Altera chip

was surface mounted onto a PCMCIA extension card, allowing the supporting circuitry to be developed. For example, the chip requires a 50-MHz TTL oscillator. In general, the Altera chip performs the following functions: 1) provides the clock frequency for all the accelerometers, 2) counts the pulse outputs from the accelerometers, 3) sets the acquisition rate for the accelerometer data, 4) performs the accelerometer calibration, 5) buffers the data to the CPU, 6) provides digital I/O for indicator LEDs, 7) provides user-definable buzzer tones for menu selections, and 8) provides a ready signal to the microprocessor for data acquisition. Input to this card comes from the accelerometers. The accelerometers are the capacitive digital type by Silicon Designs, Inc. They produce a digital pulse train in which the number of pulses per second is proportional to the applied acceleration. The Altera chip provides the 250-kHz clock frequency for the accelerometers. The initial development work involving the Altera chip was carried out at the Rehabilitation Research & Development Center in Palo Alto, California. A duplication of the Altera components has begun for incorporation into the SCOTS.

Wireless communication between the microprocessor and a separate computer was implemented to allow an operator access to the microprocessor. Such remote access would permit keyboard entry of information such as experiment parameters and data header but also would allow for remote initiation and termination of the data acquisition. Each node consists of a data radio board and host protocol board. The protocol board connects to an unused serial port on the host computer using an RS232 cable. Radio frequency (RF) transmission can be selected for either 433.92 or 916.5 MHz with a maximum transmission rate of 22.5 kilobits per second (kbps).

Assembly of the SCOTS has progressed well. Some Phase 2 work needs to be completed, primarily the process of miniaturizing the components. Currently, the Altera chip and its associated circuits are being placed on a PCMCIA card. Once this process is complete, the entire system will be returned to Adaptive Systems, Inc. so that they can convert the various components of the development system to their nC52™ modules. These modules will allow the different system components to be physically arranged in a user-defined configuration (i.e., stacked or linked end to end, for example).

Keywords
Gaze control, Portable eye tracker

Parallelization Tools for Computational Fluid Dynamics

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Objectives of the study
To assess the performance and ease of using a suite of computational tools (CAPTools) developed at the University of Greenwich for the automatic translation of serial simulation codes into parallelized versions capable of utilizing large-scale computing facilities. CAPTools is a software toolkit that automatically translates serial applications into parallelized versions based on message passing.

Progress and results
Two parallel codes and one code featuring dynamic-local grid refinement were assessed using CAPTools. For the codes submitted, CAPTools was either 1) unsuccessful to complete the analysis; or 2) unable to generate code that can be compiled; or 3) generated a compilable code but executed incorrectly. One code was successfully parallelized, but it executed poorly.

Significance of the results
This outcome is consistent with researchers' experiences at the Ames Research Center for first-time users of CAPTools. Further interaction with the University of Greenwich and further optimization work is required on the set of parallel codes that executed correctly. For one fine-grained application (DNS Code for laminar flames with complex chemistry) tested, the time spent parallelizing the code with CAPTools is similar to that taken to produce the manual code. Most of the time was spent working around instabilities in CAPTools. For one coarse-grained application (turbulent reacting flows with complex chemistry) tested, the inability of CAPTools to cope with variations in particle numbers is (probably) similar to that associated with local grid refinement. With another coarse-grained application (homogeneous turbulence code), CAPTools did not pick up parallelizations that seemed obvious to a programmer. Furthermore, the integration of manually produced and optimized code segments into CAPTools was not readily achieved. Five possible future development directions were identified:

1. There is probably a need to redefine the working model and assumptions inherent in CAPTools. We need to produce open and transparent code with direct message passing interface/shared memory direct access (MPI/SHMEM) calls.
2. Modularity in terms of parallelized solvers combined with codes parallelized manually or semiautomatically needs to be examined. Specifically, the integration of CAPTools with parallel libraries needs to be considered.
3. The potential benefit of partial/selective parallelization should ideally be assessed.
4. A view of the balance between sophisticated solvers, solution strategy, and machine architecture needs to be established (sweep lengths, processor communications, etc.).
5. Issues such as load balancing, heterogeneous systems, and, for CAPTools, variable loop limits need to be addressed.

In summary, the stability of CAPTools needs to be significantly improved before it constitutes a useful practical tool. Staff training was not the major difficulty. However, the ideas and concepts underlying the product are sound and well worth exploring further.

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Keywords
Parallelization tools, Computational fluid dynamics codes

Large-Scale Processing of Carbon Nanotubes

Investigators
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Sunita Verma, Orbital Sciences Corporation,
Ames Research Center

Objectives of the study
To develop a chemical vapor deposition (CVD) process to grow carbon nanotubes (CNT) for nanotechnology applications. CNT is a material with extraordinary mechanical and electrical properties. It has the potential for ultralightweight composites, but methods to grow large quantities are required. CNT also has the potential to revolutionize nanoelectronics, a revolution for which controlled growth on patterned wafers is critical. Two existing techniques, laser ablation (from Nobel Laureate Richard Smalley) and carbon arc growth (used mainly in Japan) cannot give large quantities for composites; they are not suitable for electronics because CNT is scraped off the walls. The Ames CVD process, in contrast, is ideal for all applications.

Progress and results
The reactor, built using DDF funding, consists of an approximately two-foot-long quartz chamber enclosed in a high-temperature furnace. The furnace has three heating zones and is capable of maintaining an isothermal growth zone. The system is capable of taking multiple wafers in a single run; they can be loaded from one end using an arm. The reactor has multiple mass-flow controllers to admit various precursors. The entire system is enclosed under a hood with a glass shower-curtain-like door with all appropriate safety measures.

The precursor system studied is CO disproportionation, a system that has been successful, and the recipe used has yielded carbon nanotubes.

The major focus during this fiscal year was to develop optimal conditions for the growth of CNT. The understanding of the growth process in the community is minimal. Developing diagnostic tools for obtaining insight into the mechanism is beyond the scope here. Therefore, we have done systematic investigations by varying temperature, gas flow rate, and catalyst preparation to correlate with CNT production as well as the number of walls.

Significance of the results
We have demonstrated that a CVD technique using CO disproportionation reaction can grow CNT. Since the DDF project completion, we have recently built a second CVD reactor through a NASA program for routine production of nanotubes. We have also been awarded a contract from the National Cancer Institute to develop nanotube-based biosensors for which the CVD work is critical.

Keywords
Carbon nanotubes, Chemical vapor deposition, Nanotechnology

Spectroscopic Studies of Mass-Selected Ions and the Evolution of Carbon-Bearing Molecules in the Galaxy

Investigators

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Objectives of the study

In recent years it has become clear that polycyclic aromatic hydrocarbons (PAHs) and related materials are prominent at all stages of the life cycle of matter in the interstellar medium. As a consequence, not only do these species hold enormous potential as probes of the interstellar medium, but they also represent the single largest source of prebiotic organic carbon in evolving planetary systems. Unfortunately, the highly reactive, transient nature of the PAH species that routinely thrive under interstellar conditions makes it notoriously difficult to generate and study all but the simplest analogs in the terrestrial laboratory. It is the goal of this project to greatly increase and diversify the inventory of PAH-related transient species that can be studied spectroscopically in the laboratory. We plan to accomplish this goal through the development of a unique, new gas phase ion source capable of producing and isolating pure, mass-selected ions that can then be trapped in an inert solid matrix and probed spectroscopically.

Progress and results

In the first year of this project, the ion production/mass-selection equipment and their associated electronics were purchased from ABB Extrel, Pittsburgh, Pennsylvania. A schematic of the system is shown in figure 1. The major milestone in the second year was the acquisition of new laboratory space sufficient to allow construction of the new instrument, and preparation of that space to receive the matrix isolation of mass-selected ions (MIMSI) equipment. While somewhat less tangible, this element is no less important for the ultimate realization of this project. The movement of the existing experimental setup to the new laboratory is currently under way.

The first phase of the project is now complete. In the second phase, an appropriate vacuum chamber for housing the new ion source/mass selection instrumentation will be purchased, and a working mass spectrometer will be constructed. In this configuration, the equipment will be optimized to produce the mass-selected ion currents necessary to conduct the matrix-isolation infrared spectroscopy measurements. In the final stage of the project, the optimized mass selected ion source will be married to the existing matrix-isolation apparatus.

Also noteworthy is the fact that, motivated by the progress to date, NASA Headquarters has authorized a National Research Council (NRC) Associateship position to support the hiring of a scientist to implement the remaining stages of the project. The search for an appropriate candidate is currently under way.

Significance of the results

The spectroscopic measurements of ionized PAH-related molecular species facilitated by this project will allow the full exploitation of those species as interstellar probes, and reveal the step-by-step evolution of carbon-bearing molecules from their birth in circumstellar shells, through their maturation in the interstellar medium, to their incorporation into planetary systems.

Keywords

Ionized polycyclic aromatic hydrocarbons, Infrared spectroscopy of molecular ions, Life cycle of interstellar organic molecules

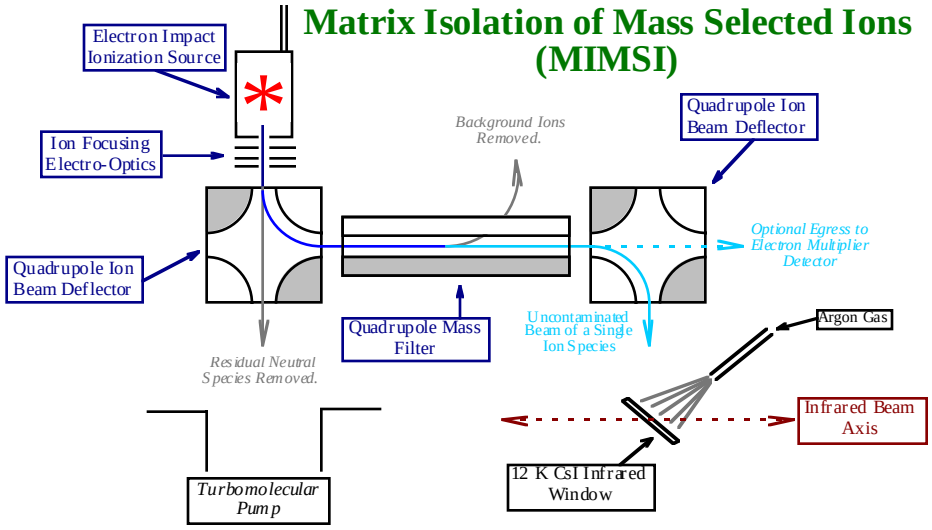

Figure 1. Matrix isolation of mass-selected ions (MIMSI).

SHARP-L1 Concept Development

Investigator
Paul Kolodziej, Ames Research Center,
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Objectives of the study
To develop concepts and technologies for advancing the technology readiness level (TRL) of the Slender Hypersonic Aerothermodynamic Research Probe - Lifting #1 (SHARP-L1) flight demonstrator described in the SHARP-FX proposal to the Future-X program, and break new ground toward the design of sharp-body hypersonic vehicle concepts.

The government/industry/university team that prepared the Future-X proposal has continued developing SHARP-L1 to retire the concerns raised by the Future-X Source Evaluation Board, and has worked to identify potential impacts of SHARP technologies on NASA missions. Since its conception, the SHARP program has utilized a dual thrust approach focused on advancing TRLs and developing advocacy. The approach is utilized here to: improve the analysis of the SHARP-L1 stability and control; design a sounding rocket experiment to test a prototype control system for SHARP-L1; and initiate studies of reusable launch vehicle (RLV) and Waverider sharp-body concepts for future NASA missions.

Progress and results
Early hypersonic vehicle concepts were based on extrapolations of the knowledge and experience acquired in the development of supersonic aircraft. These concepts were slender-body vehicles with sharp leading edges to minimize wave drag. At hypersonic velocity, the aero-thermodynamic heating is severe and the sharp leading edges that were fabricated from Inconel X, titanium, or carbon-carbon melted or ablated to a larger radius. Since a larger radius reduces the aerothermodynamic heating, the leading edge melts or ablates until an energy balance is established between the fluid and the material. The complexity of this behavior introduces significant uncertainty into the design of a hypervelocity vehicle. For reusable vehicles, sharp nose tips and wing leading edges that ablate are undesirable because of the high life-cycle costs due to refurbishment. Therefore, to maximize performance and minimize life-cycle cost, it is important to focus on the material limitations and the operating environment early in the design process.

The enabling technology for reusable, hypersonic sharp-body concepts is the ultra-high temperature ceramic composite (UHTC) materials under development at Ames. UHTCs have a unique combination of mechanical, thermal, and chemical properties that enable the fabrication of very small radii or sharp leading edges for nonablating hypersonic operation. One of the most useful approaches for understanding the conditions where these leading edges are capable of operating without ablation is the aerothermal performance constraint (APC). APCs are determined by numerical simulation of the coupled aerothermal heating / thermal response behavior of the UHTC leading edge to define the steady-state "nonablating performance" constraint on the altitude-velocity flight envelope [1]. Trajectories that cross the APC cause ablation of the sharp UHTC leading edge that requires excessive refurbishment before reflight. Trajectories that do not cross the APC minimize refurbishment between flights. By utilizing APCs in this manner, a vehicle designer is able to quickly determine if the current vehicle design will experience leading-edge ablation without waiting for an extensive thermal analysis. For example, the comparison in figure 1 demonstrates that a sharp UHTC nose tip attached to the Shuttle would not ablate during a nominal reentry.

Understanding the design constraints of the thermal protection system (TPS) behind the sharp UHTC leading edge, or body TPS, is also important. The body TPS insulates the structure, or airframe, from the aerothermal heating. On large vehicles (Shuttle), the structure may cover an area larger than 10,000 square feet (ft^2). Clearly, vehicle shapes that minimize the surface area enclosing a given volume reduce the amount of TPS and structure. Early reentry capsules implemented this strategy by utilizing spheres to enclose the maximum volume with minimum surface area. Although volumetrically efficient, spheres with a lift-to-drag ratio of zero (L/D = 0) have no hypersonic aerodynamic performance for maneuvering. Later reentry capsules (Apollo) utilized simple blunt-body geometries with L/D > 0 and operated along lifting trajectories to reduce heating, reduce deceleration, and correct for uncertainties during re-entry to minimize the landing footprint. Adding wings sufficiently increased the L/D to routinely land the Shuttle on a runway.

An historical perspective of this trend is shown in figure 2 [1]. Gemini and Apollo were volumetric efficient designs with low L/D for small adjustments of the splashdown footprint. The HL-10, M-2, and X-24 family of blunt lifting bodies achieved higher L/D to reduce the

footprint for runway landing. Subsonic aerodynamic performance was improved to provide additional margin during approach and runway landing with the X-20 and Shuttle winged glider configurations. As the vehicle geometry evolved to improve the runway landing capability, the volumetric efficiency steadily decreased, the surface area steadily increased, and the amount of TPS and structure steadily increased.

The constraints imposed on hypersonic vehicle designs by runway landing requirements were identified in Hankey's optimization study of winged glider configurations [1]. When runway landing was no longer a requirement, the maximum L/D and volumetric efficiency increased significantly. The improvement may be observed in figure 2 by comparing the X-20 and Shuttle data with the curve defining a family of wingless optimal geometries. From this curve it is possible to select a vehicle shape with sufficient hypersonic L/D required to meet the mission requirements. For example, the optimal geometry for an L/D = 0 is a sphere. Higher L/D capability is achieved by selecting optimal geometries that resemble hybrid wedge/cone combinations with sharp leading edges.

Significance of the results

To maximize volumetric efficiency and L/D, the SHARP-L1 geometry shown in figure 3 was selected from the knee in the optimal geometry curve in figure 2. Several modifications to the optimal geometry were made by the Future-X team to enhance the stability and control characteristics. These constraints on hypersonic stability and control, although not as severe as the constraints on runway landing, have a similar detrimental effect on L/D and volumetric efficiency. As a result, SHARP-L1 is now located slightly below the optimal geometry curve in figure 2. A similar trend is likely for other practical modifications to an optimal geometry, such as engine integration. To build a vehicle that meets specific mission requirements, it is important to understand these trends and select an initial concept with sufficient margin.

It is important to bridge the gap between concepts and practical applications early in the development of advanced technology by identifying end users in order to demonstrate relevance, develop advocacy, and provide independent, objective assessments. Two possible end users of SHARP technologies are the Bantam class of RLVs and Waveriders. A consortium agreement was initiated at the Georgia Institute of Technology to examine the impact of sharp UHTC leading edges and Hankey optimal geometries on vehicle size, weight, and cost. These SHARP technologies were utilized in the Stargazer shown in figure 4 [1]. Stargazer is a Georgia Tech design for a future Bantam-class RLV. A second consortium agreement was initiated at the University of Maryland to examine the impact of SHARP technologies on a class of very high L/D vehicles known as Waveriders. UHTCs enable the sharp leading edges on the Waverider shown in figure 5 [1]. A third consortium agreement was initiated at Stanford University to develop a sounding rocket experiment to acquire data on the stability and control of SHARP-L1. This experiment retires risk by performing a "hardware-in-the-loop test" of the flight control system before the SHARP-L1 flight [1]. In addition, providing students with project experience creates the educational balance required by U.S. industries competing in the global aerospace marketplace.

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Keywords

FUTURE-X, SHARP, TPS, UHTC, Volumetric efficiency, High L/D, Lifting body

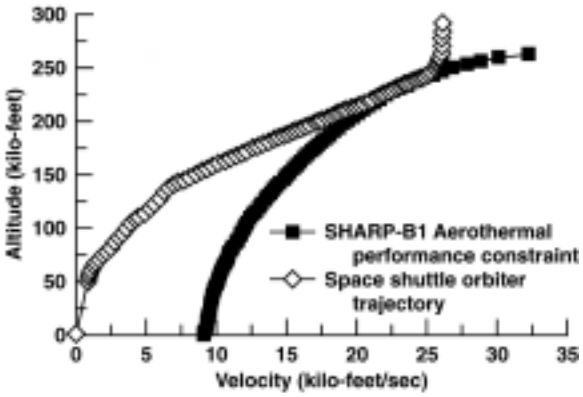

Figure 1. Aerothermal performance constraint.

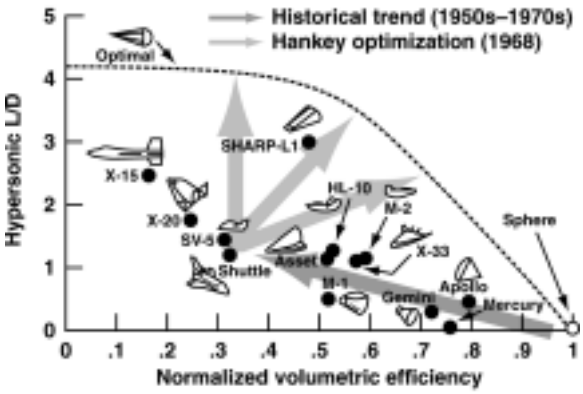

Figure 2. Hypersonic L/D vs. volumetric efficiency.

Figure 3. NASA Ames Research Center SHARP-L1.

Figure 4. Georgia Institute of Technology Stargazer.

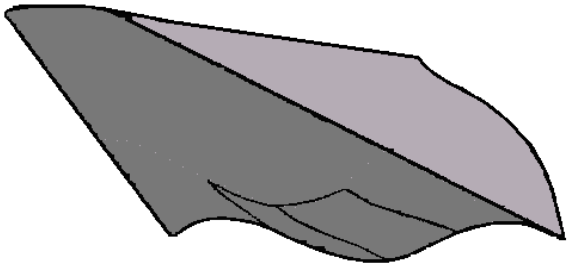

Figure 5. University of Maryland Waverider.

Development of a Fully Automatic Mini-Holographic Optical Instrument for Fast Separating and Detecting Amino Acids for Future Planetary Missions

Investigators

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Objectives of the study

To investigate and establish the feasibility of building prototype equipment that will separate and detect underivatized amino acids from soil samples for planetary spaceflight programs. The focus of the first year was development of new materials that would have specific affinity for native amino acids in general. The underlying concept for designing these new types of materials is molecular imprinting that has been successfully used in preparation of polymeric materials for chromatographic separation and sensor technology. The main objective in the second year is to develop a simple, practical methodology that would allow incorporation of the developed molecularly imprinting polymers into mini-columns and/or micro-channels. The ultimate goal is to assemble an automatic mini-instrument that would allow underivatized amino acids to be concentrated, separated, and detected in a single step.

Progress and results

In order that minute of amounts of organic molecules could be detected in planetary samples, for either in situ or return samples analysis, concentration of the target molecules is crucially important as the first step. A methodology was developed in the first year of the study to prepare polymers imprinted with the templates of target amino acids. Monomers such as methacrylic acid, dialkylaminopropyl methacrylate, and some cross-linking agents were systematically formulated to optimize the conditions for preparation of desired materials. Binding studies confirmed the amino acid-specific affinity of prepared molecularly imprinting polymers. Polymers were synthesized with improved binding properties for amino acids, although more investigation is needed to further establish their binding properties and mechanism. The concentration of amino acids in the outer planets is expected to be extremely low. Therefore, the strength of their binding properties to native amino acids needs further improvement in order to realize onsite analysis. The second year of the project focused on developing mini-columns and/or micro-channels in a chip, which contain layers of amino acid-specific molecularly imprinted polymers. With increased affinity to specific amino acids, it is believed that the prefabricated columns would then retain amino acids more strongly than other chemicals, so the concentration, separation, and possibly detection could be achieved in a single step. One of our objectives is to optimize a mini-column preparation method. Another objective is to develop a better, more efficient method to detect native amino acid at higher sensitivity. This ability would potentially eliminate the problems from derivatizing amino acids before their separation and detection. A detector chamber was designed and fabricated to detect separated amino acids using amino group-specific chemilluminecent reagents, in conjunction with an S2000 charged coupled device (CCD) fiber-optic spectrometer.

With this previously developed preparation procedure for molecularly imprinted polymers, we have worked on further optimizing the condition to obtain better quality of these types of polymers. Photo-activated polymerization is believed to be one of the best choices to synthesize molecularly imprinted polymers in situ for mini-columns and micro-channels in the chip. Alkyl halides have been widely used to photo-initiate polymerization of a spectrum of monomers under different conditions. Using functionalized methacrylates and/or methacrylic acid itself, it is possible to in situ anchor polymers on the surface of a capillary column, provided the surface has been assembled, via sol gel process, with a layer of silicone polymers with a pending group such as alkyl halide. Experiments have been performed using photo-activated group and metal catalyst(s) to polymerize MIPs inside the capillary with inside diameter of 75 or 100 micrometers (um). An ultraviolet (UV) transparent capillary was chosen for possible in situ UV-activated polymerization for molecularly imprinted polymers.

Lack of chromorphores in most of essential amino acids is the key problem in developing an efficient and highly sensitive method to detect and identify those amino acids at their native state. Stationary phase(s) with highly specific affinity for amino acids is considered to be very

important in overcoming this problem. With amino acids concentrated through the prefabricated separation phase, the constrain on threshold of the detection limit for amino acids can also be alleviated to the level achievable by the contemporary techniques. Chemilluminescence has been widely under development for detecting a variety of organic molecules, including amino acids. This chemilluminescence-based sensitivity varies, depending upon the chemilluminescent reagents. Work is continuing to set up a prototype assembly for use as a chemilluminescence-based amino acid separation/ detection device for use with a CCD spectrometer.

Significance of the results

The ability to concentrate, separate, and detect underivatized amino acids is critical for in situ sample analysis for spaceflight. As a single-step analysis, its benefits include simplicity, efficiency, and avoidance of potential sample contamination. To demonstrate the feasibility of analyzing amino acid samples in a single step, the research that investigates miniaturization instrumentation in a chip format for the present work is well justified. This work has preliminarily demonstrated that polymers with strong affinity to amino acids could be prepared, and there is more room for improvement of preparing better quality of molecularly imprinted polymers. This type of polymer has also been anchored in the inner surface of capillary columns. Via a procedure of in situ photo-activated polymerization, creating micro-channels in a chip that contains amino acid-specific molecularly imprinted polymers is quite feasible. Further investigation is needed to firmly establish a procedure for preparing micro-channels in the chip using in situ polymerization, based on the concept of molecular imprinting.

Keywords

Amino acids, Template, Molecularly imprinted polymers, Sol gel process, Mini-columns, Micro-channels

Exploring Carbon Nanotubes for Nanolithography

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Objectives of the study
Exploit properties of carbon nanotubes for use in tools for nanolithography, semiconductor, and micromechanical electronic system (MEMS) device fabrication and metrology.

Progress and results
Properties of carbon nanotubes for nanolithography are exploited. Multiwall carbon nanotubes of 10- to 20-nanometer (nm) diameter and single-wall carbon nanotubes of 1- to 2-nm diameter were prepared and made into scanning probe microscopy tips and tip arrays by an in situ growth chemical vapor deposition process. The nanotube tips were used to fabricate and image silicon oxide nanostructures on a hydrogenated silicon surface. Experiment and simulation found that nanotube tips are impervious both to high compressive and lateral forces and to breakdown in high electric fields for reliable nanolithography.

Significance of the results
Conventional tips based on scanning probe microscopy technologies have been used for nanoscale lithography and data storage. However, they break or wear down in minutes. In addition, the tip array is required for large-scale applications. Our work, for the first time, shows that nanotubes can be made into a tip array by simple chemical vapor deposition, and used for reliable nanolithography. The nanotube tips never wear out during nanolithography as other conventional tips often do. This work "will help the development of nanofabrication, since tip wear problems have been an obstacle to the use of probe microscopes in lithography and data storage at the nm size scale." (From Physics News Update, No. 390, Sept. 10, 1998)

Publications resulting from the study

Dai, Hongjie; Franklin, N.; and Han, Jie: Exploiting the Properties of Carbon Nanotubes for Nanolithography. Applied Physical Letters, vol. 73, no. 11, 1998, pp. 1508–1510.

Garg, A.; Han, J.; and Sinnott, S.B.: Interactions of Carbon-Nanotubule Proximal Probe Tips with Diamond and Graphene. Physical Review Letters, vol. 8., no. 11, 1998, pp. 2260–2263.

Han, J.; and Jaffe, R.: Energetics and Geometries of Carbon Nanoconic Tips. J. Chem. Phys., vol. 108, 1998, p. 2817.

Dai, H.; et al.: Self-Oriented Regular Arrays of Carbon Nanotubes and Their Functional Devices. Science, vol. 283, no. 5401, 1999, p. 512.

Keywords
Molecular electronics, Nanoelectronics, Nanotechnology, Carbon nanotubes

Novel Biosensors for Astrobiology Missions

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Objectives of the study
To develop infrastructure needed for the fabrication of biosensors.

Biosensor development is an area of active research and much venture capital investment in the last couple of years. Several well-funded companies are engaged in biosensor development, and some early versions are even available in the market. The market forces for the activity arise from biomedical applications and genome sequencing. Of course, such instruments, in principle, can find applications in astrobiology and planetary missions and battlefield operations envisioned by the Department of Defense (DoD). A typical state-of-the-art instrument performs optical detection and identification of biomolecules (e.g., DNA) by detecting the fluorescence from dye molecules attached to the subject biomolecules. The system consists of a light source to excite the dye molecule and a photodetector to detect the fluoresecent light. The sample itself (as small as even picoliters) is handled in microchannel arrays, which are tiny channels etched on a substrate using techniques developed by the microelectronics industry. For NASA needs, the state-of-the-art system is slow, bulky, and not well integrated. For example, Affymatrix, a Bay Area company, uses an argon ion laser (which is about the size of a desktop printer) to generate light at 438 nanometers (nm) and a confocal microscope for detection, making the detection optics also complex and bulky. The entire system is simply too big for any NASA mission.

We are pursuing two innovative approaches. The first involves seeking alternatives for the light source and the detection component that would make the system small enough to meet mass/volume requirements of NASA missions. The second, longer-term goal, is revolutionary in that we can rely on electrochemical or electrical signals (instead of fluorescence signal) by using a carbon nanotube-based sensor.

Progress and results
Semiconductor lasers, which are substantially smaller than gas lasers, have been developed and employed in a wide variety of applications. Vertical cavity surface emitting lasers (VCSEL) are fabricated using a GaAs/AlGaAs material system and are being developed for a variety of applications at Hewlett-Packard (color printer), Sandia, Lucent (communication), and the Jet Propulsion Laboratory (JPL) (deep-space missions). A VCSEL in a tiny chip would be a good replacement to the system described previously, and we have considered this concept during this fiscal year. We have also realized some shortcomings: no VCSEL is available in the blue spectrum; fabrication is still complex (involves quantum structures) and can be expensive; and others are thinking in the same line, leaving us with no proprietary advantage. More recently, we have developed an alternative design and have prepared an invention disclosure. The innovation involves the use of integrated light-emitting diodes (LEDs) and photodetector arrays. Commercially available, the LEDs cover the whole visible spectrum from blue to red, thus mitigating the problems associated with the unavailable VCSELs in the blue region. LEDs are also much cheaper and, in addition, allow us to use more efficient dye molecules in the entire visible spectrum. For detection, our innovation involves a resonant vertical cavity photodetector array (RVCDA). The combination will provide high spatial resolution because RVCDA can be made highly directional and sensitive, enabling a high-density probe array with minimum sample needs.

The direction involves purchase of components and assembling microarray, design of the source/detector system, fabrication of this system, and finally, integration of the components. Of these four tasks, microarrayer assembly was accomplished prior to the DDF funding; the second two tasks will be done using the DDF funding. A joint research interchange (JRI) has been initiated with Arizona State University (Y.H. Zhang) to fabricate the source (LED) and the detector (RVCDA).

In the second approach, the hybridization of DNA molecules actually can be detected by changes in an electrochemical signal (voltage or current). For example, a redox-active or conducting molecule would behave differently in the presence of a DNA hybrid compared to that in the presence of single strand. One then needs electrodes connecting DNA complex or other molecules. Potentially, the approach offers high sensitivity, high speed, and high selectivity. This approach needs conducting molecular wire, one end of which will be bonded to a gold electrode and the other end to target molecules such as DNA. We envision using carbon nanotube as this molecular wire. The implementation involves controlled, patterned growth of nanotubes in two-dimensional arrays, functionalization of the tube

ends, and integration with electronics, all on a chip. This goal is a long-term one, completion of which is beyond the scope of the current DDF request. An atomic force microscope (AFM), which is a key instrument needed for the proposed work, has been purchased.

Significance of the results

We have built the infrastructure needed for sensor fabrication, and as a result, a peer-reviewed contract has been awarded by the National Cancer Institute to develop the current concept for cancer diagnostics.

Publications resulting from the study

One invention disclosure has been prepared.

Keywords

Biosensor, Astrobiology, DNA sequencing

Large Eddy Simulation of Premixed Turbulent Combustion

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Objectives of the study

To develop a parallel large eddy simulation code in cylindrical geometry solving a modeled set of zero-Mach-number large eddy simulation combustion equations with simple chemistry, and subsequently investigate the large eddy simulation of an experimental premixed turbulent flame brush in stagnating turbulence.

Progress and results

The development of a parallel large eddy simulation code in cylindrical geometry solving a modeled set of zero-Mach-number large eddy simulation combustion equations with simple chemistry has been completed. Both the Smagorinski and the Dynamic Model for the hydrodynamics have been incorporated. Preliminary tests show almost linear speedup up to 32 nodes on a Cray T3E.

Figure 1 shows a schematic diagram of a premixed turbulent flame brush in stagnating turbulence and the computational domain used in simulating this experimental configuration. In the experiments of a premixed turbulent flame brush in stagnating turbulence, grid-generated isotropic turbulence is created at the jet nozzle exit, which is located approximately one diameter from a plate onto which the isotropic turbulence exiting the jet nozzle impinges. To accurately capture the injection of isotropic turbulence into the computational domain, an isotropic incompressible decaying "turbulence-in-a-box" code was written, and the decaying isotropic turbulence was then frozen and interpolated onto a cylindrical three-dimensional mesh. The velocity field of this frozen turbulence on the cylindrical mesh is interpolated onto a plane, physically representing the jet nozzle exit, passing through the cylindrical mesh. The velocity field on this plane is then used as the jet nozzle inlet velocity field in the computational domain. Preliminary cold flow simulations using this technique to inject isotropic turbulence into the computational domain indicate acceptable correspondence with available experimental data.

Instantaneous experimental images of a premixed turbulent flame brush in stagnating turbulence reveals a thin premixed wrinkled flame front separating burnt and unburnt gas. A novel local flame-thickening approach has been developed to "thicken" the flame sufficiently to be resolved on the computational mesh. This approach is based on adding to the thermal diffusivity a "flame-thickening" diffusivity proportional to the magnitude of the temperature gradient, the square of the grid spacing, and the magnitude of the pre-exponential factor in the Arrhenius reaction rate expression. Preliminary tests show that the number of mesh points in the thickened flame is independent of the grid spacing—a desirable property of a thickened-flame model. A one-dimensional theoretical analysis of the thickened-flame model proposed here supports the numerical results.

Significance of the results

These results show progress on the development of a large eddy simulation of premixed turbulent combustion in stagnating turbulence. Essential computational aspects and tools have been developed and a necessary and novel flame-thickening model has been proposed. Future work will include detailed comparisons with available experimental data under cold and hot flow conditions. From this comparison, assessment of the current large eddy simulation models for both the hydrodynamics and transport of scalars will be considered and, where necessary, modifications to these models will be proposed.

Publications resulting from the study

Louch, D.S.; and Umurhan, M.: A Flame-Thickening Approach for the Large Eddy Simulation of Premixed Turbulent Combustion (in preparation).

Louch, D.S.: Large Eddy Simulation of Premixed Turbulent Combustion in Stagnating Turbulence (in preparation).

Keywords

Premixed turbulent combustion, Large eddy simulation, Stagnating turbulence

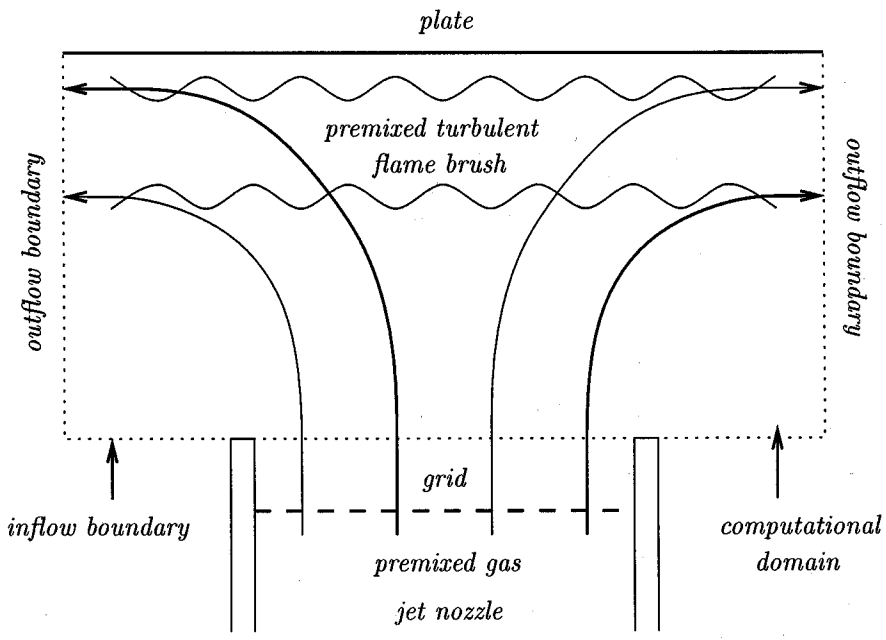

Figure 1. Schematic representation of a premixed turbulent flame brush propagating in stagnating turbulence and the computational domain.

Modeling and Optimization of Ultrafast Semiconductor Quantum Well Devices

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Objectives of the study
To demonstrate through numerical simulation the possibility of up to terahertz switching and modulation of semiconductor quantum well lasers for ultrafast information processing and to study the ultimate speed limit for such switching and modulation based on fundamental processes of carrier-carrier and carrier-phonon scatterings in semiconductor quantum wells.

Progress and results
This project has been completed satisfactorily after two years of theoretical investigation and numerical modeling and simulation. The original goals have been accomplished. We have discovered a new method of switching and modulating semiconductor quantum well lasers by using a terahertz field. The model study and numerical simulation suggest that this method is potentially an alternative one to get around the speed bottleneck due to slow carrier relaxation time in semiconductor lasers. One journal paper and two conference talks have been presented on the results.

Our original goals were to study the fundamental limit of modulation and switching speed of semiconductor lasers and to improve the speed for the future information technology. In a semiconductor optical device, the fundamental process is the interband recombination, a slow process that typically occurs on nanosecond time scale. In a typical laser modulation used for optical interconnect, the inject current to the semiconductor laser is periodically modulated, resulting in a change in density of charged carriers. This scenario will lead to a change of optical gain, the fundamental reason that semiconductors are typically limited to tens of gigahertz in modulation speed. During the investigation, we realized that, although it is fundamentally difficult to improve the switching speed through manipulation of interband processes, certain intraband processes could lead to a change in optical gain and are much faster than the interband processes. One such process is carrier heating, or change of electron temperature. When a DC electrical field is applied to the semiconductor laser, the charged carriers are heated up, leading to a decrease in optical gain. When this DC field is replaced by an alternating (AC) field, the optical gain will oscillate with a certain frequency. When this AC field is in the terahertz regime, we would expect much higher speed modulation. But in a semiconductor laser, more physical processes are involved. Thus it is evident why modeling and simulation involving all the major physical processes are necessary.

We first solved the Boltzmann equation with the carrier-carrier and carrier-phonon scattering to study the heating process with a AC electrical field (terahertz field) under the relaxation rate approximations, allowing us to determine the carrier heating as a function of AC field amplitude and frequency. We then used this information in the standard rate equation formalism to study the effect of carrier heating on laser operation. The results show an almost sinusoidal modulation of the laser intensity at twice the frequency of the AC field. Such modulation can in principle go up to terahertz frequency, without signal distortion. We also tried lower-frequency modulation and observed some distortion due to the interplay of the relaxation oscillation with the AC field modulation.

We have also conducted a more self-consistent approach by starting from the coupled Boltzmann equation with laser equations. A set of moment equations were derived that include carrier temperature, carrier density, and laser field amplitude equations. The many-body Coulomb interaction are also included. This is the first time this full set of equations was derived with an AC field and many-body effects included. We then solved this set of equations numerically to study the modulation and switching of the semiconductor quantum well lasers. The results to a large degree agree with those obtained by the simplified model. This more detailed model also allows us to study other aspects that are not possible with the simplified model. Figure 1 shows some typical results obtained by using the full model.

We have also studied the possibility to implement this modulation scheme in a realistic device through a lateral AC field applied to a diode laser. This research, however, goes beyond the original goals, and we plan to apply for other funding to implement this scheme.

In conclusion, we have demonstrated a novel mechanism, by which a semiconductor laser can be

modulated and switched at a much faster speed than possible with the more traditional scheme. At the same time, the model and numerical simulation tools developed during this investigation will also allow us to study other aspects of the physics of the device.

Significance of the results

We believe that the novel mechanism that we suggested and demonstrated numerically will help to increase the device speed for information processing by at least an order of magnitude. This will have significant consequences for certain special systems of information processing. At the same time, the theoretical model and numerical tools we developed will also allow us to study other issues related to high-speed devices and help to further improve the devices for modulation and switching.

Publications resulting from the study

Ning, C.Z.; Hughes, S.; and Citrin, D.S : Ultrafast Modulation and Switching of Quantum Well Lasers. Photonics West, San Jose, Calif., Jan. 1999.

Li, J.; and Ning, C.Z.: Quantum Well Lasers under THz Modulation. Paper presented at the annual meeting of the Optical Society, Santa Clara, Calif., Sept. 27, 1999.

Ning, C.Z.; Hughes, S.; and Citrin, D.S.: Ultrafast Modulation of Semiconductor Lasers through a Terahertz Field. Appl. Phys. Letts., vol. 75, no. 442, 1999.

Keywords

Terahertz modulation, Plasma heating, Ultrafast optoelectronics, Quantum well lasers

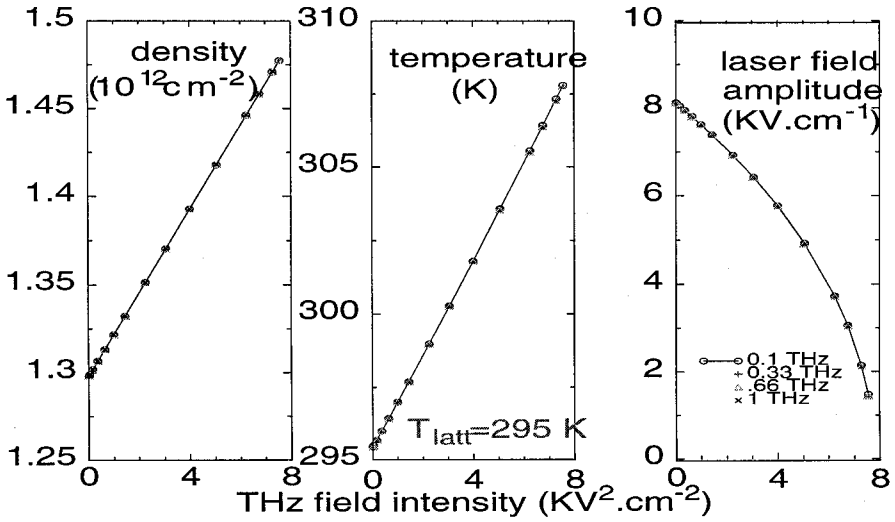

Figure 1. DC components of the physical quantities under Terahertz modulation.

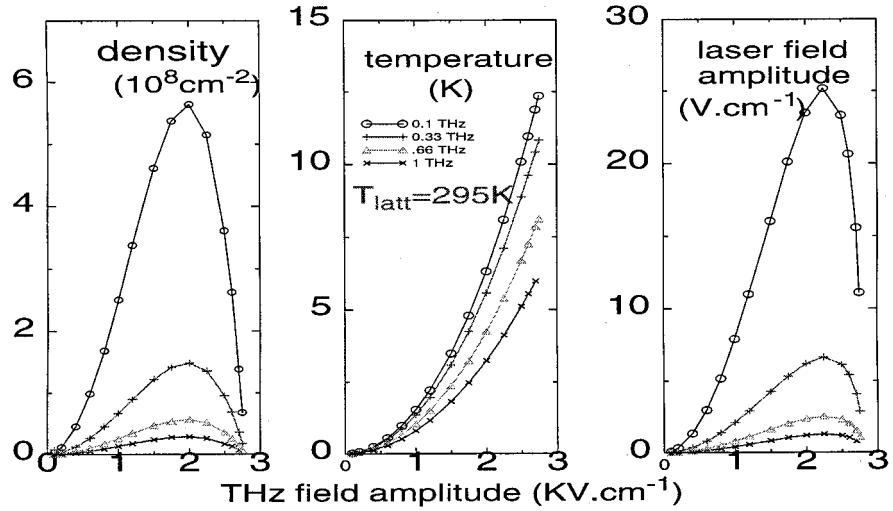

Figure 2. AC components of the physical quantities under Terahertz modulation.

Toward a Phylogeny of Biological Functions

Investigators

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Objectives of the study

One essential issue in studies of the origin and evolution of life is to determine how essential cellular functions developed and were integrated into simple cells. One approach to this problem is to exploit the vast amount of genomic data currently being compiled for many different organisms. The field of bioinformatics was created in order to analyze these data, but has largely focused on the identification of protein targets for drug discovery. Yet, the same tools that have been used to gain insight into disease pathways can also be used to study the evolution of these pathways, using the commonalities among organisms of varying degrees of antiquity. The purpose of this research is to further develop and utilize methodology for comparing similar classes of proteins across multiple genomes in order to gain understanding into the mechanisms of how essential cellular functions arise and are preserved.

Progress and results

As an example, we have chosen for our studies a family of membrane proteins known as ligand gated ion channels (LGICs). They transmit neural signals by opening or closing channel in response to the presence of small signaling molecules. We have identified putative members of this family in the genomes of several organisms. In particular, we have focused on the genome of the nematode *C. elegans* since the complete DNA of this organism has been recently sequenced, and *C. elegans* represents a likely intermediate between ancient and contemporary organisms. This last point is important, because very primitive LGICs may not be recognizable by comparison to only contemporary proteins. Because of the large degree of variability, both in sequence and structure, among subgroups of LGICs, we have narrowed our focus to the gamma amino butyric acid (GABA) and glycine receptors. Even within this restricted class of receptors, a wide range of variation has been observed. The domain structure of these proteins, however, is highly conserved: all of them have four transmembrane regions, called TM1, TM2, TM3, and TM4, separated by loop regions of varying length and an extracellular domain that is involved in binding small signaling molecules. To date, we have identified 43 proteins in *C. elegans* that have high similarity to known GABA or glycine receptors. Using the TM regions, and the small loops between TM1 and 2, and TM2 and 3, we trained a hidden Markov model (HMM) from an initial set of 58 known GABA/glycine sequences from higher organisms. Using this model, we identified 36 homologous proteins in *C. elegans.* A multiple alignment of these sequences showed very high conservation in the TM domains, and in a loop spanning TM2 and TM3. Mutations in this latter region alter the response of the protein to signaling molecules and cause other highly anomalous behavior, indicating that there is a large degree of evolutionary pressure to maintain this region.

In addition to the HMM built on the TM regions, we also targeted the amino-terminal signal region of the protein. Using this region, we built an HMM, which was used to find seven more GABA/glycine-like sequences in the *C. elegans* genome. At least one of these sequences shows a dual similarity to another class of proteins—the G-coupled receptors—which have an entirely different domain structure and cellular function. We think that this might be an artifact of the gene prediction software used at the genome center to translate the DNA sequence into protein. At this time, this is still under investigation.

In addition to being able to identify reliably, and accurately target sequences (in this case GABA/glycine members of the LGIC family), we have discovered that this methodology is a good way of resolving inconsistencies in the genomic data itself. In addition, our discovery of several partial GABA/glycine homologs and one putative fusion protein (combining LGIC and G-coupled receptor domains) may represent an evolving population of nonexpressed genes, providing a reservoir from which new functions can arise.

We plan to investigate further several of the partial GABA/glycine homologs to determine whether the entire coding region is on a single exon, or contiguous exons, in the DNA sequence. If this is the case, then it is possible that these sequences have resulted from an evolutionary important process of exon shuffling rather than an anomaly in the gene prediction software. In addition,

we also are investigating the putative fusion protein and, in particular, the intron/exon boundaries of this segment of the genome to assess the possibility of an error in the original genomic data.

Keywords
Information theory, Homology modeling, Monte Carlo, Evolution channels

DNA Damage Repair in Nature?

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Objectives of the study

To determine if enhanced rates of deoxyribonucleic acid (DNA) synthesis in the presence vs. absence of solar ultraviolet (UV) radiation that Rothschild had previously measured in microbial communities was the result of excision repair. If this were true, these would be the first measurements of excision repair in nature.

Progress and results

DNA is subject to damage, with consequences ranging from small changes in base sequence, to cancer and death. Alternatively, such damage may be repaired by the cell. Several mechanisms of DNA damage repair are known from lab studies, but little is known about DNA damage repair in nature. While studying microbial ecosystems in the field, we found that DNA synthesis rates were higher in the presence of solar UVR than in its absence. These may be the first measurements in nature of the DNA damage repair called excision repair.

Ordinary laboratory methods for detecting excision repair are inappropriate for use in the field because they require use of mutant cells, extreme levels of radiation exposure, labeling with toxic compounds, etc. Thus, the approach used here was indirect, and consisted of a series of tests. Experiments were conducted in Yellowstone National Park either on a mat composed primarily of the unicellular red alga Cyanidium, located in Nymph Creek, or on a mat composed primarily of the filamentous green alga Zygogonium, located in Norris Annex. Alternatively, some experiments were conducted at NASA Ames Research Center on excision repair mutants of the yeast Saccharomyces cerevisiae. To block exposure to UV radiation, UV opaque Plexiglas was used to construct boxes. As a control, boxes were constructed out of UV transparent Plexiglas. To block UVB radiation, boxes were made out of UV transparent Plexiglas and covered with Mylar. In all cases, the Plexiglas was over 90 percent transparent in the photosynthetically active portion of the solar spectrum [400–700 nanometers (nm)].

First, because levels of DNA synthesis had been measured in our lab by labeling newly synthesized DNA with radioactive phosphate, we checked to see if uptake of phosphate during the day and under different UV regimes could account for apparent differences in DNA synthesis. Tests in 1998 and 1999 on field samples in Yellowstone National Park showed that differences in phosphate uptake could not explain apparent differences in DNA synthesis rates, thus suggesting that these differences were real rather than experimental artifact.

Second, we eliminated the possibility that the cells simply produce more DNA at some times of day under higher levels of UV radiation that accumulates in the cell. UV boxes were placed over portions of Nymph Creek, Yellowstone National Park. Samples from the Cyanidium mat from under the different screens were removed every 1.5 hours, placed in 0.25-percent final concentration formalin, and stored at room temperature. In collaboration with Marcel Veldhuis (NIOZ, the Netherlands), samples were stained with pico green for 45 minutes, and then assayed using flow cytometry. Flow cytometry revealed two distinct populations of cells based on DNA content. These were identified as an acidophilic Chlorella and as Cyanidium. The results showed that within populations there was no significant difference in total DNA per cell under different UV treatments. Thus, this finding suggests that differences in total DNA cannot explain apparent differences in DNA synthesis rate.

Third, we determined the type of damage to the DNA in Nymph Creek during September 1998. Samples were taken from under UV transparent and UV opaque screens from different times of day, and the DNA purified. Purified DNA was tested for the presence of thymine dimers, a common form of UV-induced DNA damage that occurs primarily as the result of UVB radiation damage. Under the guidance of Anita Buma, we used immunoblotting to show that there were no detectable thymine dimers from that sample. This finding suggested that either 1) damage didn't occur, 2) the damage was in a different form, or 3) the dimers were repaired so quickly that they weren't detected.

Fourth, we examined the possibility that what we were observing could be due to indirect effects of UV radiation (e.g., oxidative damage by the photochemical production of reactive oxygen species) rather than direct effects (e.g., thymine dimers). In 1999, in collaboration

with the University of Montana, we added varying amounts of hydrogen peroxide to mat samples in Yellowstone, incubated the samples for varying amounts of time, added radioactive phosphate, and determined DNA synthesis rate as had been done previously. These results showed in Zygogonium an increase in DNA synthesis rates with the addition of up to 10 µM H_2O_2, with decreases down to 0 with increasing concentrations, presumably due to cell death. This finding demonstrates that, in a field setting, increased levels of reactive oxygen species increase DNA synthesis. Unlike DNA damage that results in thymine dimers and can be directly photolysed by the enzyme photolyase, oxidative damage is likely to be repaired by excision repair.

Finally, a series of experiments were conducted with yeast mutants because yeasts are nonphotosynthetic, so diurnal rhythms of metabolism are not tied in with solar radiation in other ways, and because excision repair mutants are available. First, we were able to show that yeast growth is inhibited by natural solar levels of UV radiation (21 May 1998). Second, growth of wild type and excision repair minus strains were grown on the roof of building 239, NASA Ames Research Center, under natural solar radiation to determine relative growth rate. At all time points from 1000 to 2400 hours there were relatively more wild type than mutant cells, suggesting that excision repair was important for cell survival under natural solar regimes. Third, yeast mutants and wild type cells were exposed to different concentrations of H_2O_2 and tested for DNA synthesis. While both strains showed an increase in DNA synthesis rates with the addition of small amounts of the oxidizing agent, a currently puzzling result, at concentrations >10 µM, the wild type synthesized more DNA per unit time than the mutant. At concentrations of H_2O_2 >25 µM, DNA synthesis was undetectable in the mutant, but continued in the wild type at concentrations >2500 µM.

Significance of the results

The results, while not definite, strongly suggest the following. First, diel differences in DNA synthesis under different UV regimes are real and not an artifact. Second, there are several lines of evidence supporting the view that we are measuring excision repair. Further, we suggest that the reason that apparently high levels of UV-induced excision repair are occurring is because the UV damage is indirect, that is, oxidative damage.

Conclusions

It is increasingly likely that at least some of what we are measuring is excision repair, although this is not confirmed. UVA radiation produces reactive oxygen species, both inside the cell and in the stream water. This finding also has important implications for astrobiology, but these may differ from implications of UVB. Some progress was made on developing assays to measure DNA damage in the lab.

Publications resulting from the study

Rothschild, L.J.: The Influence of UV Radiation on Protistan Evolution. J. Euk. Microbiol, vol. 46, 1999, pp. 548–555.

Rothschild, L.J., and Cockell, C.S.: Radiation, Microbial Evolution and Ecology, and Its Relevance to Mars Missions. Mutation Research, 1999, in press.

Cockell, C.S.; Kepner, R.; Rothschild, L.J.; Catling, D.; Lee, P.; Davis, W.; and McKay, C.P.: The Ultraviolet Photobiology of Mars: Past, Present and Future. Icarus, in press.

Cockell, C.S.; and Rothschild, L.J.: The Effects of Ultraviolet Radiation A and B on Diurnal Variation in Photosynthesis in Three Taxonomically and Ecologically Diverse Microbial Mats. Photochem. Photobiol, vol. 69, 1999, pp. 203–210.

Rothschild, L.J.: Microbes and Radiation. In Origin, Evolution and Versatility of Microorganisms, J. Seckbach, ed. Kluwer, Dordrecht, The Netherlands, 1999, pp. 551–562.

Keywords

DNA damage, Excision repair, UV radiation, Algae, Yellowstone

A Cryogenic Chamber for Investigating the Reflectance Properties of Materials as a Function of Temperature

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Objectives of the study
Develop an environmental chamber at Ames that can be interfaced with existing spectrometers in order to characterize the visual and near-infrared spectral reflectance of meteoritic and organic materials over a temperature range appropriate for the outer solar system.

Progress and results
Most of the components of the environmental chamber and cryo-tip refrigerator have been purchased. When all components are available, the chamber will be assembled, tested, and commissioned for scientific research.

Keywords
Cryogenic chamber, Temperature effects, Reflectance spectra

Stability Properties of an Initially Stationary Two-Dimensional Separation Bubble

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Objectives of the study

Wind tunnel experiments and numerical computations have the potential to enhance each other's capacity to achieve reliable and accurate simulations of the flows over bodies in flight. The obstacles standing in the way of success in wind tunnel simulations are largely factors that affect the quality of flows. The obstacles standing in the way of success in numerical simulations are largely factors that affect the predictability, verifiability, and reliability of results based on codes featuring discretized representations of systems of nonlinear governing equations. Combined studies that bring into play the interactions between theory, experiment, and computations may help remove the obstacles in both efforts. The stability characteristics of an initially stationary two-dimensional (2-D) separation bubble comprise a suitable subject for such a combined study.

Ames provided the experimental component of the combined study in the form of two wind tunnels of proven high flow quality. One tunnel has the capability of generating a sufficiently extensive zone of 2-D separated flow over a plane wall. The other tunnel has the capability of generating an axisymmetric separation bubble on a body of revolution. Henderson made available a highly accurate numerical code of proven capability for the task envisioned. The experimental protocol consisted of incremental increases in flow Reynolds number and the testing of flow stability by impulsive disturbances. Theoretical considerations led this study to anticipate observing first, the onset of flow unsteadiness, governed by a convective instability mechanism, followed by 2-D vortex shedding, governed by an absolute instability mechanism. Additionally, at some stage, self-sustained 3-D flow perturbations should have become observable. The objective was to achieve a one-to-one correspondence between the experimental observations of these instability mechanisms and their computational prediction, made possible by the capabilities of Henderson's code.

Progress and results

All attempts to produce a 2-D steady separation bubble in the wind tunnel with a plane wall resulted in unsteady behavior, even at very low flow speeds. Hot-wire signals showed that instabilities formed after separation, and they grew rapidly, leading to a turbulent reattachment. The inability to establish a steady bubble precluded the ability to distinguish between absolute and convective instabilities, a situation that would prevent the intention of carrying out a one-to-one correspondence with computational predictions. Therefore, study of the separation bubble on a plane wall was abandoned in favor of a study of the axisymmetric separation bubble on a hemisphere/cylinder body in the other wind tunnel.

The flow over a hemisphere/cylinder at zero angle of attack experiences an adverse pressure gradient in the vicinity of the junction of the hemisphere and the cylinder. Surface oil-flow visualization showed the formation of a 2-D azimuthal separation bubble. However, the scouring of oil from the surface downstream of reattachment suggested that the flow was turbulent, an observation that was confirmed by hot-wire measurements. Unfortunately, considerable unsteadiness was also observed in the reattachment region, even at very low Reynolds numbers, despite the 2-D mean flow. Therefore, this configuration also forestalled the objective to establish a one-to-one correspondence between experiment and computation for the separation bubble.

Henderson's computations indicated that for the case of a semicircular leading edge, the onset of separation occurs at a Reynolds number that would require too small a model for the experimental flow-speed range. Previous observations using a high-aspect-ratio elliptic leading edge demonstrated an attached flow, suggesting that an intermediate-aspect-ratio elliptic leading edge could be designed by computation that would generate an initially steady separation bubble and the onset of instabilities, compatible with the flow-speed range of the experiment. Researchers of this study consider this potential use of computation to design the model geometry in order to realize specific flow phenomena both a means to surmount the experimental difficulties that were encountered and a new direction for the use of Information Technology.

Significance of the results

Realization of the objectives of this study cannot be achieved unless a model can be designed that will sustain a stationary separation bubble of measurable extent within the Reynolds number ranges of the wind tunnels available. Adaptation of the computational tool to this end is both a feasible means of surmounting the experimental difficulties encountered and an opening toward a new use of Information Technology.

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Keywords

Separation bubbles, Convective and absolute instabilities, Flow quality, Numerical simulations

Section 2
Ongoing Reports

Determining the Atmosphere of Life: An Experimental Approach

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Objectives of the study
An important search strategy for the detection of life on extrasolar planets is the spectroscopic detection of potentially biogenic gases using Earth- and space-based spectrometers and interferometers. It is, therefore, important to be able to evaluate the biogenicity of these gases. We have made measurements of the production and consumption of a variety of reduced gases in microbial mats and stromatolite communities under both modern Earth conditions, and conditions that are not present now but have existed in Earth's past.

Progress and results
Progress to date has included both field and laboratory measurements of trace gas production and consumption by modern-day microbial mat communities. We have acquired and equipped a single gas chromatograph (GC) with three detectors [thermal conductivity (TCD), flame ionization (FID), and flame photometric (FPD)] and a PC-based data acquisition system. We have successfully tested and deployed our GC at our field sites, giving us a high degree of in situ analytical capability. This aspect of the work is important because many of the gases that we measure are not stable enough to store for later analysis. We have made measurements of the following gases: oxygen, nitrogen, carbon dioxide, methane, hydrogen sulfide, dimethyl sulfide, methane thiol, and ethane thiol.

Field measurements have been made in microbial mats located in Baja California and in Yellowstone National Park. To our surprise, we have detected significant production, and release, of methane in microbial mats located in Baja California. Additionally, the highest rates of methane production occur in the aerobic (actually highly oxic) surface layers of the mats (determined using oxygen microsensors). This finding is remarkable in view of the fact that methanogenesis is known to be an anaerobic process. Additionally, significant amounts of dimethyl sulfide are produced by the Baja mats. In contrast, microbial mats located in Yellowstone National Park do not appear to be a significant source of methane production. However, several organosulfur compounds, including dimethyl sulfide, methanethiol, ethane thiol, dimethyldisulfide, and mecaptoacetate are produced by these mats from hydrogen sulfide and biogenic low-molecular weight compounds.

In order to study microbial mat trace gas production and consumption under more carefully controlled conditions, we have constructed acrylic flumes in a greenhouse on the roof of Building N239 at the Ames Research Center. The greenhouse is fitted with ultraviolet-radiation-transmitting acrylic in order to be able to maintain mats under natural fluxes of ultraviolet (UV). We have used these greenhouse flumes both to maintain field-collected mats and to grow "artificial" mats starting with cultures of cyanobacteria. Measurements of trace gas production and consumption have been made in both the field-collected and "artificial" mats. Trace gas production in the field-collected mats continues at in situ rates for weeks to months after collections.

Significance of the results
To our knowledge, ours is the first study to demonstrate high rates of methane production in the highly oxic surface layers of a microbial mat. Our findings are not consistent with our understanding of the microbial process of methanogenesis. We need to consider this finding when trying to interpret the presence of reduced trace gases in the spectra of atmospheres from extrasolar planets that do not (or do not yet) contain oxygen.

Publications resulting from the study
Initial findings from this work will be presented at the American Geophysical Union Annual Meeting in San Francisco. We have submitted the following abstract: "Measurements of the Production and Consumption of Trace Gases by Modern Analogues of Early Earth Microbial Communities: Relevance to the Spectroscopic

Search for Biogenic Gases on Extrasolar Planets." Brad M. Bebout, Tori M. Hoehler, and Pieter T. Visscher. The abstract was submitted to the special session on Astrobiology.

Keywords
Microbial mat, Trace gases, Life detection, Methane, Organosulfur compounds

Modeling Dust Grains in Protoplanetary Disk Atmospheres

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Ames Research Center

Whitney Raas, undergraduate physics student,
University of California, Los Angeles

Objectives of the study

To demonstrate that the silicate feature at 9.7 microns that is commonly observed in young stellar objects is consistent with emission from dust in the optically thin atmospheres of pre-Main Sequence disks (solar nebula analogs). Data from long-term medium-resolution spectroscopic monitoring of this feature (CoI and collaborators) will be used to constrain the numerical disk models under study, resulting in a derivation of dust geometry, dynamics, and dust chemical evolution.

Progress and results

The final reduction of the eight-year High-Efficiency Infrared Faint-Object Grating spectrograph (HIFOGS) infrared (IR) spectrophotometric monitoring data base has been completed, using the latest spectral flux calibrators and atmospheric transmission corrections. More than two dozen objects are now available for theoretical modeling.

Three sources with highly variable silicate and/or polycyclic aromatic hydrocarbon (PAH) features were identified: DG Tau, MWC 1080, and BD +40 4124. Chi-square fitting of the continuum was performed, and the optical extinctions of the dust features of these three objects were derived for all observing epochs. In support of our hypothesis, DG Tau continues to have a silicate absorption feature even though its optical dimming event has ended.

Modeling of the dust-emission feature in DG Tau has also now begun, and progress has been made on the theoretical modeling, which will be used to constrain dust evolution in the observed systems. The goal of this modeling is to show that emission from the surface layers of a dusty disk can produce a spectrum in the 8–13 micron region that matches the CoI data in detail. In particular, we intend to demonstrate that the variability of the spectrum can be reproduced by plausible changes in dust distribution or chemistry in the context of the dusty disk model.

To accomplish our goal, self-consistent accretion disk models (Bell et al. 1997) will be used to produce medium-resolution spectral energy distributions that can be compared with data. These models were originally developed to explore conditions at the planet-forming midplane. To match models to observations, emphasis must now be placed on the thermal profile of the surface layers of the disk. This process was begun in a work (Bell 1999) in which the effect of external heating on the temperature profile of the surface layers of the disk was included.

In the optically thin surface layers where the time between collisions with the gas is long compared to the time scale for the dust to radiate its heat to free space, dust grains will have a temperature very different from the surrounding gas. Using simplified dust emissivities (e.g., Chiang and Goldreich 1997), we have developed a method to derive atmospheric dust temperatures due to the freely streaming external radiation from the distant central star. With this result, we are able to derive conditions in the atmosphere of the disk for the case where the disk is a passive reradiator of energy originally emitted by the central star. Combination of these new results with detailed dust optical constants (Koike et al. 1993, Jaeger et al. 1998) will allow us to simulate emission from this passive disk system following the method developed by Wooden et al. (1999a, Harker 1999, Harker et al. 1999).

Significance of the results

The three objects identified are seen to have dust features that vary on time scales of months to one or two years, a time scale that is too slow to be caused by fluctuations in the light reflected from the source (which is expected to occur from night to night) and too rapid to be caused by movement of material at large distances from the central star (which would occur over many years). Further, the observation that the silicate feature of DG Tau remains in absorption while the optical emission has brightened considerably argues that the feature is generated in a region of the system that is not directly illuminated by the central object. These observations support our hypothesis that the 10-micron feature arises from emission by a

flattened protoplanetary disk at about one astronomical unit (AU) and not from a spherical or toroidal envelope at tens or hundreds of AUs.

Publications resulting from the study

Bell, K. Robbins.: Reprocessing in Luminous Disks. Astrophys. J., vol. 526, Nov. 20, 1999.

Wooden, D.H.; Harker, D.E.; and Woodward, C.E.: Crystalline Silicates, Comets, and Protoplanetary Disk Evolution. Proceedings of Thermal Emission Spectroscopy and Analysis of Dust, Disks, and Regoliths Conference, Houston, Texas, Apr. 28–30, 1999, in press.

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10. Wooden, D H.; Harker, D.E.; and Woodward, C.E.: Crystalline Silicates, Comets, and Protoplanetary Disk Evolution. Proceedings of Thermal Emission Spectroscopy and Analysis of Dust, Disks, and Regoliths Conference, Houston, Texas, Apr. 28–30, 1999b, in press.

Keywords

Solar nebula, Protoplanetary disks, Young stellar objects, Pre-Main Sequence stars, Dust evolution, Silicate mineralogy

SOI Electronics for "Faster, Better, Cheaper" Spacecraft

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Objectives of the study
To show that aluminum-nitride (AlN)-based silicon-on-insulator (SOI) electronics overcomes the self-heating problem of standard SOI.

1. To demonstrate the significantly better operation of AlN-based SOI for advanced, space-based electronics. To accomplish this, we will compare the operation of equivalent conventional metal-oxide-semiconductor field effect transistor (MOSFET), standard SOI, and AlN-based SOI devices under the extremes of small device size, low voltage/power, low and high temperature, and high radiation exposure.
2. To optimize AlN-based SOI technology for space applications.

Progress and results
Six problem sets were created and completed in order to learn the PROPHET electronic device simulation software and the electronic device physics that will be used in the project. PROPHET is also prepared for the electronic device simulations required for this project: the carrier recombination model was improved, transient simulation capabilities were enhanced, the first alpha particle strike simulations were performed, and PROPHET was modified to run successfully in parallel [message passing interface (MPI)] mode for the first time. Finally, PROPHET has been installed at Washington State University, allowing us to continue work on this project both from Ames and WSU.

Significance of the results
The enhancements and simulations accomplished in this short time with PROPHET are the expected incremental steps on the way to meeting all the objectives of this project. Detailed and extensive investigations have begun.

Publications resulting from the study

Osman, Mohamed A.: Low Power Fast SOI Electronics for Space Applications. JRI proposal to Ames Research Center, July 1, 1999.

Awadalla, Salah A.: Low-Power, Fast SOI (Silicon-on-Insulator) Electronics for Space Application. Final Report for the Ames Educational Associates Program, Position #1999115, Aug. 2, 1999.

Keywords
SOI, Silicon-on-insulator, Electronics, Radiation, Self-heating, Space environment

Obtaining Mass and Density of Extrasolar Giant Planets: Measurement of Planetary Transits

Investigators
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Laurance Doyle and Jon Jenkins,
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Objectives of the study
To obtain the mass and density of extrasolar giant planets by high-precision, ground-based photometric monitoring of stars that have known planets during times of predicted transit.

Each short-period planet has about a 10-percent chance of exhibiting a transit. The transit signature of a Jupiter mass planet is a 1-percent dimming of the light received from the star that lasts for about three hours.

Progress and results
Test data were taken of the stars Upsilon Andromedae, 51 Pegasi, HD217107, and HD187123 in 1998 and 1999. Computer hardware and software were acquired to archive and reduce the data on CD-ROM. Procedures were developed in NOAO IRAF to calibrate images and extract stellar magnitudes through aperture photometry. An Interactive Data Language (IDL) program was completed to analyze and plot the extracted light curves for the object and comparison stars.

Two-millimagnitude photometric precision was achieved on the nights of September 4 and 7, 1999, during predicted times of planetary transits of the stars HD187123. No evidence of the predicted 1-percent (10 millimagnitudes) transit signal was seen.

Significance of the results
The technique has been demonstrated. Further instrumental and data-reduction improvements are needed to achieve the precision goal of 1 millimagnitude. Evidence for a transit will allow the first measurement of the mass and radius of an extrasolar planet, thereby determining whether the planet is a gaseous jovian-type planet or a rocky terrestrial-type planet.

Publications resulting from the study
Friday Lunchtime Astronomy Seminar Series (FLASH) talk was presented at the University of California, Santa Cruz, on August 29, 1999.

Keywords
Astronomy, Extrasolar planets, Photometry

Interacting Robotic Elements for Autonomous Space Applications

Investigators
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Objectives of the study
To develop a community of small identical robotic elements that can accomplish tasks collectively that are well beyond the capabilities of its individual members.

Progress and results
We have successfully designed (with Polybot [1] as a template) and built an initial hardware testbed for our research. This testbed consists of one-degree-of-freedom robotic elements attached serially. The robot is very inexpensive, is simple to program, and is controllable using a portable computer and battery. (See fig. 1.)

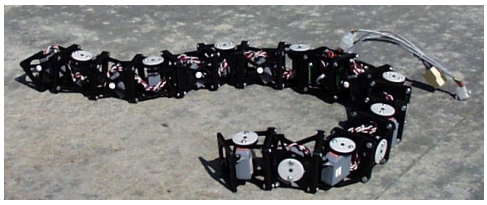

Figure l. Serpentine robot.

This testbed provides an ideal starting point for our explorations because it has many small identical elements that must act in tight coordination in order to achieve global tasks, but it avoids the complexities of completely independent elements. We have programmed the robot to imitate a variety of serpentine gaits, including side-winding, lateral undulatory, sinusoidal, coiling, and rearing as well as some more artificial gaits such as rolling track, lateral rolling, and going up a stair. These gaits are all open-loop and do not require sensing.

We are currently designing a second-generation mechanism that will be stronger, lighter, and more powerful. This mechanism will incorporate a micro-processor chip on each element that will allow us to attach pressure, position, light, and proximity sensors onto the segments. (See fig. 2.)

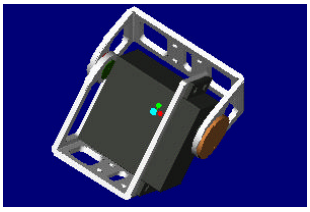

Figure 2. Second-generation module.

With this mechanism we will design closed-loop controllers for adaptive gait modulation and demonstration tasks such as autonomously navigating to a light source, navigating a narrow fissure, and digging to a sensed object. We feel that a collective/localist control architecture is well suited to this kind of highly redundant mechanism.

Significance of the results
We have constructed a robotic mechanism that provides an excellent testbed for explorations into collective control. Our progress in locomotion is on par with the best progress that has been made in serpentine locomotion to date. We have a concrete plan for building a mechanism with the potential for sensor-based autonomous behavior.

Publications resulting from the study

A Serpentine Robot for Planetary and Asteroid Surface Exploration. Abstract submitted to Fourth IAA International Conference on Low-Cost Planetary Missions

Keywords
Collective robotics, Robotic control, Serpentine robot, Robotic locomotion

Evolvable Hardware: Automatic Design of Realizable, Active, Integrated Circuits

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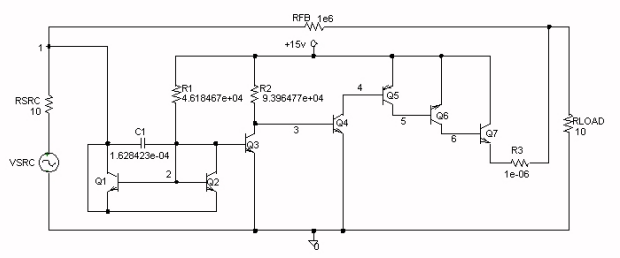
Objectives of the study
To use computer-simulated Darwinian evolution to automatically produce high-level integrated electronic circuit designs whose properties permit physical implementation in silicon. This entails designing an effective evolutionary algorithm and solving difficult multiobjective optimization problems.

Progress and results
We have three main results:

1. Our linear representation of circuits—a circuit-constructing programming language—was shown to be effective when used in a genetic algorithm [1]. Transistor-placing language constructs were added because transistors are ubiquitous in analog integrated circuit design.
2. Our parallel genetic algorithm software was updated to easily allow new fitness function inclusion, and to run faster by calling the simulator directly rather than via the operating system.
3. We devised a technique for using coevolutionary search that was shown to be better than manually encoded fitness schedules and as effective as using a single fitness function [2].

We have successfully produced circuit designs for analog filters and amplifiers. As an example, below we show an evolved 85-decibel (dB) amplifier (a circuit that outputs a voltage that is approximately 18,000 times the input voltage). This design is electrically well behaved, but is not yet implementable because of specifications that were not included in the fitness function. For example, current transients can develop in our evolved circuits that could cause certain components to malfunction intermittently. To remedy this situation, current constraints for each circuit device would be added.



Significance of the results
The results obtained thus far lead us to believe that we are very close to producing implementable circuit designs. We believe that by adding further constraints on the design of these amplifier circuits, we will evolve circuit designs that can be directly (perhaps automatically) translated into physical integrated circuit specifications that are then used in the manufacturing process. As shown in [2], the use of coevolution is effective at setting the appropriate difficulty level of the fitness function.

Publications resulting from the study

Lohn, J.D.; and Colombano, S.P.: A Circuit Representation Technique for Automated Circuit Design. IEEE Trans. on Evolutionary Computation, vol. 3, no. 3, Sept. 1999, pp. 205–219.

Lohn, J.D.; Haith, G.L.; Colombano, S.P.; and Stassinopoulos, D.: A Comparison of Dynamic Fitness Schedules for Evolutionary Design of Amplifiers. Proc. of the First NASA/DoD Workshop on Evolvable Hardware, Pasadena, Calif., IEEE Computer Society Press, 1999, pp. 87–92.

Lohn, J.D.: Experiments on Evolving Software Models of Analog Circuits. Communications of the ACM, Special issue on evolvable hardware, Apr. 1999, pp. 67–69.

Lohn, J.D.: GA Synthesis of Analog Circuits. Accepted for publication in NASA Tech Briefs.

Patent application submitted: “System and Method and Computer Program Product for Automated Circuit Design Using Linear Genetic Algorithms,” J. Lohn and S. Colombano Inventors, March 1999.

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Keywords

Evolvable hardware, Evolutionary computation, Automated circuit design, Genetic algorithms

Effect of Clear Cutting vs. Natural Burn on a Dominant Forest Ecosystem

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Objectives of the study
To determine effect of different types of disturbance on microbial communities.

Progress and results
Year 1 collections have been made, and molecular analysis has begun.

Significance of the results
Disturbance by clear cutting appears, preliminarily, to have a different effect than fire, and this effect can be long-lasting, up to several years. Thus, the redundancy hypothesis, the dominant paradigm, is not supported.

Keywords
Yellowstone, Ectomycorrhizae, Polymerase chain reaction, RFLP, DNA fingerprinting

The Role of H_2 in Microbial Community Evolution and the Search for Life on Extrasolar Planets

Investigators

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Tori M. Hoehler,
National Research Council, ARC

Objectives of the study

To understand how cycling of the central metabolite H_2 affects the overall structure and function of microbial mat ecosystems, with particular emphasis on the regulation of reduced gas production and emission. The primary objectives are twofold:

1. To catalog and quantify the major environmental variables that control hydrogen concentrations in the photic and aphotic zones of microbial mats.
2. To relate the production and emission of "biosignature" gases from microbial mats to the cycling of hydrogen within the microbial community, and thereby to the local environmental conditions.

Progress and results

Much of the initial work has focused on development of the gas chromatograph (GC)-based technology necessary to deal with the extremely small spatial scales that mats present. At present, we have developed a van-portable analytical system that allows for onsite analysis of samples as small as five microliters of gas (on the scale of individual photosynthetically produced gas bubbles). This technique also enables us to resolve H_2 concentrations within mats at the millimeter scale. The system has now been used to study mats from hot springs in Yellowstone National Park and hypersaline ponds in Baja, Mexico.

Initial studies of the hypersaline Baja mats show that H_2 concentrations within the cyanobacteria-dominated photic zone are as much as two orders of magnitude higher than in the permanently anoxic aphotic zone. In turn, the H_2 concentrations within this aphotic zone are still an order of magnitude higher than in underlying (non-mat-associated) sediments. In both layers of the mat, H_2 concentrations appear to be sensitive to variations in temperature and salinity; in the photic zone, a dependence on irradiance and CO_2 availability may also occur.

Work at the Yellowstone field site suggests that hot-spring cyanobacteria give rise to significantly lower H_2 levels than those studied in hypersaline ponds. We believe this may relate to differences in carbon availability within the two systems and will further investigate the phenomenon during future Yellowstone visits.

Lastly, we are beginning to couple our studies of hydrogen with characterizations of "biosignature" gas emissions. Recently, this endeavor led to characterization of a significant flux of carbon monoxide from both hypersaline and hot-spring mats that has not previously been observed.

Significance of the results

The demonstration that H_2 levels within mat ecosystems are dramatically elevated relative to "normal" sediments carries important implications for the evolution of anaerobic bacteria and the development of structural and functional relationships between phototrophic and chemo- or heterotrophic microorganisms. During the extensive period of Earth's history in which cyanobacterial mats were thought to be the dominant biosphere, this realm of elevated H_2 concentrations would have represented the primary environmental setting for most anaerobes, suggesting that a significant portion of the evolution of these bacterial communities could have occurred in conditions that are seldom found in nature today.

The demonstration of H_2 dependence on environmental forcing factors lays the groundwork for a quantitative and predictive approach to microbial mat ecology. Establishment of these relationships will allow the application of simple thermodynamic models to understand the function and emergent behavior of the microbial community as a whole.

The demonstration that hypersaline and hot spring microbial mats both generate significant amounts of carbon monoxide is potentially quite important in the context of NASA's Origins Program, because it helps to constrain the performance parameters for the Terrestrial Planet Finder telescope that will analyze the atmospheres of extrasolar planets. Confirmation of these early results could make an important addition to the list of potential "biosignature compounds" to be used in the search for life on those planets.

Publications resulting from the study

Early results will be presented at the 1999 fall meeting of the American Geophysical Union in a talk entitled, "Hydrogen Concentrations in Microbial Mat Ecosystems."

Keywords

Hydrogen, Microbial mats, Biosignature gases

Darwin's Eye—Light at the Bottom of the Ocean

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Objectives of the study

To determine if chemoautotrophic organisms exist in the vicinity of hydrothermal vents that have the capability to utilize nonsolar electromagnetic radiation. The discriminating criterion used to make this determination will be the existence, or lack, of chlorophyllic compounds in these organisms.

One of the key unanswered questions in the theory of the origin of photosynthesis is often poised as "what use is half an eye?" Photosynthesis is a very complicated process. If any step in the cycle is incomplete, the process will not function. In other words, it either works or it doesn't. Possessing an almost functional process doesn't provide an organism with an evolutionary advantage. So how did photosynthesis evolve on the early Earth? This conundrum is referred to as the problem of Darwin's eye.

One potential explanation is that an intermediate point to photosynthesis may have been the ability to detect light and move toward or away from it. Such phototaxis may exist near deep-sea hydrothermal vents. In this environmental niche, early chemoautotrophic bacteria may have used light emitted from hydrothermal vents to locate themselves near enough to a vent to acquire the chemical nutrients they need, but far enough away to avoid being cooked by the hot vent effluent (Monastersky, 1996; White et al., 1999; Yurkov et al., 1999).

This photosynthesis theory fits with other recent developments in evolutionary biology such as ribonucleic acid (RNA) sequencing. RNA analysis suggests that a common ancestor for all terrestrial life is thermophilic chemoautotrophs (Woese et al., 1990). Consider that current theories place the origin of life on Earth at some time between 3.8 and 4.3 million (Ga). During this period, the Earth was subject to sustained bombardment by asteroidal bodies. Deep benthic and subsea floor habitats were the least impacted environments and possibly the only ones capable of sustaining life (Sleep, 1992).

Although extremely speculative, it is possible that these thermophilic chemoautotrophs may have evolved in the hydrothermal vent environment to at least partially supplement their metabolic requirements through photosynthesis. If some of these bacteria were later dispersed to hot-water vents in shallow water, this earlier adaptation would help them develop full-fledged photosynthesis using the solar energy.

Relevance to NASA Mission:
Life is an intricate balance between reducing and oxidizing species. On Earth, the only known source of O to drive this process is photosynthesis. Demonstrating that photosynthesis can utilize nonsolar sources of electromagnetic energy, such as that present at deep ocean hydrothermal vents, would greatly expand the inventory of potential extraterrestrial environments capable of supporting life.

The most illustrative example is the icy satellites of Jupiter and Saturn. It has been postulated that some of these satellites may contain subsurface oceans isolated from solar radiation by an ice crust tens of kilometers thick. Photosynthesis driven by solar energy is unlikely in these locations. Alternative sources of O_2, such as have been postulated in this proposal, may be the defining criteria for life in these environments. Discovering such processes at work on the Earth would change our perspective on the potential for life in our Solar System.

Progress and results

In order to conduct this research, we first must acquire samples of relevant microbial organisms. These microbes must be collected from specific areas surrounding characterized hydrothermal vent. The organisms will then have to be screened to ensure they did not originate from surface environments and that they are native to the hydrothermal vent environment.

Once collected, we plan to use spectrophotometry to determine the spectral adsorption characteristics of these organisms and identify any pigments. Fluorescent microscopy will be used to validate any samples that appear to have the characteristic chlorophyllic adsorption spectra.

Development of Deep-Sea Sample Acquisition Apparatus
The first task was to develop a system capable of collecting microbial samples of indigenous hydrothermal vent microflora. We focused on filtration-based approaches, allowing us to process large quantities of sea water and use statistical methods to segregate between surface detrus and indigenous organisms.

McLane Research Laboratories fabricated a water-filtration apparatus capable of operating at depths of 5000 meters for periods in excess of one year. The resulting instrument is referred to as the water transfer system (WTS).

The WTS is designed to collect in situ suspended particulate matter in an aquatic environment. A dual multiport valve directs the water through 24 user-replaceable 47-millimeter filters for a time-series operation. A positive displacement pump is placed downstream from the filters to prevent sample contamination. Both the multiport valve and the positive displacement pump are controlled by an internal computer, and can be accessed by an external computer via serial communications (RS-232 port).

Field Deployment
The WTS was deployed to a hydrothermal vent on the Juan de Fuca Ridge at a location referred to as the Clam Bed (47,57.78N 129,05.50W). The unit was deployed via the Woods Hole Oceanographic Institutes (WHOI) Atlantis research vessel using the Alvin submersible. Atlantis departed from Astoria, Oregon, on August 23, 1999. The deployment was conducted in collaboration with Charles Fisher of Pennsylvania State University.

Originally it was intended that a maximum of three dives would be conducted during this deployment (weather and time permitting). Atlantis was scheduled to be on deployment from August 23 through September 7, 1999.

The first deployment of the WTS occurred on August 25. The unit was deployed in 3200 meters of ocean and was retrieved two days latter. The system was designed to sit on the bottom for a predetermined time period and then wake up and collect 24 samples. Upon retrieval, it was apparent that the samples had not been collected.

A series of diagnostics revealed that the position sensor was the source of the problem.

The WTS ultimately collected a full set of 24 samples, and Atlantis returned to port on September 5.

The samples are currently in cold storage at ARC. Analysis will be initiated in coordination with the availability of FY00 funding. The WTS will be deployed again in July 2000 as part of a collaboration with the College of William and Mary.

Publications resulting from the study

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Keywords

Darwin’s eye, Phototroph, Juan de Fuca Ridge, Photosynthesis

Survivability of Microbes in Mars' Wind-Blown Dust Environment

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Objectives of the study

Our hypothesis is that Earth microorganisms can survive under wind-blown Mars dust-storm conditions. To determine the potential of survivability of airborne Earth microbes on the surface of Mars during a dust storm, we have the following objectives: 1) Determine how long microorganisms can survive in a simulated Martian dust environment. 2) Under what conditions Earth microbes in a Mars wind-blown environment survive best, relating to soil type and particle size.

Progress and results

All the materials and equipment necessary for this study have been acquired and some of the initial tests and first experiments have been performed. For example**,** the protocol for sterilizing the chamber between tests has been completed and tested.

The approach is to determine the survival rate of microbes mixed with sterile Mars analog soil in a chamber that can simulate the environment of Mars during a dust storm. To date we have used Bacillus subtilis (ATCC# 6051) as our test organism.

The efficiency of recovery of samples of the airborne portion of the dust-microbe mixtures has been determined to be approximately 90 percent.

Tests were conducted by mixing washed and dried cultures of the organism with the sterile Martian soil analog such that the number of microbes equals approximately 5×10^6 per gram of dry weight soil. The microbe/Mars soil analog sample is placed in the spherical chamber equipped with a variable-speed rotor (to create the simulated dust storm), a light/ultraviolet (UV) illumination port equipped with a deuterium amp as a UV source, and gas ports. Samples were aseptically placed in the chamber, and the chamber was then sealed, flushed with a simulated Martian atmosphere (96.9 percent CO_2, 3 percent O_2, 0.1 percent H_2O), at a pressure of 10 torr. The fist series of experiments exposed the microbe-dust mixture for 100 minutes. At the end of a test the dust was aseptically removed from the chamber by flushing gas through a port into a syringe equipped with a 0.45 micrometer (μm) pore-size filter attached to a syringe**.** The number of surviving microbes per gram of soil was determined by using the most probable number (MPN) method (Koch, 1994).

The data from this first series of experiments indicates that at least 10 percent of the microbes survive the exposure. The results of this first series of initial experiments suggest that microbes are protected from solar UV radiation by dust in a simulated Martian atmosphere.

Significance of the results

The data obtained from this research will lead to a better understanding of the conditions under which life can survive. A primary goal of research in Astrobiology includes identifying the pathways through which life arose, evolved, and may have distributed itself throughout the universe. Interplanetary transfer is one mechanism by which life may distribute itself throughout the universe. One possible mechanism of interplanetary transfer is by spacecraft, either from Earth to Mars, or Mars to Earth (if life exists on Mars). It is known that certain organisms can survive exposure to the space environment (Mancinelli et al., 1998). Planetary protection requires that spacecraft landing on the Martian surface be cleaned and the bioload reduced, but it need not be sterilized (Nealson et al., 1992). This scenario opens the door for Earth organisms to travel to Mars. Mars regularly has huge dust storms that engulf the planet, shading the surface from solar UV radiation. These storms serve as a mechanism for global transfer of dust particles. If live organisms were to be transported to the surface of Mars, they could be picked up with the dust during a dust storm and transported across the planet.

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Keywords
Mars, UV radiation, Microbes, Dust, Wind

Energy Metabolism of Cultured Cells in Continuous Hypergravity

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Objectives of the study

1. Adapt existing sensor technology to continuously measure O_2 in cell cultures exposed to uninterrupted centrifugation in order to assess cellular bioenergetics.
2. Determine if continuous exposure to hypergravity affects the bioenergetics of osteoblasts in culture and identify the stage(s) during differentiation when cells adapt to changes in gravity.
3. Determine if continuous exposure to hypergravity affects the bioenergetics of macrophages at different stages of differentiation and activation.

Progress and results

1. A self-contained, programmable measurement system was designed and built that allows continuous monitoring of dissolved oxygen concentrations in cell cultures exposed to centrifugation. Clark-style amperometric sensors were constructed and modified, and their performance is now being tested in a cell culture medium. See figures for detailed description of the sensor unit.
2. Cell culture conditions were established for growth of osteoblasts and bacterial activation of macrophages in sealed dishes, to be compatible with the O_2 sensor unit.
3. Primary osteoblasts exposed to 20 hours of centrifugation at 10 x gravity units (G) consumed more glucose than cells maintained in stationary control incubators. These cells were viable despite centrifugation, as assessed by nuclear morphology. In contrast, glucose consumption by two different cell lines derived from osteosarcomas was not affected by centrifugation.
4. Several centrifuge experiments conducted at different G levels using macrophages yielded inconsistent results. Cell culture conditions were subsequently optimized; future experiments employing the optimized conditions will include use of the O_2 sensor unit.

Significance of the results

1. Changes in glucose consumption by normal (primary) osteoblasts observed following centrifugation lends preliminary support to the hypothesis that hypergravity stimulates energy metabolism of normal cells. Furthermore, since glucose consumption by osteosarcoma cells was not affected by centrifugation, these preliminary experiments indicate that the metabolic responses of normal cells and cancer cells to hypergravity are markedly different.
2. We now have a novel tool (i.e., the programmable O_2 sensor unit) to conduct the experiments described in Aims 2 and 3. This unit is also potentially of value to the general scientific community for the analysis of cellular metabolism under various other culture conditions.

Keywords

Metabolism, Cell biology, Sensors, Bone, Osteoblasts, Macrophages

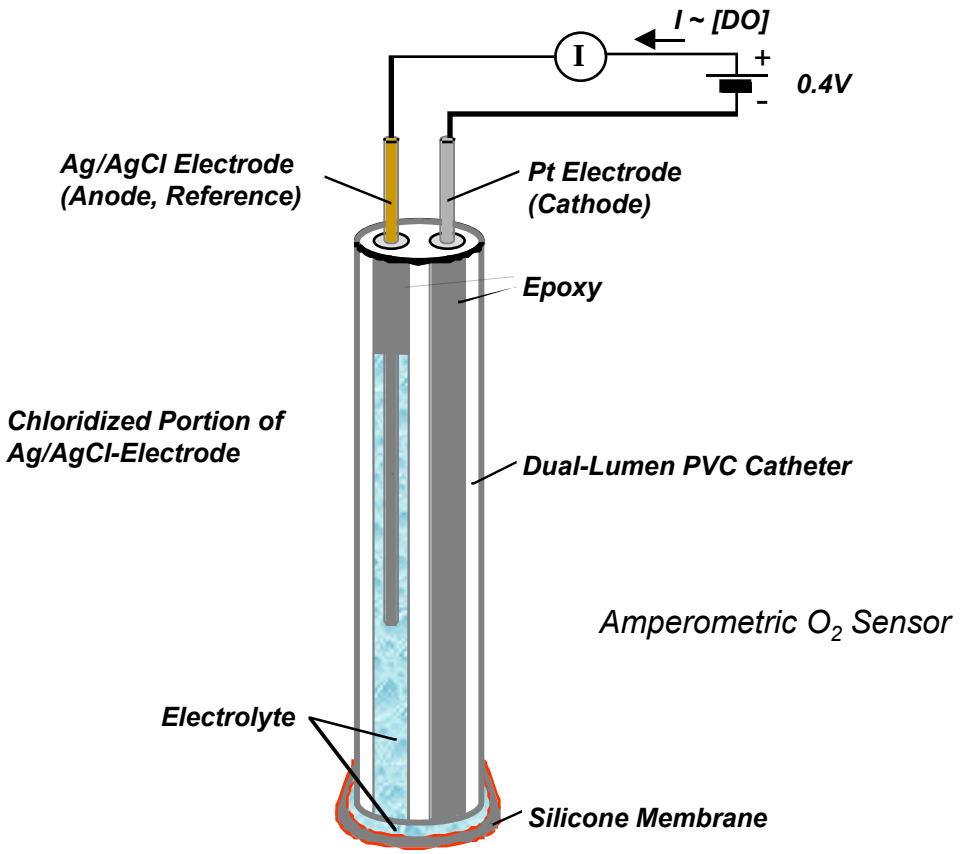

Figure 1. Design of the O_2 Sensor. The oxygen sensors are miniaturized Clark-style amperometric sensors. Their design is based on a dual-lumen polyvinylchloride (PVC) catheter. One lumen contains a 100-micrometer (µm)-diameter platinum wire embedded in epoxy, and the other an AgCl reference electrode. Oxygen is measured by applying a bias voltage of –0.4 volts (V) across the two electrodes (Platinum Wire = Cathode; Reference Electrode = Anode). O_2 is then reduced at the platinum cathode according to:

$$O_2 + 2H_20 + 4e^- => 4OH^-$$

The current that flows through the sensor in response to the applied bias voltage is dependent on how many O_2 molecules are reduced at the cathode. The diffusion of oxygen to the cathode is limited by a silicone membrane, which also protects the cathode from contamination.

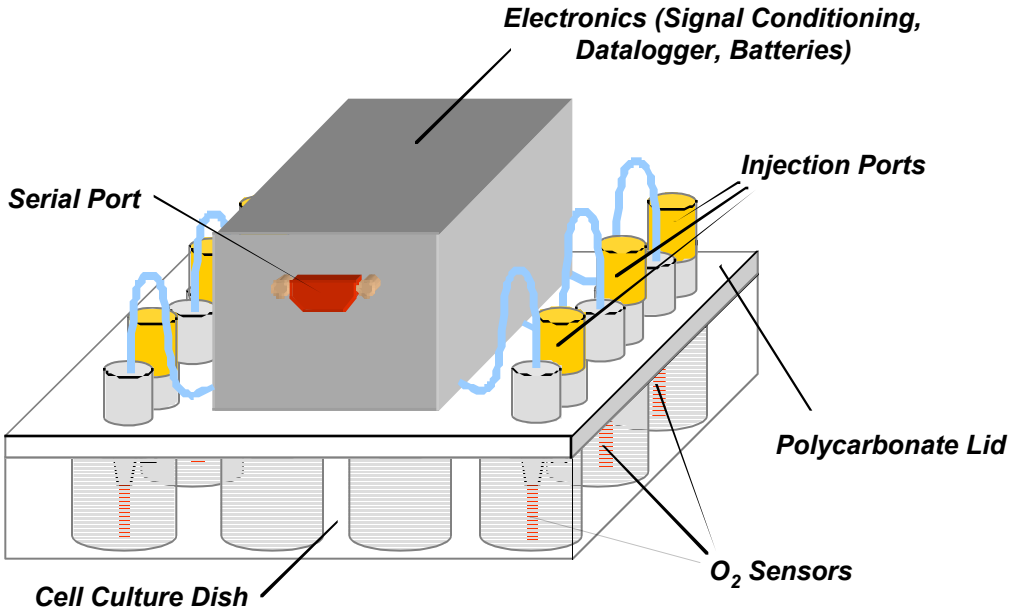

Figure 2. Diagram of sensor unit. The programmable, three-channel system consists of a signal conditioning circuit, a datalogger, and three O_2 sensors (see fig. 1). In addition to O_2 concentrations, it also records the temperature of the environment. The sampling parameters of the datalogger are computer-programmable by the user through a LabVIEW program. The heart of the O_2 system is a peripheral interface controller, which controls the sensor operation, data acquisition, and data storage. The data is stored in EEPROM memory. The LabVIEW program is used to upload the data and save it as an Excel-compatible spreadsheet file. The electronics is mounted on a polycarbonate lid, which also holds the O_2 sensors and seals the chambers of the plastic culture dish.

Figure 3. Photo of the sensor on a tissue culture dish (see description for fig. 2).

Simulation-Based Prototyping of Solid-State Quantum Computers: A Pathway for Revolutionary Computing in the 21st Century

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Objectives of the study
To test the feasibility of encapsulation of atomic and/or ionic dopants in bucky onions for fabricating arrays of encapsulated dopants suitable for quantum computation application in solid-state materials such as silicon.

Progress and results
To test the idea of encapsulating atoms at the center of bucky onions (BOs), we have developed a scheme for the generation of the atomic coordinates of bucky shells of different sizes, successively enclosing smaller bucky shells. The scheme has been implemented in a program to generate coordinates for bucky shells of any radius. A bucky onion is then constructed with bucky shells of different sizes. Two different families of bucky onions, depending on how pentagons are connected in each shell, are discovered, and analytic expressions for the number of atoms in each have been derived. In the next step, these bucky onions will be dynamically tested in atomistic simulations, and will be used for encapsulating atomic or ionic dopants. Encapsulation of a single P atom within C_{36} as the innermost bucky shell, using the first-principles total energy calculations, was tested for stability. The geometry of C_{36} was optimized and a sequence of density-functional theory (DFT) simulations with one P atom encapsulated was performed. The most stable energy configuration was found to be where P sits off-centered toward a hexagon with 1.3 electron volts (eV) binding energy relative to a free P atom outside of C_{36}. Investigations of the effect of electron irradiation induced defect generation, and examination of several possible defects, to vary pressure in the innermost bucky shell, have been started.

Significance of the results
The basic ground work in preparing bucky shells and testing of one shell with an encapsulated P atom has been completed.

Atomistic simulations will be performed for irradiated and defected BOs for inducing pressure effects on the inner core shells, and DFT simulations of P atom encapsulation in thus pressurized innermost bucky shells will be performed.

Keywords
Solid-state quantum computers, Bucky onions, Silicon, Atomic dopants

Investigating the Youngest Stars with High-Resolution Infrared Spectroscopic Observations

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Objectives of the study
To observe high-resolution near-infrared (IR) spectra of the youngest stars possible.

Progress and results
Some new observations were made and some data were reduced. These data show that for the first time we have found that young stars that drive Herbig Haro flows have FU Orionis type spectra.

Significance of the results
This evidence is the most convincing to date that massive circumstellar disks are critical for powering the energetic winds of young stars.

Keywords
Infrared, Star formation, Stars, Spectroscopic

Computer Modeling in Bio-Nanotechnology: Computer-Aided Genetic Engineering of a Protein-Based Holographic Data Storage Material

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Objectives of the study
Bacteriorhodopsin (BR) is a retinal protein molecule found in the photosynthetic system of a salt-marsh bacterium called *Halobacterium salinarium*. In its native form, the BR molecule is located in a cell membrane commonly called the purple membrane, and it functions as a light-driven proton pump that transports protons across the cell membrane. Effectively, BR is used by the bacterium to directly convert sunlight into chemical energy. The absorption of light initiates a photocycle in the BR molecule that accompanies the proton transport. The characteristics of this photocycle make the BR membrane a potentially useful material for development as an optically sensitive film that is self-developing and erasable. In the present study, we have undertaken to use quantum chemistry calculations and molecular dynamics simulations to elucidate the photochemical pathways in bacteriorhodopsin. Our objective is to identify specific genetic variations of the polypeptide chain in BR that should result in modifications to the photocycle leading to improved performance of BR films for optical applications such as high-density holographic data storage.

Progress and results
The photocycle in native or modified BR is initiated by the absorption of an ultraviolet (UV) photon that induces isomerization about one of the C=C double bonds in the retinal chromophore (denoted the C13 cis pathway). This process takes several picoseconds to complete (1 ps = 10^{-12} second), but the initiation takes only about 0.5 ps. Our objective is to study this first step in the photoisomerization, because that preordains the rest of the cycle. Better optical characteristics have been observed with certain genetic variations that result in the isomerization occurring at a different C=C bond (denoted the C9 cis). For this project, we are analyzing one of these genetic variants as well as the native protein in an attempt to understand why the respective photocycles start out on different isomerization pathways.

The plan of this project follows: First map out the potential energy surfaces for different photoisomerization pathways using quantum chemistry calculations. Next, construct a force field that describes the changes in energy for retinal and for the BR membrane as they undergo isomerization. Then, carry out molecular dynamics (MD) simulations using this force field to model the first steps in the photocycle. Genetic variants will be considered by varying the protein structure surrounding the retinal molecule.

During the first year of the project, we worked to elucidate the ground and excited electronic potential energy surfaces for photoisomerization of these two C=C double bonds in the retinal molecule and its Schiff-base derivative. We also started working on constructing the force field needed for the MD simulations and preparing the MD computer code. The actual simulations will be run next.

Significance of the results
The significance of the results will not become apparent until the MD simulations are run.

References

Hermone, A.; and Jaffe, R.: Computer-Aided Genetic Engineering of Bacteriorhodopsin. Paper presented at 1999 Centennial Meeting of American Physical Society, Atlanta, Georgia, Mar. 1999.

Keywords
Holography, Optical data storage, Bacteriorhodopsin, Photoisomerization, Retinal, Molecular dynamics

Development of a Parallel Processing Cloud Physics Model

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Objectives of the study
To develop a parallel processing cloud physics model.

Progress and results
We have begun testing the new parallelized version of the Large Eddy Simulation (LES) Model on our workstation cluster. We are merging our detailed microphysical model and the LES model. We will explore system-related issues required to run our code on the SGI Origin machines at Ames.

Significance of the results
The work has just begun.

Keywords
Cloud modeling, Climate, Parallel processing

EEG Monitoring of Cognitive Workload

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Objectives of the study

The proposed work uses noninvasive human experimentation to test our hypotheses that (1) an energy density index of neural activity can be correlated with performance during a continuous, extended-length arithmetic task presented via a video display terminal (VDT) and that (2) changes in the index will precede changes in performance.

Progress and results

A software upgrade to the EEG system has been installed; preliminary data have been acquired and analyzed; and details of the stimulus presentation program have been iterated based on these data and on subject input. Initial trials were not sufficiently taxing to bring about the desired decrement in performance over a reasonable time interval, and effort was expended to correct this.

Subjects are instrumented for 19-electrode EEG and are given visually presented arithmetic problems for a period of one hour to one and one-half hours. The data are analyzed, and the energy density metric *U* is calculated from the scalp voltage data using the following equation:

$$U(x,y) = V(x,y) \cdot \rho(x,y) = -\varepsilon\, V(x,y)\, \nabla^2 V(x,y)$$

U can be calculated from the 19-electrode data for a given electrode location over a small time period; for any combination of electrodes over a chosen time interval; or for the whole scalp over the entire event-related potential (ERP) duration. The latter approach was used for the preliminary data. Representative data from three subjects appear in figure 1.

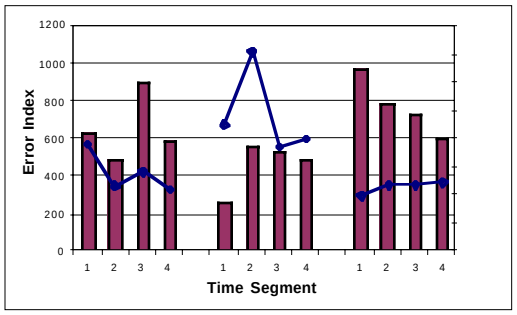

Figure 1. Data for 3 subjects. Numbers on the x-axis indicate successive time segments during a continous effort (1,2,3,4) for each subject.

Significance of the results

The data are not sufficient to permit statistical conclusions. However, trends are intriguing. The trend in the early data is for EEG energy to decrease as error index decreases, though the correlation is weak. Data from subjects 1 and 2 in figure 1 exhibit this behavior. Subject 3 appears to exhibit a different relationship, with energy decreasing as error index increases. Continuing work will examine the local (electrode-specific) relationship of the energy metric with performance in search of underlying commonality. The arithmetic task will be modified to achieve a higher level of difficulty.

References

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Keywords

Electroencephalography, EEG, ERP, Energy density, Workload

Coherent and Miniaturized Terahertz Sources for Space- and Earth-Based Applications

Investigators

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Objectives of the study

1. To demonstrate terahertz optical gain for semiconductor intersubband transitions.
2. To engineer the quantum nanostructures for maximizing optical gain through Raman effects and through exitonic enhancement to achieve large enough gain to reach lasing threshold for a coherent and compact terahertz source.

Progress and results

We have made significant progress in the investigation of the physical mechanism for gain processes in an optically pumped intersubband quantum well structure. We have shown that Raman processes allow up to a 100-percent increase in optical gain. We have also studied the saturation effects of the Raman gain.

Significance of the results

The results achieved so far are very significant. For the first time the Raman effect in an optically pumped intersubband laser is studied self-consistently. The result shows that Raman processes are an important means to increase optical gain without relying heavily on population inversion. This result is especially important since population inversion is exceedingly difficult to achieve with longer wavelength, such as terahertz radiation. The results on saturation and even decrease of optical gain with increasing optical pumping provide an important guide in the gain optimization process. All these results will be important for achieving our final goal of realizing enough optical gain for a terahertz laser.

Publications resulting from the study

1. Liu, Ansheng; and Ning, C.Z.: Terahertz Optical Gain Based on Intersubband Transitions in Optically Pumped Semiconductor Quantum Wells: Coherent Pump-Probe Interactions. Applied Phys. Letters, vol. 75, no. 9, Aug. 30, 1999, pp. 1207–1209.
2. Liu, A.; and Ning, C.Z.: Exiton-Enhanced Intersubband Raman Gain in Semiconductor Quantum Wells. Optical Society Annual Meetings, Santa Clara, Calif., Sept. 27–Oct. 1, 1999.
3. Liu, A.; and Ning, C.Z.: Coherent Pump-Probe Interactions and Terahertz Intersubband Gain in Semiconductor Quantum Wells. Integrated Photonics Research Conference (IPR'99), Santa Barbara, Calif., July 19–23, 1999.

Keywords

Quantum wells, Intersubband transitions, Terahertz radiation, Raman processes

A Self-Configuring Biomimetic Wing—A New Concept for the Mars Airplane

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Objective of the study
To develop a computational fluid dynamics (CFD) computer code to simulate the flight characteristics and control mechanisms of a biomimetic wing: a wing inspired by nature that can reshape during flight to suit the atmospheric conditions and the task it must perform.

Progress and results
A CFD computer code is being developed to simulate the flight characteristics and control mechanisms of a biomimetic wing: a wing inspired by nature that can reshape during flight to suit the atmospheric conditions and the task it must perform. While many CFD codes exist for aerodynamic analyses of passenger and military aircraft, none are capable of simulating an aircraft wing that redefines its shape during flight like a bird. The materials and fabrication methods needed to build such a wing are just becoming available. The most promising material is a synthetic muscle called an ionic polymer metal composite (IPMC), which changes shape when energized by a low voltage from a battery. The most promising fabrication technique is called monolayering and is based on techniques used to manufacture printed circuit boards. We have established contacts at the Jet Propulsion Laboratory (JPL), the Johnson Space Center (JSC), the University of New Mexico, and Virginia Polytechnic Institute who are developing these materials and fabrication technologies. Using our computer simulations, we will direct their research and demonstrate how IPMC devices can be used to build a biomimetic wing for a micro air vehicle. We plan to continue the computer simulations in FY00 and fund the development of the first IPMC-based biomimetic wing.

During this fiscal year, a new algorithm was developed to solve the equations governing fluid flow with deformable boundaries. This technique can be used to model the airflow around an airfoil or wing that changes shape in response to the fluid pressure. The boundary of the domain may move with a prescribed time-dependent motion; i.e., it may be reconfigured to a specific shape. The boundary may also move in response to the pressure loading exerted upon it by the fluid. In the latter case, rules governing the response of the boundary are coupled with the equations of fluid motion. This coupling is bidirectional and nonlinear, so that the boundary response affects the fluid motion, and fluid stresses in turn affect the boundary motion. The rules governing the shape change may be optimized such that drag is minimized.

The CFD algorithm uses a Cartesian grid that has several boundary curves embedded within it. Each curve is further represented as a union of piecewise connected linear segments. At the present time, the algorithm is limited to inviscid flow and the zero-mass flux boundary condition at the boundary is strictly enforced by using a signed distance level set function. By convention, the level set zero defines the boundary, and positive and negative level set values are set in the solid and fluid domains, respectively. An advection equation is solved in pseudotime, to advect density, pressure, and velocities. The advection velocities are the gradients of the level set function. After advection, the normal component of the velocity is reversed in a frame of reference attached to the boundary. A code has been developed for parallel architectures (SGI ORIGIN 2000, Cray T3E) for this purpose. In FY00, the algorithm will be extended and viscous effects and turbulence models will be incorporated.

Keywords
Biomimetic, Wing, Airfoil, Self-configuring, Computational fluid dynamics

NASA Center for Computational Astrobiology (NCCA)

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Objectives of the study
The NASA Center for Computational Astrobiology (NCCA) was formed to advance understanding of the origin, evolution, and distribution of life in the universe using theoretical and computational tools. It has 36 member scientists who are involved in interdisciplinary research in the field of astrobiology. The DDF funding was used to support three new research projects from the areas central to astrobiology: protobiological evolution, dynamics of microbial ecosystems, and evolution of genomes. The principal investigators of these projects are Andrew Pohorille, Christopher Potter, and Shoudan Liang, respectively. The projects are described below.

Progress and results
Nongenomic Evolution of Catalytic Peptides in Protocells
A. Pohorille, M. New, and D. Stassinopoulos

The ability of organic matter to self-organize into self-sustaining, reproducing, and evolving structures governed the transformation of matter from inanimate to animate on the early Earth. Probably the earliest such structures were protocells—membrane-enclosed, cell-like structures capable of supporting essential life functions. Our main hypothesis is that initially protocells evolved in the absence of a genome. Only later did coded information storage emerge. Central to this new concept of non-genomic evolution are peptide-bond-forming proto-enzymes. They were initially very weak, nonspecific catalysts, generating peptides of various lengths and sequences. A few of the peptides so generated could have been better catalysts of peptide bond formation than the protoenzymes that formed them. These better proto-enzymes would, in turn, generate even more peptides. Some of the newly generated peptides would undoubtedly function as proteases. Since proteases cleave unstructured peptides more rapidly than structured ones, and since functional peptides have to have an ordered structure, the proteases would preferentially destroy nonfunctional peptides. Occasionally, the newly produced peptides would be capable of performing novel functions, eventually leading to the emergence of nucleic acids and their coupling with peptides.

The goal of the proposed work is to establish conditions required for nongenomic evolution to take place and to determine whether these conditions are biochemically plausible. We employ a simple, computationally tractable model that is still capable of capturing the essential biochemical features of the real system. All peptides are characterized by three traits: their length, their catalytic efficiencies, and the degree of structure. Since microscopic rules that relate the peptide sequence to its catalytic efficiency are not known, we adopt a stochastic model.

Preliminary results on a simple system containing only synthesis and hydrolysis of peptides have demonstrated that nongenomic evolution is possible under a relatively wide range of conditions. In fact, we either observed systems that clearly evolve or systems that do not evolve at all. This suggests a possibility of phase transition between evolving and nonevolving systems. Demonstrating nongenomic evolution would shed fundamental, new light at the origin and evolution of the protocellular metabolism.

Modeling of Microbial Ecosystem Dynamics
Christopher Potter, David Des Marais, Brad Bebout, and Peter Visscher

Ecosystem models of microbial dynamics, for example in hypersaline, low sulfate, and marine benthic environments, are being developed and tested. This task builds upon the structure of existing simulation models for aquatic microbial dynamics, while adding new couplings of population and community processes to mechanistic algorithms for biogeochemical fluxes and ecosystem gas exchange with the early Earth-like atmosphere. To facilitate such linkages, most existing modeling approaches are commonly constructed with physical stratification patterns for microbial groupings along taxonomic or functional assumptions. Irradiation and temperature boundary conditions typically drive reaction diffusion processes in pore water that can be represented for several biochemical state variables, such as dissolved oxygen, carbon, nitrogen, and sulfide, coupled to changes in microbial biomass for dominant populations. Diel

cycles must be considered to capture natural variation in physical boundary conditions. Different taxonomic or functional groups of microbes can be characterized by different maximum metabolic rates and limiting factors to the construction of taxonomically specific molecules or pigments.

Our next generation of process-oriented models integrates further components for microbial community composition, primary production and respiration, vertical mineral and gas concentration gradients, metabolic reaction rates, mineralization, deposition, and gas emission fluxes. This integration will be built upon the knowledge gained from field and laboratory measurements. Gas emission estimates in our models focus chiefly on compounds of C, N, O, and S. Changing physical conditions of the environment will be evaluated using simulation trials to determine the outcome of competition for light and mineral substrates in the microbial ecosystem. New hypotheses generated by these simulations will be tested in subsequent field and laboratory experiments for feedback to the model framework and global extrapolations of gas emission fluxes to the atmosphere.

The development and evaluation of simulation models will provide astrobiologists with a means of integrating knowledge gained from experimental data sets for microbial ecosystem dynamics, while creating linkages with other research activities for early Earth-like environments. Computer models will provide a common language for multidisciplinary studies and, eventually, a simulation framework for extrapolation of ecosystem dynamics and biogeochemical cycling up to planetary scales that are relevant to remote characterization of a global atmosphere.

Toward Understanding Gene Expression: Investigating Complementary Segments of Unknown Function Abundant in Genomes

S. Liang, K. Harrington, R. B. Laughlin, and Z. Peng

This research is directed at identifying mechanisms that control gene expression. Recent efforts have targeted thoroughly mapped genomes such as E. coli, where the available data are extensive and of high quality, with an emphasis on computerized statistical searches for anomalous deoxyribonucleic acid (DNA) sequences and relationships between sequences that are highly nonrandom and are strategically placed in the genome. Our focus is on analyzing the DNA sequences that control gene transcription termination. Preliminary research suggests that a particular kind of DNA sequences is statistically highly significant and has biological functions that we do not yet understand. The DNA sequence relationship we found is both nonrandom and strategically placed. The related sequences, which we call convolution segment pair dyads (CSPDs), are DNA sequences that are composed of two pairs of two adjacent segments separated by relatively small gaps; the two pairs have structures S1G1S2 and S2′G2S1′. The gap separating S1 and S2 is denoted G1, that separating S2′ from S1′ is denoted G2; the two gap segments do not need to bear any relationship to each other. Segments S1 and S2 are contiguous, with their complements denoted S1′ and S2′ (also contiguous).

In our research we have concentrated on segment pairs {S1, S2} whose combined lengths are 60 bases and with each subsegment having a length of at least 15 bases. With these restrictions, we have found that the CSPDs possess many remarkable and intriguing properties: (a) Large CSPDs are unexpectedly abundant; there are several thousand such CSPDs in the E. coli genome. Because of their large lengths, it is impossible that they could occur by chance. (b) The great majority of these paired sequences occur in noncoding regions of the genome, and these regions form a relatively small fraction of the genome. Because of this strategic placement on the noncoding region, it seems plausible that these CSPDs play a role in promoting and/or regulating gene transcription. (c) The size of the gaps between the subsegments is also not random. (d) The CSPDs are fairly evenly distributed on the genome. (e) The distance distribution between the two halves of the dyad, i.e., between one segment pair and its convolution segment pair, is also fairly smooth. In spite of the convolution relationship between the pairs, the two halves of the dyad are just about as likely to be separated by a million bases as by a thousand bases.

These striking results merit further research. Many different avenues will be pursued, but in the immediate future we will investigate whether CSPDs are (a) associated with particular classes of genes, (b) associated with adjacent gene transcription directionality, (c) present in eukaryotes such as yeast, and other completely sequenced genomes, (d) built from a smaller list of words, (e) substructures of larger aggregates, such as convolution segment triads, or (f) instructions or promoters for ribonucleic acid (RNA) polymerase.

Keywords

Origin of life, Microbial ecosystem, Genomes

Unsteady Pressure Measurements on Helicopter Rotors Using Pressure-Sensitive Paint

Investigators
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Objectives of the study
To understand the dynamic responses of pressure-sensitive paint (PSP) and to demonstrate methods for using PSP to measure unsteady pressures on helicopter rotors.

Progress and results
Significant progress was made on several fronts:

1. A two-dimensional airfoil model for the Compressible Dynamic Stall Facility in the Fluid Mechanics Lab was designed and built. The model is an NACA 0012 airfoil that is instrumented with eight dynamic pressure transducers that will allow direct comparison with PSP results. A PC-based dynamic-pressure data-acquisition system has been purchased. PSP and dynamic transducer measurements will be made on this model in the coming year at model oscillation frequencies up to 20 hertz (Hz).
2. A preliminary design was developed for an apparatus to study the effects of periodic stagnation temperature variations on PSP measurements. This apparatus will be built in the coming year using FY00 funds.
3. PSP and temperature-sensitive paint (TSP) measurements were made on a two-bladed rigid rotor in the Army Anechoic Chamber at a rotor speed of 1800 revolutions per minute (rpm). Although to first order the flow was steady, this test demonstrated elements of a PSP system required for making unsteady measurements on a rotor in forward flight, including flash illumination and the use of a reference paint to account for the radial variation in stagnation temperature. (See fig.)
4. As part of the hover experiment, a study was made of the spectral filtering required to isolate the PSP or TSP signal from reflected excitation illumination. The study showed how leakage of the excitation light into the signal can be reduced to negligible levels with minimal signal attenuation. This study has wide-ranging application to all intensity-based PSP measurements.
5. A method for determining the optimum thickness of PSP for unsteady measurements was developed. This method is based on solutions for the dynamic response of PSP published by Mosharov (ref. 1). The optimum thickness depends on the frequency to be measured and characteristics of the paint being used. The optimum thickness is that which results in a –1.25-decibel (dB) attenuation of the input pressure.

Significance of the results
The accomplishments to date have laid the foundation for substantially increasing our ability to use PSP to measure unsteady pressures on helicopter rotor blades. In particular, the model instrumented with dynamic pressure transducers will allow us to make a direct comparison between unsteady PSP and conventional transducer pressure measurements in a constant-stagnation-temperature environment. The effects on PSP measurements of periodic stagnation temperature changes will be studied in the apparatus to be built in the coming year. Valuable experience was gained in making PSP measurements on subscale rotors. A rational basis has been developed for determining the optimum paint thickness for unsteady PSP measurements. The method for controlling spectral leakage will result in significantly better PSP data quality in all intensity-based PSP measurements.

Publications resulting from the study

Schairer, E.: Optimum Thickness of Pressure-Sensitive Paint for Unsteady Measurements. Paper presented at 7th Annual Pressure-Sensitive Paint Workshop, Purdue University, Oct 11–13, 1999.

Hand, L.: Control of Spectral Leakage in Luminescence Measurements. Paper presented at 7th Annual Pressure-Sensitive Paint Workshop, Purdue University, Oct 11–13, 1999.

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1. Mosharov, V.; Radchenko, V.; and Fonov, S.: Luminescent Pressure Sensors in Aerodynamic Experiment. Central Aerohydrodynamic Institute, CWA International Corporation, 1997.

Keywords
Pressure-sensitive paint, Dynamic measurements, Helicopter rotors

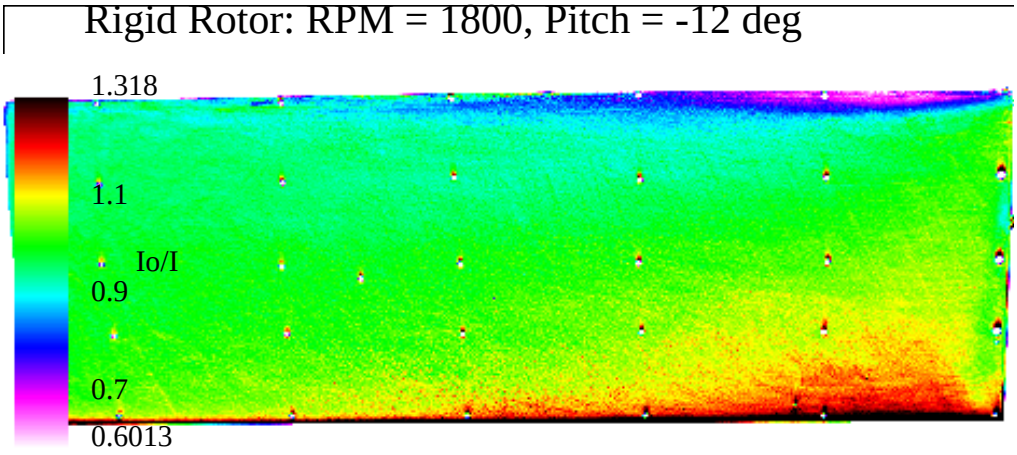

Figure 1. Ratio of images: static/1800 rpm.

Development of a System for Quantifying in vivo Bone Strains in Rodents in Normal and Altered Gravity Environments

Investigators

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Objectives of the study

To develop a permanent method of strain gauge attachment to bone and an implantable biotelemetry system to transmit the data to quantify bone strains in rodents on a long-term basis.

Progress and results

In FY99, the following objectives have been accomplished:

Experiment 1: Pilot study to establish surgical techniques and initial bone bonding (n = 12 rats).
Experiment 2: Examination of wire, waterproofing, bone site, and bioactive enhancers to optimize gauge attachment and gauge integrity (n = 36 rats).
Experiment 3: Waterproofing experiment (no animals used).
Hardware development: Development and fabrication of a prototype along with a receiver demodulator unit.

Experiment 1 was a pilot study that established surgical techniques and initial bone bonding (n = 12 rats). Using existing techniques and materials, gauges were prepared and coated with hydroxyapatite (HA) at the University of Arizona. Gauges were implanted on the lateral anterior face of the proximal tibia in 12 rats. Gauge resistance, wire integrity, and strain while walking at 8, 12, and 16 miles per minute (m/min) were measured at 7, 8, 9, and 10 weeks. One rat consistently exhibited expected strain patterns and values at 7, 8, 9, and 10 weeks. Peak strains reached 800 microstrain, a level consistent with values reported in dogs and humans. By 10 weeks, 9 of the 12 rats showed corrosion, resulting in virtually no strain data in these animals. The strain measurements in these were unstable and showed inconsistent loading on the bone when the animal was walking or running. After sacrifice of the rats, all bone/gauges were examined, and the bones from rats 3 (good strain pattern) and 4 (irregular strain pattern) were sent to the University of Arizona for testing. The degree of gauge attachment in rat 3 ranged from 97 to 136 percent. In rat 4, attachment ranged from 50 to 69 percent. Conclusions: Water infiltration caused corrosion and gauge failure in 75 percent of the animals. Gauge attachment to the bone was insufficient in the remaining animals except for rat 3.

In experiment 2, an examination of wire, waterproofing, bone site, and bioactive enhancers to optimize gauge attachment and gauge integrity (n = 28 rats) was accomplished. Different kinds of lead wire and different kinds of waterproofing were tested to determine if corrosion could be reduced. Different bone sites were chosen (tibia or femur) to determine whether attachment was affected by bone site. Glue was tested to determine whether it was necessary to use the HA coating and transforming growth factor (TGF) was used to determine whether attachment could be enhanced by using a bioactive compound that stimulates bone formation. Gauges were implanted as in experiment 1 and tests were conducted at 7, 8, 9, and 10 weeks. Visual inspection of the exteriorized wire showed corrosion gradually increasing with time. Weeks 7 and 10 showed 5- to 10-percent and 50-percent corrosion, respectively, of the wires. Two configurations showed the least corrosion, both in number of wires affected and severity of corrosion. Three rats (AAT1, 6, and ANT5) demonstrated consistent strains between weeks 7 and 10. Peak-to-peak strain magnitude while walking at 8, 12, and 16 m/min ranged from 750 to 1000 microstrain and patterns were consistent between

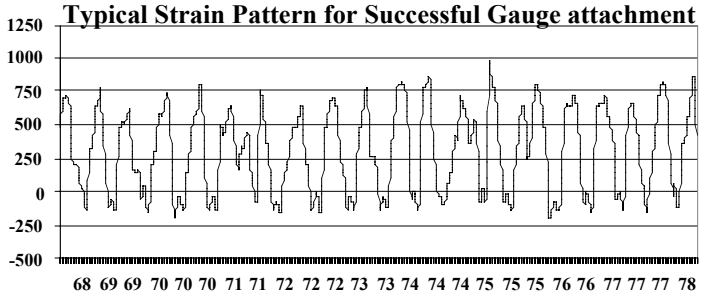
animals and over time. Subsequent testing showed that attachment in these animals averaged 89 percent (range = 80 to 100 percent). In some of the animals, the bone near the attachment site showed deformities, including bone growth over the gauge ("pearl effect") and narrowing of the bone distal to the gauge/bone interface ("blood-flow-interruption defect"). However, the three rats with the most consistent strains showed no bone deformation. Figure 1 shows gauge attachment, and Table 1 shows a typical strain measurement.

Gauge Attachment Analysis

Number of Animals	Gauge Attachment	Strain Measurements
3	80-100%	Ideal
3	80-100%	Inconsistent
15	50-80%	Poor/None
7	0%	None

Figure 1. Gauge attachment.

Table 1. Gauge attachment analysis



Experiment 3: A waterproofing study was conducted using three different materials to waterproof the soldered junction of the wires and the strain gauge, and different types of wire insulation were used with the different waterproofing materials. The gauges were then submerged in 50-degree Fahrenheit saline for 10 weeks to try to recreate the corrosion problems seen with the implanted strain gauges. After 10 weeks, however, there was minimal corrosion and no impedance changes to any of the gauges, as anticipated.

Hardware Development: The design and fabrication of the implantable transmitter that will interface to the strain gauge in vivo was completed. The transmitter has been designed to be very flexible in accommodating change in the baseline impedance of the strain gauge. An existing design of a receiver/demodulator was also fabricated to be used in this application. Both of these devices will be tested in FY00 with rats that have implanted strain gauges.

Significance of the results

We have demonstrated that HA-treated micro strain gauges can be attached to the tibia for periods of up to 10 weeks. Strain can be accurately measured in these animals using this new method under conditions of walking or running. Although there are reliability issues, namely consistent gauge attachment and corrosion, it is a reasonable assumption that these problems can be solved through modifying attachment techniques and materials. As it exists now, this method holds great promise to provide a path to better understanding bone metabolism and skeletal integrity.

Publications resulting from the study

Data from the studies are being prepared for publication; they were presented as posters at the annual meetings of the American Society for Bone and Mineral Research (Sept. 1999) and the American Society for Gravitational and Space Biology (Oct. 1999).

Keywords

Bone metabolism, Bone strain, Implantable telemetry

Telepresent Exploration of Hydrothermal Vent System in Antarctica

Investigator(s)

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Objectives of the study

This study has two main objectives:

1. To apply virtual reality visualization technologies that have previously been developed by team members for operating robots on Mars to the underwater environment.
2. To perform a prototype mission with an underwater vehicle outfitted with these technologies in a hydrothermal vent environment to further Astrobiology objectives of better understanding and characterizing these environments.

Progress and results

A remotely operated underwater vehicle (ROV) was purchased and outfitted with the capability to measure water column properties, to collect physical samples with a robotic arm, and to collect stereo and color-zoom imaging. A precise stereo camera alignment jig was built for providing accurate, repeatable pointing of stereo cameras. An acoustic navigation system and supporting equipment was purchased.

A field experiment was performed using the U.S. Coast Guard icebreaker vessel the Polar Star as a platform to deploy a small commercial ROV outfitted with a stereo camera system that was a prototype of the system built by NASA. This mission focused on underwater archeology. A sunken whaling fleet vessel was located using the ROV. Data from the mission was made available on the world wide web using NASA telecommunication technology as part of an educational outreach activity associated with the mission. Stereo images obtained during this expedition were used to build three-dimensional models of underwater structures using the Ames Stereo Pipeline, a stereo correlation and terrain reconstruction technique developed for the Mars Pathfinder mission (Stoker et al., 1999), proving that stereo correlation algorithms developed at Ames for application to surface robots would work in the underwater environment.

During the summer field test, aspects of the system tested included the ability to build models of complex objects using the Ames Stereo Pipeline and the ability to measure those objects using the three-dimensional (3-D) interface. The Ames Stereo Pipeline succeeded at building 3-D models of complex objects from a distance of approximately 3 feet, with “diver estimated” visibility of 10 feet. The system was evaluated by the two project archaeologists, Jeremy Bates of Santa Clara University and Michele Hope of the Alaska Office of the Minerals Management Service, as “significantly better” than systems currently in use for field collections of data on marine artifact size and location.

A collaboration was developed with Oregon State University researchers who specialize in the study of hydrothermal environments. We submitted with these collaborators a joint proposal to the National Science Foundation Life in Extreme Environments program to use a telepresent remotely operated ROV (TROV) outfitted with a zero-angle photon spectrometer (ZAPS) instrument developed at OSU to search for and study hydrothermal sources in the area of Deception Island, Antarctica.

Significance of the results

Applying stereo modeling technology to the underwater environment will represent a breakthrough for operating remote vehicles in this environment. This study to date has taken important steps towards realizing this breakthrough.

Publications resulting from the study

Weast, Aaron B.; Ota, Jeffrey M.; Kitts, Christopher A.; Bulich, Chad; Laurence, Alana M.; Lwin, Calvin M.; Wigle, Trevor D.; Perkins, William B.; and Cook, Jason F.: Integrating Digital Stereo Cameras with Mars Pathfinder Technology for 3D Regional Mapping Underwater. Proceedings of the 1999 IEEE Aerospace Conference, vol. 1, Snomass, Colo., March 6–13, 1999.

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Keywords

Virtual reality, ROV, Stereo terrain modeling

In Search of MONSTERS (Multicellular Organisms Not Seen by Traditional Environmental Researchers)

Investigators

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Key Personnel
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Probe Design and Construction:

Sensors 2000 group:
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Field Research Team
Jonathan Trent, Fred Martwick, Charlie Friedricks, Susanne Johansen Trent, Mark Fonda, YNP Rangers

Data Analysis
Jonathan Trent, John and Vicki Pearse (University of California, Santa Cruz), Susanne J. Trent

Objectives of the study

To answer the fundamental astrobiological questions:

- What are the upper temperature limits for macroscopic eukarya on Earth?
- How do environmental factors such as dissolved oxygen and pH impact such organisms in high-temperature habitats?

Technical objectives for Year One follow:

1. Design and construct a baited video camera/pH/oxygen/depth probe
2. Field test this camera/probe system under field conditions to define its operational range.

Video cameras (faster, better, cheaper):
Requirements for the video cameras were that they should be functional at temperatures up to 90°C and pH down to 0, have macro and wide-angle capabilities, bright and stable internal light source, depth capabilities of up to 30 meters, battery life of at least four hours, digital output, a compact and lightweight design, and they should cost less than $2000 each. Fortunately, recent developments in submersible-video-camera technology (primarily for applications in the plumbing industry) allowed us to purchase such cameras from DeepSea Power and Light for $1700. These cameras were modified to withstand high temperature simply by disconnecting the "overheating" circuit that inactivated the camera and LED lights above 70°C. Laboratory tests indicated that the cameras transmitted intelligible (although somewhat degraded) images at 100°C. These cameras are compact, they come with 30 meters of cable, and they proved to be ideal for field work.

Environmental monitors: Sensors were needed to determine the temperature, pH, oxygen, and depth in the vicinity of the video images. A temperature/pH probe was purchased from Royce, a membrane oxygen sensor from Innovative, and a depth probe from Druck. These sensors were arranged in a Delran housing around the cameras (fig. 1). The housing was further modified to include a bait-holding tray that was meant to attract MONSTERS (not shown).

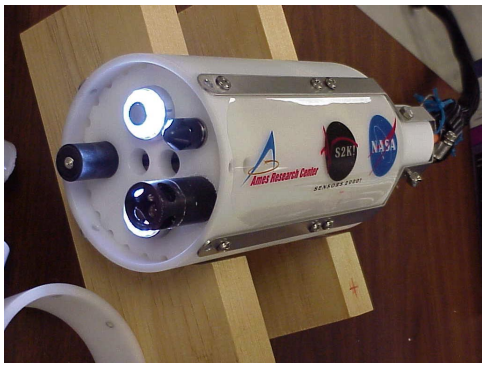

Figure 1. The MONSTER probe with the two cameras (LED lights on), pH/temperature probe (middle), oxygen probe (left) and depth sensor (right).

Progress and results

1. The video system exceeded expectations for collecting clear images in hydrothermal areas.
2. Temperature, pH, and oxygen sensors must be upgraded for future deployments.
3. Baited traps will require long (time-lapse) deployments.
4. The system was manageable by three experienced hikers.

5. The system was deployed and recovered without major impact to sensitive habitats.

Plans for Year Two

1. Upgrade sensors and acquire a mobile (pioneer) camera system.
2. Continue the search in Yellowstone National Park and in other areas.

Keywords
Yellowstone, Thermophiles, Eukarya, Video in hot springs

Modeling Cholera Outbreaks Using Remotely Sensed Data

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Objectives of the study
The mechanism of survival of Vibrio cholerae, the bacterium that causes cholera, has long been a key question in cholera epidemiology. The occurrence of Vibrio cholerae, in sufficiently large numbers to create cholera outbreaks, is directly or indirectly dependent on sea-surface temperature (SST), nutrient concentration, and phytoplankton/zooplankton production in the marine environment (Colwell et al., 1990; Tamplin et al. 1990; Epstein et al., 1993; Epstein, 1993). These investigators have demonstrated that the Vibrio cholerae attaches to zooplankton, specifically copepods, which provide a primary vehicle for dispersal. Phytoplankton provide the main food source for zooplankton, so the two forms of plankton are tightly linked in space and time. Recent studies also suggest that the spatial and temporal patterns of SST, plankton, and cholera are influenced by El Niño events (Patz, et al., 1996). These links suggest that monitoring key environmental parameters, such as SST and ocean pigment (i.e., chlorophyll and phytoplankton), would be useful in tracking the movement of Vibrio cholerae and possibly predicting cholera outbreaks in coastal areas. Although V. cholerae cannot be detected in any state by remote-sensing techniques, remote sensing has been able to quantify SST and phytoplankton concentrations in the open oceans (Brown, Brown, and Evans, 1993; Reynolds and Smith, 1994; Weaver and Wrigley, 1994). Previous work, by Ames Research Center and University of Maryland investigators, has demonstrated a coupling between remotely sensed SST and cholera in the Bay of Bengal and Bangladesh. The time lag between increasing SST and increasing incidence of cholera suggests the potential for developing a remote-sensing-based model to predict cholera outbreaks in coastal regions. However, at the time of this work the capability to remotely sense phytoplankton in the ocean was not available. This situation has now changed with the successful launch of the SeaWiFS ocean color scanner in the fall of 1997. Extraction of chlorophyll/phytoplankton concentration can be problematic in coastal regions, but the situation has been improved with new algorithms developed for use with SeaWiFS data (McClain et al. 1994a; McClain et al. 1994b; Mueller et al. 1995)

We proposed to test the hypothesis that it is possible to use remote-sensing data to (1) quantify SST; (2) detect and track phytoplankton pigment concentrations associated with zooplankton to infer the presence of Vibrio cholerea; and (3) combine the two remotely sensed measurements to predict the risk of cholera outbreaks in coastal regions.

Progress and results
Analysis of SeaWiFS data thus far shows that for much of the global ocean, SST and chlorophyll-a (Chl-a) concentration are closely related. For coastal Latin America, the correlation coefficient $R^2 = 0.66$ for these data, but previous work has shown that this relationship is weak in the Bay of Bengal, where $R^2 = 0.14$. For the limited time that SeaWiFS-derived Chl-a and cholera case data have been available for Lima, Peru, the pattern indicates that the 1998 cholera outbreak followed an increase in ocean height and temperature. (See fig. 1.) The situation is different in the Bay of Bengal, where the cholera outbreaks occur coincident with the Chl-a and sea-surface height patterns. (See fig. 2.) A model developed and tested using data from coastal Peru will not apply to the Bay of Bengal, but may apply to other areas where SST and Chl-a concentrations are closely related.

Significance of the results
A remote-sensing-based model will allow for the development of a remote-sensing-based early warning system for cholera. This project seeks to exploit the current capability to simultaneously remotely sense the spatial and temporal changes in SST and phytoplankton to develop this predictive model.

Publications resulting from the study
A publication describing the model will be submitted to a journal such as the Center for Disease Control's (CDC's) journal "Emerging Infectious Diseases," and a paper describing the earlier work in the Bay of Bengal has been submitted to the Proceedings of the National Academy of Sciences (PNAS). The results will also be presented to the National Science and Technology Council Committee on International Science, Engineering and Technology (CISET) Working Group on Emerging and Re-emerging

Infectious Diseases, of which the NASA Ames investigators are members.

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Keywords

Cholera, Remote sensing, Sea-surface temperature, Sea-surface height, Phytoplankton

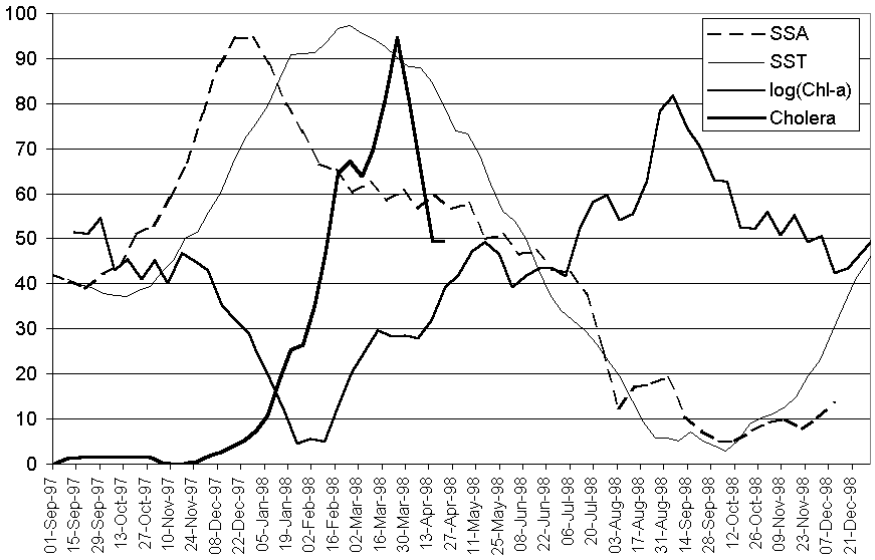

Figure 1. Coastal Latin America cholera case, sea-surface temperature (SST), sea-surface height anomalies (SSA), and Chl-a concentration data for September 1997 through 1998 show a strong link between SST and Chl-a. The cholera outbreak shown here appeared to follow an increase in SST and SSA. The data ranges have been each rescaled to 0–100.

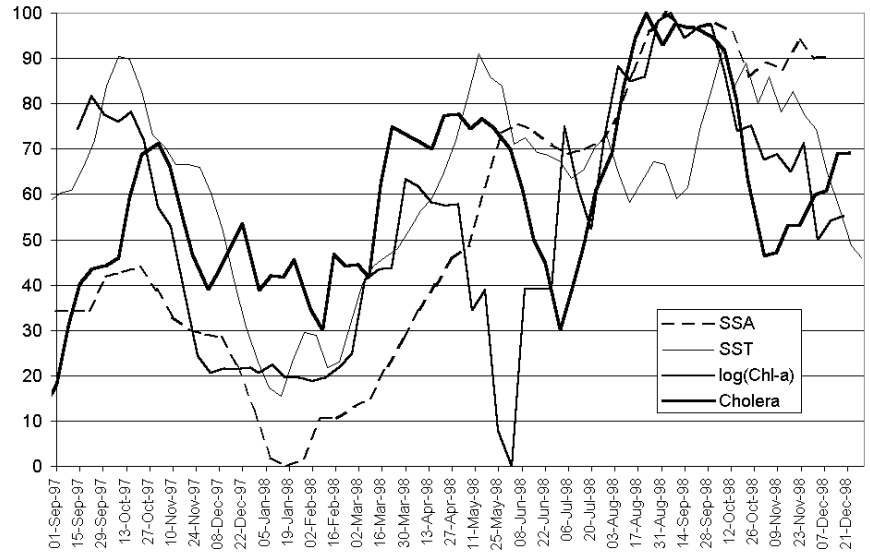

Figure 2. Bay of Bengal cholera case, SST, sea surface height anomalies (SSA), and Chl-a data for September 1997 through 1998 indicate the pattern of cholera outbreaks follow the Chl-a and SSA patterns. The data ranges have been each rescaled to 0–100.

Conceptual Design Study of a Martian Autonomous Rotorcraft for Science (MARS)

Investigators
Larry A. Young and Robert T.N. Chen,
Ames Research Center,
Moffett Field, CA, 94035-1000

Objectives of the study
The next few years promise a unique convergence of NASA Aeronautics and Space programs. NASA planetary science missions are becoming increasingly more sophisticated. This scenario will ultimately culminate, in part, in the development of planetary aerial vehicles. Early work in this area has principally focused on conceptual design of fixed-wing aircraft configurations for Mars exploration. However, autonomous vertical lift vehicles hold considerable potential for supporting planetary science and exploration missions.

The Army/NASA Rotorcraft Division—in collaboration with the Center for Mars Exploration—at the Ames Research Center has been performing initial conceptual design studies over the past year of a Martian autonomous rotorcraft for science (MARS) planetary exploration and missions. Initial results have been quite promising. As a result of this early work, the principal investigators have generalized their thoughts as to the utility of rotorcraft, vertical takeoff and landing (VTOL) vehicles, and hybrid airships for not only Mars exploration, but planetary science missions as a whole. Nonetheless, primary emphasis of the work is on MARS.

Why vertical lift vehicles for planetary exploration? For the same reasons such vehicles are flexible aerial platforms for terrestrial exploration and transportation: the ability to hover and fly at low speeds and to take off and land at unprepared remote sites. Further, autonomous vertical lift planetary aerial vehicles would have the following specific advantages/capabilities for planetary exploration:

1. Hovering and low-speed flight capability enables detailed and panoramic survey of remote site(s).
2. Rotorcraft and VTOL configurations enable remote-site sample return to lander platform and precision placement of probes.
3. Soft landing capability for vehicle reuse (i.e., lander refueling and multiple sorties) and remote-site monitoring.
4. Hover/soft landings are good fail-safe “hold” modes for autonomous operation of planetary aerial vehicles.
5. These vehicles offer greater range and speed than a rover to perform detailed surveys.
6. These vehicles offer greater resolution of surface details than an orbiter; they could perform imaging of planetary surfaces or atmospheric phenomena.

Progress and results
Software design tool refinement has continued for the MARS conceptual design. Secondly, a university grant has been initiated for a conceptual design study of an autonomous control system for a MARS. Third, a task order contract task has been initiated for the conceptual and preliminary design of a hover/static-thrust test stand for testing of rotors designed for the Mars atmosphere (essentially no experimental data exist for airfoils in the low-Reynolds, high-Mach-number regime consistent with rotor operation in the Mars atmosphere). Fourth, and finally, Sikorsky Aircraft (the sponsor for the Year 2000 American Helicopter Society Student Design Competition) has made MARS the design topic for the competition.

Significance of the results
If proven to be a feasibility, a MARS (and vertical lift planetary aerial vehicles, in general) would hold great promise for supporting NASA planetary science programs and the manned exploration of space. This work focuses on the key technology issues that will determine whether a MARS is feasible or not.

Publications resulting from the study
An abstract on vertical lift planetary aerial vehicles (including the MARS) has been submitted and accepted for presentation at the American Helicopter Vertical Lift Aircraft Design Specialist’s Meeting, San Francisco, Calif., Jan. 2000.

Keywords
Mars, Martian, Rotorcraft, Autonomous, Robotic, Vertical lift, Planetary aerial vehicles

Organic Reductant as Key to Maghemite Formation on Mars?

Investigator(s)
Aaron P. Zent,
Ames Research Center,
Moffett Field, CA 94035-1000

Janice L. Bishop and Rocco L. Mancinelli,
SETI Institute, Ames Research Center

Objectives of the study
To evaluate the potential of maghemite (an iron oxide mineral) as an indicator for astrobiology on Mars; and to characterize the spectroscopic properties of maghemite and develop techniques for spectral identification of maghemite on Mars.

Progress and results
Nearly all the materials and equipment necessary for this study have been acquired and some of the initial syntheses and reactions have been performed.

Synthesis of the iron oxyhydroxide minerals ferrihydrite and goethite (starting materials) is being performed according to procedures outlined in Schwertmann and Cornell (1991) and Cornell and Schwertmann (1996). These minerals will be heated slowly using differential thermal analysis (DTA) in order to test the formation of maghemite and magnetite at temperatures in the 200- to 300-degree Centigrade (°C) range (with a Mars-like O_2 level) for variable time periods (one to several hours) and variable amounts of organic reductants. Maghemite formation was identified at temperatures near 280 °C using normal DTA scanning rates in a previous study for terrestrial applications (Campbell et al., 1997). By controlling the heating rate (and stabilizing at key temperatures), we will be able to better examine maghemite formation and the applicability of these reactions to Mars.

We will begin with 1–10 weight percent (wt.%) glucose because this was used in a related study (Campbell et al., 1997) and test additional hydrocarbons that would be more likely to have associated with organisms. The Campbell et al. (1997) experiments showed that less reductant is necessary for maghemite formation in a N_2 atmosphere than in air and that different mineral products were achieved under 99.999-percent N_2 vs. 99.6-percent N_2 atmospheres. The Mars atmosphere contains 0.13-percent O_2 (Owen et al., 1977). We will configure gas mixtures with variable percentages of atmospheric O_2 for our experiments.

The product will be measured using visible-infrared (IR) reflectance spectroscopy in the NASA-sponsored RELAB facility at Brown University and using Mössbauer spectroscopy at the Ørsted Laboratory at the University of Copenhagen.

Significance of the results
Identifying and characterizing potential biomarker minerals on Mars is essential to astrobiology. Because maghemite is thought to be ubiquitous in the surface dust and soil particles on Mars (Hviid et al., 1997; Madsen et al., 1999) and a mechanism for formation of this maghemite on Mars is not known at present, this study is expected to provide important information about maghemite formation mechanisms and the possible importance of an organic reductant in this process.

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Hviid S.F.; Madsen, M.B.; Gunnlaugsson, H.P.; Goetz, W.; Knudsen, J.M.; Hargraves, R.B.; Smith, P.; Britt, D.; Dinesen, A.R.; Mogensen, C.T.; Olsen, M.; Pedersen, C.T.; and Vistisen, L.: Magnetic Properties Experiments on the Mars Pathfinder Lander: Preliminary Results. Science, vol. 278, no. 5344, pp. 1768–1770, Dec. 5, 1997.

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Owen, T.; Biemann, K.; Rushneck, D.R.; Biller, J.E.; Howarth, D.W.; and Lafleur, A.L.: The Composition of the Atmosphere at the Surface of Mars. J. Geophys. Res., vol. 82, no. 28, pp. 4635–4639, Sept. 30, 1977.

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Keywords
Maghemite, Mars, Biomarker, Astrobiology, Iron oxide

Appendix A-1
Final Reports

Ames Research Center

DIRECTOR'S DISCRETIONARY FUND REPORT

Fiscal Year 1999 Final Report

Title of Investigation

Where Are the Hidden Supernovae?

Investigator(s) (show affilation)

J. Bregman, D. Wooden, and T. Roellig, ARC

Funding

Year initiated	FY98	Expected completion date	FY00
Total prior to FY99	$40,000	Authorized in FY99	$40,000
		Requested for FY00 (if any)	0

Total expended in FY99 (estimated)

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

Status of Study

Completed in FY99 [ ] Continued in FY00 with funds remaining [X]

with FY00 funds [ ]

If transitioned to other funding

to RTOP (number)

to Program (name)

to Other (identify)

Purpose of investigation

To determine whether there are supernovae hidden from view at optical wavelengths in the cores of starburst galaxies and to measure how often they occur.

FY99 applications of results, patents, reports/publications, papers at meetings, awards received, etc.

None

Planned future work

Complete lab tests of detectors will be conducted, followed by telescope observations at Lick Observatory.

Prepared by	Org. Code	M/S	Phone
Jesse Bregman	SSA	245-6	(650) 604-6136

Ames Research Center

DIRECTOR'S DISCRETIONARY FUND REPORT

Fiscal Year 1999 Final Report

Title of Investigation

Graphics Software Architectures for True Three-Dimensional High-Resolution Volumetric Displays

Investigator(s) (show affilation)

Steve Bryson, ARC; Chris Henze, MRJ, Inc., ARC

Funding

Year initiated	FY98	Expected completion date	FY01
Total prior to FY99	$80,000	Authorized in FY99	$80,000
		Requested for FY00 (if any)	0

Total expended in FY99 (estimated)

In-house	0
Contracts (identify)	0
Grants (identify)	0

Status of Study

Completed in FY99 [ ] Continued in FY00 with funds remaining [X]

with FY00 funds [ ]

If transitioned to other funding

to RTOP (number)

to Program (name)

to Other (identify)

Purpose of investigation

Development of a simple graphics library that renders three-dimensional graphical primitives using the sparse raster approach. This library would support points, lines, and polygonal surfaces, and would allow simple monochromatic shading algorithms such as Gouraud shading and simple lighting. This library would be used to implement simple demonstration programs using a volume display, including an interactive scientific visualization application.

FY99 applications of results, patents, reports/publications, papers at meetings, awards received, etc.

None

Planned future work

Begin research as soon as the required hardware is delivered.

Prepared by	Org. Code	M/S	Phone
Steve Bryson	INR	T27A-1	(650) 604-4524

Ames Research Center

DIRECTOR'S DISCRETIONARY FUND REPORT

Fiscal Year 1999 Final Report

Title of Investigation

Self-Contained Oculometer Tracking System (SCOTS) to Study Gaze Control in Humans during Self-Locomotion

Investigator(s) (show affiliation)

Malcolm Cohen, ARC; Geoffrey Bush, Lockheed Martin Space Operations, ARC; and Eric Sabelman, Dept. of Veterans Affairs Medical Center

Funding

Year initiated	FY98	Expected completion date	FY99
Total prior to FY99	$39,800	Authorized in FY99	$40,000
		Requested for FY00 (if any)	0

Total expended in FY99 (estimated)

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

Status of Study

Completed in FY99 [X] Continued in FY00 with funds remaining [ ]

with FY00 funds [ ]

If transitioned to other funding

to RTOP (number)

to Program (name)

to Other (identify)

Purpose of investigation

The SCOTS will enable investigators and clinicians to quantitatively measure both the horizontal and vertical eye movements of both eyes while also measuring the movement of the head in three-dimensional space.

FY99 applications of results, patents, reports/publications, papers at meetings, awards received, etc.

None

Planned future work

Fine-tune the algorithms that measure head movement so that the more meaningful expression gaze (sum of eye in head and head in space) is given as position in space.

Prepared by	Org. Code	M/S	Phone
Geoffrey Bush	SLR	242-3	(650) 604-1678

Ames Research Center

DIRECTOR'S DISCRETIONARY FUND REPORT

Fiscal Year 1999 Final Report

Title of Investigation

Parallelization Tools for Computational Fluid Dynamics

Investigator(s) (show affilation)

Maylene Duenas, ARC; T.S. Kuan and R.P. Linstedt, Imperial College of Science, Technology & Medicine, London, UK

Funding

Year initiated	FY99	Expected completion date	FY00
Total prior to FY99	0	Authorized in FY99	$48,818
		Requested for FY00 (if any)	

Total expended in FY99 (estimated)

In-house		
Contracts (identify)		
Grants (identify)	$48,818	NAG2-1283

Status of Study

Completed in FY99 [ ] Continued in FY00 with funds remaining [X]

with FY00 funds [ ]

If transitioned to other funding

to RTOP (number)

to Program (name)

to Other (identify)

Purpose of investigation

Assess and use the CAPTools software kit developed at the University of Greenwich on parallel computational fluid dynamics (CFD) computation codes.

FY99 applications of results, patents, reports/publications, papers at meetings, awards received, etc.

None

Planned future work

Continue working with researchers at Imperial College and U. of Greenwich on the development of parallelization tools for FORTRAN applications. The resultant software will be commercialized in conjunction with Silicon Graphics, Inc.

Prepared by	Org. Code	M/S	Phone
Maylene Duenas	D	19-6	(650) 604-6370

Ames Research Center

DIRECTOR'S DISCRETIONARY FUND REPORT

Fiscal Year 1999 Final Report

Title of Investigation

Large-Scale Processing of Carbon Nanotubes

Investigator(s) (show affilation)

John Finn and Meyya Meyyappan, ARC; Sunita Verma, Orbital Sciences Corporation, ARC

Funding

Year initiated	FY98	Expected completion date	9/30/99
Total prior to FY99	$40,000	Authorized in FY99	$40,000
		Requested for FY00 (if any)	0

Total expended in FY99 (estimated)

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

Status of Study

Completed in FY99 [X] Continued in FY00 with funds remaining [ ]

with FY00 funds [ ]

If transitioned to other funding

to RTOP (number)

to Program (name)

to Other (identify)

Purpose of investigation

To develop a chemical vapor deposition process for growing carbon nanotubes.

FY99 applications of results, patents, reports/publications, papers at meetings, awards received, etc.

Presentation at NanoSpace 98, Johnson Space Center, Houston

Planned future work

Work will be continued through NASA program funding.

Prepared by	Org. Code	M/S	Phone
Meyya Meyyappan	AS	229-3	(650) 604-2616

Ames Research Center

DIRECTOR'S DISCRETIONARY FUND REPORT

Fiscal Year 1999 Final Report

Title of Investigation

Spectroscopic Studies of Mass-Selected Ions and the Evolution of Carbon-Bearing Molecules in the Galaxy

Investigator(s) (show affilation)

Douglas M. Hudgins, Thomas M. Halasinski, and Robert Walker, ARC

Funding

Year initiated	FY98	Expected completion date	FY99
Total prior to FY99	$38,000	Authorized in FY99	$40,000
		Requested for FY00 (if any)	0

Total expended in FY99 (estimated)

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

Status of Study

Completed in FY99 [X] Continued in FY00 with funds remaining [ ]

with FY00 funds [ ]

If transitioned to other funding

to RTOP (number)

to Program (name)

to Other (identify)

Purpose of investigation

To greatly increase and diversify the inventory of PAH-related transient species that can be studied spectroscopically in the laboratory.

FY99 applications of results, patents, reports/publications, papers at meetings, awards received, etc.

None

Planned future work

Continue with the project as planned.

Prepared by	Org. Code	M/S	Phone
Douglas M. Hudgins	SSA	245-6	(650) 604-4216

Ames Research Center

DIRECTOR'S DISCRETIONARY FUND REPORT

Fiscal Year 1999 Final Report

Title of Investigation

SHARP-L1 Concept Development

Investigator(s) (show affilation)

Paul Kolodziej, ARC

Funding

Year initiated	FY99	Expected completion date	FY99
Total prior to FY99		Authorized in FY99	$100,000
		Requested for FY00 (if any)	0
Total expended in FY99 (estimated)			
In-house	$43,000		
Contracts (identify)			
Grants (identify)	$57,000	University Consortium Agreements	

Status of Study

Completed in FY99 [X] Continued in FY00 with funds remaining [ ]

with FY00 funds [ ]

If transitioned to other funding

to RTOP (number)

to Program (name)

to Other (identify)

Purpose of investigation

Develop technology and advocacy for SHARP-L1, a flight demonstration of nonablating, hypersonic sharp leading edges.

FY99 applications of results, patents, reports/publications, papers at meetings, awards received, etc.

None

Planned future work

Apply SHARP-L1 technology to future NASA missions.

Prepared by	Org. Code	M/S	Phone
Paul Kolodziej	ASM	234	(650) 604-0356

Ames Research Center

DIRECTOR'S DISCRETIONARY FUND REPORT

Fiscal Year 1999 Final Report

Title of Investigation

Development of a Fully Automatic Mini-Holographic Optical Instrument for Fast Separating and Detecting Amino Acids for Future Planetary Missions

Investigator(s) (show affilation)

Narcinda Lerner, ARC; Jr-Lung Chen and Thomas Shen, SETI Institute, ARC

Funding

Year initiated	FY98	Expected completion date	9/30/98
Total prior to FY99	$40,000	Authorized in FY99	$40,000
		Requested for FY00 (if any)	0

Total expended in FY99 (estimated)

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

Status of Study

Completed in FY99 [X] Continued in FY00 with funds remaining [ ]

with FY00 funds [ ]

If transitioned to other funding

to RTOP (number)

to Program (name)

to Other (identify)

Purpose of investigation

To develop molecularly imprinted polymers with specific binding property for underivatized amino acid, and, using designed polymers, to prepare affinity mini-columns, and finally, based upon these mini-columns, to assemble an instrument that will efficiently separate and detect free amino acids for returned samples from future planetary spacecraft missions.

FY99 applications of results, patents, reports/publications, papers at meetings, awards received, etc.

None

Planned future work

None

Prepared by	Org. Code	M/S	Phone
Narcinda Lerner/Jr-Lung Chen/Tom Shen	SSX	239-12	(650) 604-1156

Ames Research Center

DIRECTOR'S DISCRETIONARY FUND REPORT

Fiscal Year 1999 Final Report

Title of Investigation

Exploring Carbon Nanotubes for Nanolithography

Investigator(s) (show affilation)

Dan Machak, ARC; Jie Han, MRJ, ARC; and Hongjie Dai, Stanford University

Funding

Year initiated	FY98	Expected completion date	FY99
Total prior to FY99	$40,000	Authorized in FY99	$40,000
		Requested for FY00 (if any)	0

Total expended in FY99 (estimated)

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

Status of Study

Completed in FY99 [X] Continued in FY00 with funds remaining [ ]

with FY00 funds [ ]

If transitioned to other funding

to RTOP (number)

to Program (name)

to Other (identify)

Purpose of investigation:

Exploit mechanical and chemical properties of carbon nanotubes for use in tools for nanolithography and semiconductor device fabrication and metrology. Multiwall and single-wall nanotube probes are made into scanning probe microscopy for these purposes. This technology has important applications in nanoelectronics and semiconductor industries.

FY99 applications of results, patents, reports/publications, papers at meetings, awards received, etc.

Dai, Hongjie; Franklin, N.; and Han, Jie: Exploiting the Properties of Carbon Nanotubes for Nanolithography. Applied Physical Letters, vol. 73, no. 11, 1998, pp. 1508–1510.

Garg, A.; Han, J.; and Sinnott, S.B.:Interactions of Carbon-Nanotubule Proximal Probe Tips with Diamond and Graphene. Physical Review Letters, vol. 8., no. 11, 1998, pp. 2260–2263.

Han, J.; and Jaffe, R.: Energetics and Geometries of Carbon Nanoconic Tips. J. Chem. Phys., vol. 108, 1998, p. 2817.

Dai, H.; et al.: Self-Oriented Regular Arrays of Carbon Nanotubes and Their Functional Devices. Science, vol. 283, no. 5401, 1999, p. 512.

Planned future work

None

Prepared by	Org. Code	M/S	Phone
Jie Han	IN	T27A-1	(650) 604-4799

Ames Research Center

DIRECTOR'S DISCRETIONARY FUND REPORT

Fiscal Year 1999 Final Report

Title of Investigation

Novel Biosensors for Astrobiology Missions

Investigator(s) (show affilation)

Meyya Meyyappan , ARC

Funding

Year initiated	FY99	Expected completion date	FY99
Total prior to FY99	0	Authorized in FY99	$100,000
		Requested for FY00 (if any)	0

Total expended in FY99 (estimated)

In-house	$65,000	
Contracts (identify)		
Grants (identify)	$35,000	Arizona State University - # NCC2-5331

Status of Study

Completed in FY99 [X] Continued in FY00 with funds remaining [ ]

with FY00 funds [ ]

If transitioned to other funding

to RTOP (number)

to Program (name)

to Other (identify)

Purpose of investigation

To initiate a biosensor project using nanotubes.

FY99 applications of results, patents, reports/publications, papers at meetings, awards received, etc.

One invention disclosure has been prepared.

Planned future work

Work will continue under a National Cancer Institute contract.

Prepared by	Org. Code	M/S	Phone
Meyya Meyyappan	AS	229-3	(650) 604-2616

Ames Research Center

DIRECTOR'S DISCRETIONARY FUND REPORT

Fiscal Year 1999 Final Report

Title of Investigation

Large Eddy Simulation of Premixed Turbulent Combustion

Investigator(s) (show affilation)

Parviz Moin, ARC; Derek S. Louch, Center for Turbulence Research, ARC, and Stanford University

Funding

Year initiated	FY99	Expected completion date	FY99
Total prior to FY99	0	Authorized in FY99	$75,000
		Requested for FY00 (if any)	0

Total expended in FY99 (estimated)

In-house		
Contracts (identify)		
Grants (identify)	$75,000	Center for Turbulence Research

Status of Study

Completed in FY99 [X] Continued in FY00 with funds remaining [ ]

with FY00 funds [ ]

If transitioned to other funding

to RTOP (number)

to Program (name)

to Other (identify)

Purpose of investigation

To develop a parallel large eddy simulation code in cylindrical geometry solving a modeled set of zero-Mach-number large eddy simulation combustion equations with simple chemistry and subsequently investigate the large eddy simulation of an experimental premixed turbulent flame brush in stagnating turbulence.

FY99 applications of results, patents, reports/publications, papers at meetings, awards received, etc.

Louch, D.S.; and Umurhan, M.: A Flame-Thickening Approach for the Large Eddy Simulation of Premixed Turbulent Combustion (in preparation).

Louch, D.S.: Large Eddy Simulation of Premixed Turbulent Combustion in Stagnating Turbulence (in preparation).

Planned future work

Future work will include detailed comparisons with available experiment data under cold and hot flow conditions. From this comparison, assessment of the current large eddy simulation models for both the hydrodynamics and transport of scalars will be considered and, where necessary, modifications to these models will be proposed.

Prepared by	Org. Code	M/S	Phone
Parviz Moin	D	202A-1	(650) 604-5127

Ames Research Center

DIRECTOR'S DISCRETIONARY FUND REPORT

Fiscal Year 1999 Final Report

Title of Investigation

Modeling and Optimization of Ultrafast Semiconductor Quantum Well Devices

Investigator(s) (show affilation)

Cun-Zheng Ning and J. Li, ARC

Funding

Year initiated	FY98	Expected completion date	FY99
Total prior to FY99	$40,000	Authorized in FY99	$40,000
		Requested for FY00 (if any)	

Total expended in FY99 (estimated)

In-house	$5000	
Contracts (identify)		
Grants (identify)	$35,000	$35,000 JRI grant (NCC 2-5267) to Arizona State University

Status of Study

Completed in FY99 [X] Continued in FY00 with funds remaining [ ]

with FY00 funds [ ]

If transitioned to other funding

to RTOP (number)

to Program (name)

to Other (identify)

Purpose of investigation

To demonstrate through numerical simulation the possibility of up to terahertz switching and modulation of semiconductor quantum well lasers for ultrafast information processing and to study the ultimate speed limit for such switching and modulation based on fundamental processes of carrier-carrier and carrier-phonon scatterings in semiconductors.

FY99 applications of results, patents, reports/publications, papers at meetings, awards received, etc.

Ning, C.Z.; Hughes, S.; and Citrin, D.S : Ultrafast Modulation and Switching of Quantum Well Lasers. Photonics West, San Jose, Calif., Jan. 1999.

Li, J.; and Ning, C.Z.: Quantum Well Lasers under THz Modulation. Paper presented at the annual meeting of the Optical Society, Santa Clara, Calif., Sept. 27, 1999.

Ning, C.Z.; Hughes, S.; and Citrin, D.S.: Ultrafast Modulation of Semiconductor Lasers through a Terahertz Field. Appl. Phys. Letts., vol. 75, no. 442, 1999.

Planned future work

None

Prepared by	Org. Code	M/S	Phone
Cun-Zheng Ning	INR	N229-1	(650) 604-3983

Ames Research Center

DIRECTOR'S DISCRETIONARY FUND REPORT

Fiscal Year 1999 Final Report

Title of Investigation

Toward a Phylogeny of Biological Functions

Investigator(s) (show affilation)

Andrew Pohorille, Peter Cheeseman, Karl Schweighofer, and Michael New, ARC

Funding

Year initiated	FY99	Expected completion date	FY00
Total prior to FY99	$40,000	Authorized in FY99	$40,000
		Requested for FY00 (if any)	

Total expended in FY99 (estimated)

In-house	$10,000	
Contracts (identify)		
Grants (identify)	$30,000	JRI with UCSF; NCC2-5295

Status of Study

Completed in FY99 [ ] Continued in FY00 with funds remaining [X]

with FY00 funds [ ]

If transitioned to other funding

to RTOP (number)

to Program (name)

to Other (identify)

Purpose of investigation

To develop and utilize methodology for comparing similar classes of proteins across multiple genomes in order to gain understanding into the mechanisms of how essential cellular functions arise and are preserved.

FY99 applications of results, patents, reports/publications, papers at meetings, awards received, etc.

None

Planned future work

Investigate further several of the partial GABA/glycine homologs to determine whether the entire region is on a single exon, or contiguous exons, in the DNA sequence.

Prepared by	Org. Code	M/S	Phone
Andrew Pohorille	SSX	239-4	(650) 604-5759

Ames Research Center

DIRECTOR'S DISCRETIONARY FUND REPORT

Fiscal Year 1999 Final Report

Title of Investigation

DNA Damage Repair in Nature?

Investigator(s) (show affilation)

Lynn J. Rothschild, ARC; Anita Buma, University of Groningen, Netherlands; and Cindy Wilson, University of Montana

Funding

Year initiated	FY98	Expected completion date	FY99
Total prior to FY99	$40,000	Authorized in FY99	$40,000
		Requested for FY00 (if any)	

Total expended in FY99 (estimated)

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

Status of Study

Completed in FY99 [X] Continued in FY00 with funds remaining [ ]

with FY00 funds [ ]

If transitioned to other funding

to RTOP (number)

to Program (name)

to Other (identify) Funding has been applied for, but decisions not due until May 2000.

Purpose of investigation

To determine if enhanced rates of DNA synthesis in the presence vs. absence of solar UV radation that Rothschild had previously measured in microbial communities was the result of excision repair. If this were true, these would be the first measurements of excision repair in nature.

FY99 applications of results, patents, reports/publications, papers at meetings, awards received, etc.

Rothschild, L.J.: The Influence of UV Radiation on Protistan Evolution. J. Euk. Microbiol, vol. 46, 1999, pp. 548–555.

Rothschild, L.J., and Cockell, C.S.: Radiation, Microbial Evolution and Ecology, and Its Relevance to Mars Missions. Mutation Research, 1999, in press.

Cockell, C.S.; Kepner, R.; Rothschild, L.J.; Catling, D.; Lee, P.; Davis, W.; and McKay, C.P.: The Ultraviolet Photobiology of Mars: Past, Present and Future. Icarus, in press.

Cockell, C.S.; and Rothschild, L.J.: The Effects of Ultraviolet Radiation A and B on Diurnal Variation in Photosynthesis in Three Taxonomically and Ecologically Diverse Microbial Mats. Photochem. Photobiol, vol. 69, 1999, pp. 203–210.

Rothschild, L.J.: Microbes and Radiation. In Origin, Evolution and Versatility of Microorganisms, J. Seckbach, ed. Kluwer, Dordrecht, The Netherlands, 1999, pp. 551–562.

Honors: Elected Fellow of the Linnean Society of London, May 24, 1999

Planned future work

Determine relative influence of oxidative damage induced by UVA vs. direct effect UV radiation. Obtain further proof of excision repair hypothesis. Apply results to astrobiology questions and microgravity experiments.

Prepared by	Org. Code	M/S	Phone
Lynn J. Rothschild	SGE	239-20	(650) 604-6525

Ames Research Center

DIRECTOR'S DISCRETIONARY FUND REPORT

Fiscal Year 1999 Final Report

Title of Investigation

A Cryogenic Chamber for Investigating the Reflectance Properties of Materials as a Function of Temperature

Investigator(s) (show affilation)

Ted L. Roush, ARC

Funding

Year initiated	FY99	Expected completion date	FY00
Total prior to FY99	0	Authorized in FY99	$40,900
		Requested for FY00 (if any)	0

Total expended in FY99 (estimated)

In-house	$30,900		
Contracts (identify)			
Grants (identify)			

Status of Study

Completed in FY99 [ ] Continued in FY00 with funds remaining [X]

with FY00 funds [ ]

If transitioned to other funding

to RTOP (number)

to Program (name)

to Other (identify)

Purpose of investigation

Develop an environmental chamber at Ames that can be interfaced with existing spectrometers in order to characterize the visual and near-infrared spectral reflectance of meteoritic and organic materials over a temperature range appropriate for the outer solar system.

FY99 applications of results, patents, reports/publications, papers at meetings, awards received, etc.

None

Planned future work

Assemble chamber components, test, and begin research measurements.

Prepared by	Org. Code	M/S	Phone
Ted L. Roush	SST	245-3	(650) 604-3526

Ames Research Center

DIRECTOR'S DISCRETIONARY FUND REPORT

Fiscal Year 1999 Final Report

Title of Investigation

Stability Properties of an Initially Stationary Two-Dimensional Separation Bubble

Investigator(s) (show affilation)

Murray Tobak, ARC; Jonathan H. Watmuff, MCAT Inst., ARC; Ronald D. Henderson, California Institute of Technology

Funding

Year initiated	FY99	Expected completion date	FY99
Total prior to FY99		Authorized in FY99	$5500
		Requested for FY00 (if any)	

Total expended in FY99 (estimated)

In-house	$5500		
Contracts (identify)			
Grants (identify)			

Status of Study

Completed in FY99 [X] Continued in FY00 with funds remaining [ ]

with FY00 funds [ ]

If transitioned to other funding

to RTOP (number)

to Program (name)

to Other (identify)

Purpose of investigation

To achieve a one-to-one correspondence between experimental observations and computational predictions of the instability mechanisms underlying the behavior of an initially two-dimensional (2-D) separation bubble.

FY99 applications of results, patents, reports/publications, papers at meetings, awards received, etc.

None

Planned future work

None

Prepared by	Org. Code	M/S	Phone
Murray Tobak / Jonathan H. Watmuff	AIP	260-1	(650) 604-5855

Appendix A-2
Ongoing Reports

Ames Research Center

DIRECTOR'S DISCRETIONARY FUND REPORT

Fiscal Year 1999

Title of Investigation

Determining the Atmosphere of Life: An Experimental Approach

Investigator(s) (show affilation)

Brad Bebout and David Des Marais, ARC; Pieter Visscher, University of Connecticut

Funding

Year initiated	FY99	Expected completion date	FY00
Total prior to FY99	0	Authorized in FY99	$40,000
		Requested for FY00 (if any)	$40,000

Total expended in FY99 (estimated) $40,000

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

Status of Study

Completed in FY99 [ ] Continued in FY00 with funds remaining [ ]

with FY00 funds [X]

If transitioned to other funding

to RTOP (number)

to Program (name)

to Other (identify)

Purpose of investigation

In support of NASA's strategy, to detect potentially biogenic trace gases in the atmospheres of extrasolar planets, we are quantifying the production and consumption of biogenic gases in modern analogues of early Earth microbial communities.

FY99 applications of results, patents, reports/publications, papers at meetings, awards received, etc.

Abstract: "Measurements of the Production and Consumption of Trace Gases by Modern Analogues of Early Earth Microbial Communities: Relevance to the Spectroscopic Search for Biogenic Gases on Extrasolar Planets" submitted to Am. Geophys.U. annual meeting (Astrobiology session).

Planned future work

Additional characterization of the trace gas concentrations within microbial communities will be made using microsensors and incubation of modern-day microbial communities under early Earth atmospheres.

Prepared by	Org. Code	M/S	Phone
Brad Bebout	SSX	239-4	(650) 604-3227

Ames Research Center

DIRECTOR'S DISCRETIONARY FUND REPORT

Fiscal Year 1999

Title of Investigation

Modeling Dust Grains in Protoplanetary Disk Atmospheres

Investigator(s) (show affilation)

K. Robbins Bell and Diane H. Wooden, ARC; Steve Desch and David Harker, NRC; and Whitney Raas, UCLA

Funding

Year initiated	FY99	Expected completion date	FY00
Total prior to FY99	0	Authorized in FY99	$15,000
		Requested for FY00 (if any)	$15,000

Total expended in FY99 (estimated)

In-house	$8000	
Contracts (identify)	$7000	NRC
Grants (identify)		

Status of Study

Completed in FY99 [ ] Continued in FY00 with funds remaining [ ]

with FY00 funds [X]

If transitioned to other funding

to RTOP (number)

to Program (name)

to Other (identify)

Purpose of investigation

To demonstrate that the silicate feature at 9.7 microns that is commonly observed in young stellar objects is consistent with emission from dust in the optically thin atmospheres of Pre-Main Sequence disks (solar nebula analogs). Data from long-term medium-resolution spectroscopic monitoring of this feature (CoI and collaborators) will be used to constrain the numerical disk models under study, resulting in a derivation of dust geometry, dynamics, and dust chemical evolution.

FY99 applications of results, patents, reports/publications, papers at meetings, awards received, etc.

Bell, Wooden, and Desch each presented independent posters at the Gordon Research Conference on Origins of Solar Systems, June 1999, New Hampshire.

Bell, Wooden, and Desch also each presented independent posters at the Center for Star Formation workshop, July 1999, Santa Cruz, Calif.

Planned future work

Continue work to achieve goals given.

Prepared by	Org. Code	M/S	Phone
K. Robbins Bell	SST	245-3	(650) 604-0788

Ames Research Center

DIRECTOR'S DISCRETIONARY FUND REPORT

Fiscal Year 1999

Title of Investigation

SOI Electronics for "Faster, Better, Cheaper" Spacecraft

Investigator(s) (show affilation)

Bryan A. Biegel, ARC; Mohamed A. Osman and Salah Awadalla, Washington State University

Funding

Year initiated	FY99	Expected completion date	FY00
Total prior to FY99	0	Authorized in FY99	$40,000
		Requested for FY00 (if any)	$40,000

Total expended in FY99 (estimated)

In-house		
Contracts (identify)		
Grants (identify)	$30,000	$4000 EAP grant #1999115; $26,000 JRI grant (NCC 2-5346) to Washington State University

Status of Study

Completed in FY99 [ ] Continued in FY00 with funds remaining [ ]

with FY00 funds [X]

If transitioned to other funding

to RTOP (number)

to Program (name)

to Other (identify)

Purpose of investigation

We are investigating through numerical simulation whether a new electronics technology, aluminum-nitride (AlN) silicon-on-insulator (SOI), can achieve predicted dramatic improvements in the radiation-hardness, heat immunity, small size, and low power of space-based electronics.

FY99 applications of results, patents, reports/publications, papers at meetings, awards received, etc.

Awadalla, Salah: Low-Power, Fast SOI (Silicon-on-Insulator) Electronics for Space Applications. Final report to Ames Educational Associates Program, Aug. 2, 1999.

Planned future work

Our objectives in this work are to use the electronic device modeling program PROPHET:
* To show that AlN-based SOI overcomes the self-heating problem of standard SOI.
* To demonstrate the significantly better operation of AlN-based SOI for advanced, space-based electronics. To accomplish this, we will compare the operation of equivalent conventional metal-oxide-semiconductor field effect transistor (MOSFET), standard SOI, and AlN-based SOI devices under the extremes of small device size, low voltage/power, low and high temperature, and high radiation exposure.
* To optimize AlN-based SOI technology for space applications.

Prepared by	Org. Code	M/S	Phone
Bryan A. Biegel	INR	T27A-1	(650) 604-0171

Ames Research Center

DIRECTOR'S DISCRETIONARY FUND REPORT

Fiscal Year 1999

Title of Investigation

Obtaining Mass and Density of Extrasolar Giant Planets: Measurement of Planetary Transits

Investigator(s) (show affilation)

Timothy P. Castellano, ARC; Laurance Doyle and Jon Jenkins SETI Institute, ARC

Funding

Year initiated	FY99	Expected completion date	FY00
Total prior to FY99	0	Authorized in FY99	$37,000
		Requested for FY00 (if any)	$39,000

Total expended in FY99 (estimated)

In-house	$25,000		
Contracts (identify)			
Grants (identify)	$10,000		

Status of Study

Completed in FY99	☐	Continued in FY00 with funds remaining	☐
		with FY00 funds	X

If transitioned to other funding

to RTOP (number)	
to Program (name)	
to Other (identify)	

Purpose of investigation

To obtain the mass and density of extrasolar giant planets by high-precision, ground-based photometric monitoring of stars that have known planets during times of predicted transit.

FY99 applications of results, patents, reports/publications, papers at meetings, awards received, etc.

Friday Lunchtime Astronomy Seminar Series (FLASH) talk was presented at the University of California, Santa Cruz, on August 29, 1999.

Planned future work

Continue the investigation by adding newly discovered short-period planets to the target list. Improve and automate photometry and data reduction.

Prepared by	Org. Code	M/S	Phone
Tim Castellano	SSA	245-6	(650) 604-4716

Ames Research Center

DIRECTOR'S DISCRETIONARY FUND REPORT

Fiscal Year 1999

Title of Investigation

Interacting Robotic Elements for Autonomous Space Applications

Investigator(s) (show affiliation)

Silvano P. Colombano, Al Globus, Gary L. Haith, Creon Levit, Jason D. Lohn, and Dimitris Stassinopoulos, ARC

Funding

Year initiated	FY99	Expected completion date	FY00
Total prior to FY99	0	Authorized in FY99	$40,000
		Requested for FY00 (if any)	$40,000

Total expended in FY99 (estimated)

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

Status of Study

Completed in FY99 [ ] Continued in FY00 with funds remaining [ ]

with FY00 funds [X]

If transitioned to other funding

to RTOP (number)

to Program (name)

to Other (identify)

Purpose of investigation

To explore, using physical robotic hardware, control strategies for robotic systems with many robotic elements that must act in coordination.

FY99 applications of results, patents, reports/publications, papers at meetings, awards received, etc.

Working robotic hardware has been designed, built, and assembled. It is currently controlled with open-loop gait generators.

"A Serpentine Robot for Planetary and Asteroid Surface Exploration." Abstract submitted to Fourth IAA International Conference on Low-Cost Planetary Missions.

Planned future work

We plan to build a stronger, lighter, more powerful mechanism that will incorporate pressure sensing, position, light, and proximity sensing. Using this new mechanism, we will explore collective approaches to closed-loop control for a variety of tasks, including servoing to a light and light digging.

Prepared by	Org. Code	M/S	Phone
Gary L. Haith	IC	269-3	(650) 604-3049

Ames Research Center

DIRECTOR'S DISCRETIONARY FUND REPORT

Fiscal Year 1999

Title of Investigation

Evolvable Hardware: Automatic Design of Realizable, Active, Integrated Circuits

Investigator(s) (show affiliation)

Silvano P. Colombano, ARC; and Jason D. Lohn, Caelum Research Corporation

Funding

Year initiated	FY99	Expected completion date	FY00
Total prior to FY99	0	Authorized in FY99	$40,000
		Requested for FY00 (if any)	$40,000

Total expended in FY99 (estimated)

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

Status of Study

Completed in FY99 [ ] Continued in FY00 with funds remaining [ ]

with FY00 funds [X]

If transitioned to other funding

to RTOP (number)

to Program (name)

to Other (identify)

Purpose of investigation

To use computer-simulated Darwinian evolution to automatically produce integrated electronic circuit designs whose properties permit physical implementation in silicon.

FY99 applications of results, patents, reports/publications, papers at meetings, awards received, etc.

Patent application submitted: "System and Method and Computer Program Product for Automated Circuit Design Using Linear Genetic Algorithms." J. Lohn and S. Colombano, Inventors, March 1999.

Artificial Evolution of Analog Circuits. Paper given at Navy Center for Applied Research in Artificial Intelligence Spring 1999 Seminar Series, Naval Research Laboratory, Washington, D.C., Apr. 1999.

Planned future work

Our focus is semiconductor fabrication of evolved amplifier designs. We will continue improving our amplifier designs using coevolutionary search for multi-objective optimization.

Prepared by	Org. Code	M/S	Phone
Jason D. Lohn	IC	269-1	(650) 604-5138

Ames Research Center

DIRECTOR'S DISCRETIONARY FUND REPORT

Fiscal Year 1999

Title of Investigation

Effect of Clear Cutting vs. Natural Burn on a Dominant Forest Ecosystem

Investigator(s) (show affilation)

Ken Cullings, Ames Research Center

Funding

Year initiated	FY99	Expected completion date	FY01
Total prior to FY99	0	Authorized in FY99	$40,000
		Requested for FY00 (if any)	$40,000

Total expended in FY99 (estimated)

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

Status of Study

Completed in FY99 [ ] Continued in FY00 with funds remaining [ ]

with FY00 funds [X]

If transitioned to other funding

to RTOP (number)

to Program (name)

to Other (identify)

Purpose of investigation

To determine effects of different types of disturbance on microbial communities.

FY99 applications of results, patents, reports/publications, papers at meetings, awards received, etc.

None as yet. Study was begun in late spring, samples collected, and analysis is just beginning.

Planned future work

Complete Year 1 analysis, and proceed with Year 2 sampling and analysis.

Prepared by	Org. Code	M/S	Phone
Ken Cullings	SSX	239-4	(650) 604-2773

Ames Research Center

DIRECTOR'S DISCRETIONARY FUND REPORT

Fiscal Year 1999

Title of Investigation

The Role of H_2 in Microbial Community Evolution and the Search for Life on Extrasolar Planets

Investigator(s) (show affilation)

David J. Des Marais, ARC; and Tori M. Hoehler, National Research Council

Funding

Year initiated	FY99	Expected completion date	FY00
Total prior to FY99	0	Authorized in FY99	$40,000
		Requested for FY00 (if any)	$40,000

Total expended in FY99 (estimated)

In-house	$37,000	
Contracts (identify)	$18,360	Equipment, supplies, service contract for biogeochemical analyses
Grants (identify)	$20,000	Co-op agreement for technician

Status of Study

Completed in FY99		Continued in FY00	with funds remaining	
			with FY00 funds	X

If transitioned to other funding

to RTOP (number)

to Program (name)

to Other (identify)

Purpose of investigation

To understand the importance of hydrogen in shaping the structure, function, and emergent properties of microbial ecosystems, with particular respect to its role in regulating emissions of reduced "biosignature" gases.

FY99 applications of results, patents, reports/publications, papers at meetings, awards received, etc.

None

Planned future work

Year 2 will focus on intensive application of our newly developed gas chromatograph (GC)-based methodologies to Baja and Yellowstone field sites. Additionally, work on development of hydrogen microsensor technology will begin.

Prepared by	Org. Code	M/S	Phone
Tori M. Hoehler	SSX	239-4	(650) 604-1355

Ames Research Center

DIRECTOR'S DISCRETIONARY FUND REPORT

Fiscal Year 1999

Title of Investigation

Darwin's Eye—Light at the Bottom of the Ocean

Investigator(s) (show affilation)

Michael Flynn, ARC; Chuck Fisher, Pennsylvania State University; and Cindy Lee Van Dover, College of William and Mary

Funding

Year initiated	FY99	Expected completion date	FY00
Total prior to FY99	0	Authorized in FY99	$40,000
		Requested for FY00 (if any)	$40,000

Total expended in FY99 (estimated)

In-house	$5000	
Contracts (identify)	$20,000	McLane Labs
Grants (identify)	$15,000	Pennsylvania State University

Status of Study

Completed in FY99 [ ] Continued in FY00 with funds remaining [ ]

with FY00 funds [X]

If transitioned to other funding

to RTOP (number)

to Program (name)

to Other (identify)

Purpose of investigation

To determine if chemoautotrophic organisms exist in the vicinity of hydrothermal vents that have the capability to utilize nonsolar electromagnetic radiation.

FY99 applications of results, patents, reports/publications, papers at meetings, awards received, etc.

Flynn, M.; Hines, J.; and McKay, C.: Astrobiology Hydrothermal Vent Field Deployment- FY99. Paper presented at the 30th International Conference on Environmental Systems, SAE, in press.

Planned future work

Analytical evaluation of collected samples and second FY00 sample collection dive.

Prepared by	Org. Code	M/S	Phone
Michael Flynn	SSR	239-15	(650) 604-1163

Ames Research Center

DIRECTOR'S DISCRETIONARY FUND REPORT

Fiscal Year 1999

Title of Investigation

Survivability of Microbes in Mars' Wind-Blown Dust Environment

Investigator(s) (show affilation)

Mark L. Fonda, ARC; and Rocco Mancinelli, SETI Institute, ARC

Funding

Year initiated	FY99	Expected completion date	FY00
Total prior to FY99	0	Authorized in FY99	$40,000
		Requested for FY00 (if any)	$40,000

Total expended in FY99 (estimated)

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

Status of Study

Completed in FY99 [ ] Continued in FY00 with funds remaining [ ]

with FY00 funds [X]

If transitioned to other funding

to RTOP (number)

to Program (name)

to Other (identify)

Purpose of investigation

Our hypothesis is that Earth microorganisms can survive under wind-blown Mars dust-storm conditions. To determine the potential of survivability of airborne Earth microbes on the surface of Mars during a dust storm, we have the following objectives: 1) Determine how long microorganisms can survive in a simulated Martian dust environment. 2) Under what conditions Earth microbes in a Mars wind-blown environment survive best, relating to soil type and particle size.

FY99 applications of results, patents, reports/publications, papers at meetings, awards received, etc.

Mancinelli, R.L.; White, M.R.; and Rothschild, L.J.: Biopan-Survival I: Exposure of the Osmophiles Synechococcus (Nägeli) sp. and Haloarcula sp. to the Space Environment. Adv. Space Res., vol. 22, no. 3, 1998, pp. 327–334.

Planned future work

We will continue testing B. subtilis and will add E. coli to the organisms that we test. We will expose the organisms alone and in combination for increasing periods of time until either all the organisms die, or the exposed population reaches a steady state of survival.

Prepared by	Org. Code	M/S	Phone
Rocco L. Mancinelli	SSX	239-12	(650) 604-6165

Ames Research Center

DIRECTOR'S DISCRETIONARY FUND REPORT

Fiscal Year 1999

Title of Investigation

Energy Metabolism of Cultured Cells in Continuous Hypergravity

Investigator(s) (show affilation)

Ruth K. Globus, ARC; Carsten Mundt, Sverdrup, ARC; Steven Weinstein, SFSU; and Svetlana Komarova, NRC

Funding

Year initiated	FY99	Expected completion date	FY 2000
Total prior to FY99	0	Authorized in FY99	$40,000
		Requested for FY00 (if any)	$40,000

Total expended in FY99 (estimated)

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

Status of Study

Completed in FY99	☐	Continued in FY00	with funds remaining	☐
			with FY00 funds	X

If transitioned to other funding

to RTOP (number)

to Program (name)

to Other (identify)

Purpose of investigation

Determine if exposure of cultured cells to hypergravity by centrifugation stimulates energy metabolism, including respiratory rate.

FY99 applications of results, patents, reports/publications, papers at meetings, awards received, etc.

None

Planned future work

Complete oxygen sensor unit testing. Measure oxygen using sensor unit in macrophages and bone cells during centrifugation at different stages of differentiation.

Prepared by	Org. Code	M/S	Phone
Ruth Globus	SLR	236-7	(650) 604-5247

Ames Research Center

DIRECTOR'S DISCRETIONARY FUND REPORT

Fiscal Year 1999

Title of Investigation

Simulation-Based Prototyping of Solid-State Quantum Computers: A Pathway for Revolutionary Computing in the 21st Century

Investigator(s) (show affilation)

T. R. Govindan, ARC; Deepak Srivastava, MRJ, Inc., ARC; and Kyeongjae Cho and Seongjun Park, Stanford University

Funding

Year initiated	FY99	Expected completion date	FY00
Total prior to FY99	0	Authorized in FY99	$40,000
		Requested for FY00 (if any)	$40,000

Total expended in FY99 (estimated)

In-house	$8000	
Contracts (identify)		
Grants (identify)	$30,000	$30,000 JRI grant awarded to Stanford University

Status of Study

Completed in FY99 [ ] Continued in FY00 with funds remaining [ ]

with FY00 funds [X]

If transitioned to other funding

to RTOP (number)

to Program (name)

to Other (identify)

Purpose of investigation

Through atomistic, tight-binding, and ab initio simulations, we are investigating if it is feasible to encapsulate atomic/ionic dopants in bucky onions for solid-state quantum computer applications in bulk silicon.

FY99 applications of results, patents, reports/publications, papers at meetings, awards received, etc.

None

Planned future work

To test the electronic properties of an encapsulated atomic dopant (P atom) in the inner core shell of a pressurized bucky onnion. If the properties are found suitable for quantum computer application, we will proceed with the second phase of testing arrays of such encapsulated dopants in bulk silicon.

Prepared by	Org. Code	M/S	Phone
Deepak Srivastava	INR	T27A-1	(650) 604-3486

Ames Research Center

DIRECTOR'S DISCRETIONARY FUND REPORT

Fiscal Year 1999

Title of Investigation

Investigating the Youngest Stars with High-Resolution Infrared Spectroscopic Observations

Investigator(s) (show affilation)

Thomas P. Greene, ARC

Funding

Year initiated	FY99	Expected completion date	FY01
Total prior to FY99	0	Authorized in FY99	$40,000
		Requested for FY00 (if any)	$39,000

Total expended in FY99 (estimated)

In-house	$40,000	Includes $12,000 to Education Associates and $23,000 to SETS
Contracts (identify)		
Grants (identify)		

Status of Study

Completed in FY99 [ ] Continued in FY00 with funds remaining [ ]

with FY00 funds [X]

If transitioned to other funding

to RTOP (number)

to Program (name)

to Other (identify)

Purpose of investigation

Understand the early evolution of young stars and their preplanetary disks by conducting Infrared spectroscopic observations.

FY99 applications of results, patents, reports/publications, papers at meetings, awards received, etc.

None

Planned future work

Conduct, reduce, and interpret more observations.

Prepared by	Org. Code	M/S	Phone
Thomas Greene	SSA	245–6	(650) 604-5520

Ames Research Center

DIRECTOR'S DISCRETIONARY FUND REPORT

Fiscal Year 1999

Title of Investigation

Computer Modeling in Bio-Nanotechnology: Computer-Aided Genetic Engineering of a Protein-Based Holographic Data Storage Material

Investigator(s) (show affilation)

Richard Jaffe, Andrew Pohorille, Dogan Timucin, and Andreas Parusel, ARC; Ann Hermone, UCSF, ARC

Funding

Year initiated	FY99	Expected completion date	FY00
Total prior to FY99	0	Authorized in FY99	$40,000
		Requested for FY00 (if any)	$40,000

Total expended in FY99 (estimated)

In-house		
Contracts (identify)		
Grants (identify)	$40,000	NCC 2-5294 to UCSF

Status of Study

Completed in FY99 [ ] Continued in FY00 with funds remaining [ ]

with FY00 funds [X]

If transitioned to other funding

to RTOP (number)

to Program (name)

to Other (identify)

Purpose of investigation

Use qunatum chemistry and molecular dynamics simulations to study the intial step of the photoisomerization process in bacteriorhodopsin in order to understand how to genetically engineer the protein to enhance the photocycle for the purpose of holographic data storage.

FY99 applications of results, patents, reports/publications, papers at meetings, awards received, etc.

Hermone, A. and Jaffe, R.:Computer-Aided Genetic Engineering of Bacteriorhodopsin. Paper presented at 1999 Centennial Meeting of American Physical Society, Atlanta, Georgia, Mar. 1999.

Planned future work

Run simulations.

Prepared by	Org. Code	M/S	Phone
Richard Jaffe	ASC	230-3	(650) 604-6458

Ames Research Center

DIRECTOR'S DISCRETIONARY FUND REPORT

Fiscal Year 1999

Title of Investigation

Development of a Parallel Processing Cloud Physics Model

Investigator(s) (show affilation)

Eric Jensen, Andrew Ackerman, and Nagi Mansour, ARC

Funding

Year initiated	FY99	Expected completion date	FY00
Total prior to FY99	0	Authorized in FY99	$40,000
		Requested for FY00 (if any)	$80,000

Total expended in FY99 (estimated)

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

Status of Study

Completed in FY99	☐	Continued in FY00 with funds remaining	☐
		with FY00 funds	X

If transitioned to other funding

to RTOP (number)

to Program (name)

to Other (identify)

Purpose of investigation

To develop a parallel processing cloud physics model.

FY99 applications of results, patents, reports/publications, papers at meetings, awards received, etc.

Planned future work

Explore system-related issues required to run our code on the SGI Origin machines at Ames.

Prepared by	Org. Code	M/S	Phone
Eric Jensen	SGP	245-4	(650) 604-4392

Ames Research Center

DIRECTOR'S DISCRETIONARY FUND REPORT

Fiscal Year 1999

Title of Investigation

EEG Monitoring of Cognitive Workload

Investigator(s) (show affilation)

Bernadette Luna and Mark Kliss, ARC; Leslie D. Montgomery and Yu-Tsuan Ku, Lockheed Martin Engineering and Sciences, ARC; and Raul Guisado, Center for Neurodiagnostic Study

Funding

Year initiated	FY99	Expected completion date	FY00
Total prior to FY99	0	Authorized in FY99	$40,000
		Requested for FY00 (if any)	$40,000

Total expended in FY99 (estimated)

In-house		
Contracts (identify)	$12,000	Lockheed Martin Engineering and Sciences NAS2-14263
Grants (identify)		

Status of Study

Completed in FY99		Continued in FY00 with funds remaining	X
		with FY00 funds	X

If transitioned to other funding

to RTOP (number)

to Program (name)

to Other (identify)

Purpose of investigation

To test our hypotheses that (1) an energy density index of neural activity can be correlated with performance during a continuous, extended-length arithmetic task presented via a video display terminal (VDT), and that (2) changes in the index will precede changes in performance.

FY99 applications of results, patents, reports/publications, papers at meetings, awards received, etc.

None

Planned future work

Examine the local (electrode-specific) relationship of the energy metric with performance in search of underlying commonality, and modify the arithmetic task to achieve a higher level of difficulty.

Prepared by	Org. Code	M/S	Phone
Bernadette Luna	SSR	239-15	(650) 604-5250

Ames Research Center

DIRECTOR'S DISCRETIONARY FUND REPORT

Fiscal Year 1999

Title of Investigation

Coherent and Miniaturized Terahertz Sources for Space- and Earth-Based Applications

Investigator(s) (show affilation)

Cun-Zheng Ning and T.R. Govindan, ARC; A. Liu, Arizona State University, ARC

Funding

Year initiated	FY99	Expected completion date	FY00
Total prior to FY99	0	Authorized in FY99	$40,000
		Requested for FY00 (if any)	$40,000

Total expended in FY99 (estimated)

In-house	$5000		
Contracts (identify)			
Grants (identify)	$35,000		

Status of Study

Completed in FY99 [ ] Continued in FY00 with funds remaining [ ]

with FY00 funds [X]

If transitioned to other funding

to RTOP (number)

to Program (name)

to Other (identify)

Purpose of investigation

We are investigating the possibility of generating coherent terahertz radiation in semiconductor quantum well intersubband transitions. We are investigating the physical processes in such a quantum structure, such as Raman and exitonic processes, to mazimize the optical gain to eventually achieve lasing operation in such structures.

FY99 applications of results, patents, reports/publications, papers at meetings, awards received, etc.

Liu, Ansheng; and Ning, C.Z.: Terahertz Optical Gain Based on Intersubband Transitions in Optically Pumped Semiconductor Quantum Wells: Coherent Pump-Probe Interactions. Applied Phys. Letters, vol. 75, no. 9, Aug. 30, 1999, pp. 1207–1209.

Liu, A.; and Ning, C.Z.: Exiton-Enhanced Intersubband Raman Gain in Semiconductor Quantum Wells. Optical Society Annual Meetings, Santa Clara, Calif., Sept. 27–Oct. 1, 1999.

Liu, A.; and Ning, C.Z.: Coherent Pump-Probe Interactions and Terahertz Intersubband Gain in Semiconductor Quantum Wells. Integrated Photonics Research Conference (IPR'99), Santa Barbara, Calif., July 19–23, 1999.

Planned future work

To study other gain-enhancing processes, such as exiton effects. To finalize a structure based on all the gain-enhancing processes with maximized optical gain and minimized loss. To collaborate with Arizona State University to grow and experimentally test the structure for terahertz lasing.

Prepared by	Org. Code	M/S	Phone
Cun-Zheng Ning	INR	N229-1	(650) 604-3983

Ames Research Center

DIRECTOR'S DISCRETIONARY FUND REPORT

Fiscal Year 1999

Title of Investigation

A Self-Configuring Biomimetic Wing—A New Concept for the Mars Airplane

Investigator(s) (show affilation)

Shishir Pandya, ARC; David Kenwright and Chris Henze, MRJ, Inc., ARC; and Ravi Samtaney, MRJ, Inc./California Institute of Technology

Funding

Year initiated	FY99	Expected completion date	FY01
Total prior to FY99	0	Authorized in FY99	$40,000
		Requested for FY00 (if any)	$40,000

Total expended in FY99 (estimated)

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

Status of Study

Completed in FY99	☐	Continued in FY00 with funds remaining	☐
		with FY00 funds	X

If transitioned to other funding

to RTOP (number)	
to Program (name)	
to Other (identify)	

Purpose of investigation

To develop a computational fluid dynamics (CFD) computer code to simulate the flight characteristics and control mechanisms of a biomimetic wing: a wing inspired by nature that can reshape during flight to suit the atmospheric conditions and the task it must perform.

FY99 applications of results, patents, reports/publications, papers at meetings, awards received, etc.

None

Planned future work

Extend the algorithm and incorporate viscous effects and turbulence models.

Prepared by	Org. Code	M/S	Phone
Shishir Pandya	AI	T27B-1	(650) 604-3981

Ames Research Center

DIRECTOR'S DISCRETIONARY FUND REPORT

Fiscal Year 1999

Title of Investigation

NASA Center for Computational Astrobiology (NCCA)

Investigator(s) (show affilation)

Andrew Pohorille and Christopher Potter, ARC; and Shoudan Liang, SETI Inst., ARC

Funding

Year initiated	FY99	Expected completion date	FY00
Total prior to FY99	0	Authorized in FY99	$100,000
		Requested for FY00 (if any)	0

Total expended in FY99 (estimated)

In-house	$85,000	
Contracts (identify)		
Grants (identify)	$15,000	JRI with Stanford and UCSF

Status of Study

Completed in FY99 [ ] Continued in FY00 with funds remaining [X]

with FY00 funds [ ]

If transitioned to other funding

to RTOP (number)

to Program (name)

to Other (identify)

Purpose of investigation

(1) To build mathematical models of nongenomic origin of life; (2) to model microbial ecosystem dynamics; and (3) to investigate mechanism of gene expression by analyzing complementary sequences in genomes.

FY99 applications of results, patents, reports/publications, papers at meetings, awards received, etc.

New, M.H.; and Pohorille, A.: An Inherited Efficiencies Model of Nongenomic Evolution. *Simulation Theory and Practice*, submitted.

Planned future work

(1) Extend the initial model of two protein functions to many-functional systems; (2) continue modeling of microbial systems ; and (3) statistically analyze complementary sequences of unknown function in genomes and establish their role in termination of gene transcription.

Prepared by	Org. Code	M/S	Phone
Andrew Pohorille	SSX	239-4	(650) 604-5759

Ames Research Center

DIRECTOR'S DISCRETIONARY FUND REPORT

Fiscal Year 1999

Title of Investigation

Unsteady Pressure Measurements on Helicopter Rotors Using Pressure-Sensitive Paint

Investigator(s) (show affilation)

Edward T. Schairer, Larry A. Hand, James H. Bell, and Rabi Mehta, ARC

Funding

Year initiated	FY99	Expected completion date	FY00
Total prior to FY99	0	Authorized in FY99	$40,000
		Requested for FY00 (if any)	$40,000

Total expended in FY99 (estimated)

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

Status of Study

Completed in FY99 [ ] Continued in FY00 with funds remaining [ ]

with FY00 funds [X]

If transitioned to other funding

to RTOP (number)

to Program (name)

to Other (identify)

Purpose of investigation

To study the dynamic response of pressure-sensitive paint for unsteady pressure measurements on helicopter rotor blades.

FY99 applications of results, patents, reports/publications, papers at meetings, awards received, etc.

Two presentations were given at the 7th Annual Pressure-Sensitive Paint Workshop at Purdue University, Oct. 11–13 1999: (1) Optimum Thickness of Pressure-Sensitive Paint for Unsteady Measurements (E. Schairer), and (2) Control of Spectral Leakage in Luminescence Measurements (L. Hand).

Planned future work

Unsteady pressure-sensitive paint (PSP) measurements will be made on an oscillating two-dimensional airfoil. The PSP measurements will be compared to measurements using unsteady pressure transducers. The model has been built, and the transducers and data acquisition system have been purchased. An apparatus will be built to study the unsteady responses of PSP in a controlled environment.

Prepared by	Org. Code	M/S	Phone
Edward T. Schairer	AIP	260-1	(650) 604-6925

Ames Research Center

DIRECTOR'S DISCRETIONARY FUND REPORT

Fiscal Year 1999

Title of Investigation

Development of a System for Quantifying in vivo Bone Strains in Rodents in Normal and Altered Gravity Environments

Investigator(s) (show affilation)

Julie Schonfeld, ARC; B. Halloran, UCSF; Brian Rabkin, UCSF/UC Berkeley; and John Szivek, U. of Arizona

Funding

Year initiated	FY99	Expected completion date	FY00
Total prior to FY99	0	Authorized in FY99	$39,580
		Requested for FY00 (if any)	$39,760

Total expended in FY99 (estimated)

In-house	$32,380
Contracts (identify)	$7200
Grants (identify)	

Status of Study

Completed in FY99 [ ] Continued in FY00 with funds remaining [ ]

with FY00 funds [X]

If transitioned to other funding

to RTOP (number)

to Program (name)

to Other (identify)

Purpose of investigation

To develop a permanent method of strain gauge attachment to bone, and a corresponding implantable biotelemetry system to quantify bone strains in rodents on a long-term basis.

FY99 applications of results, patents, reports/publications, papers at meetings, awards received, etc.

Posters, American Society for Bone and Mineral Research (Sept. 1999) and the American Society for Gravitational and Space Biology (Oct. 1999).

Planned future work

Explore alternate materials for better attachment of the strain gauge to the bone and test and utilize the bone strain biotelemetry instrumentation developed.

Prepared by	Org. Code	M/S	Phone
Julie Schonfeld	FES	213-2	(650) 604-6504

Ames Research Center

DIRECTOR'S DISCRETIONARY FUND REPORT

Fiscal Year 1999

Title of Investigation

Telepresent Exploration of Hydrothermal Vent System in Antartica

Investigator(s) (show affilation)

Carol Stoker, Larry Lemke, Jeff Ota, Daryl Rasmussen, and Ted Blackmon, ARC

Funding

Year initiated	FY99	Expected completion date	FY00
Total prior to FY99	0	Authorized in FY99	$40,000
		Requested for FY00 (if any)	$ 40,000

Total expended in FY99 (estimated)

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

Status of Study

Completed in FY99 [ ] Continued in FY00 with funds remaining [ ]

with FY00 funds [X]

If transitioned to other funding

to RTOP (number)

to Program (name)

to Other (identify)

Purpose of investigation

To develop telepresence systems for the study of underwater environments relevant to Astrobiology. These systems will include the following elements:

1) A lightweight, portable, remotely operated submarine vehicle (ROV) capable of being rapidly deployed in either ocean or lake settings,
2) A virtual reality data archiving capability that can support analysis and archiving of data acquired during field deployments of the ROV.

FY99 applications of results, patents, reports/publications, papers at meetings, awards received, etc.

Weast, Aaron B.; Ota, Jeffrey M.; Kitts, Christopher A.; Bulich, Chad; Laurence, Alana M.; Lwin, Calvin M.; Wigle, Trevor D.; Perkins, William B.; and Cook, Jason F.:Integrating Digital Stereo Cameras with Mars Pathfinder Technology for 3D Regional Mapping Underwater. Proceedings of the 1999 IEEE Aerospace Conference, vol. 1, Snomass, CO, March 6–13, 1999.

Derbes, Alex; and Ota, Jeff: Mars Pathfinder Robotics Visualization Applied to Submarine Archaeology. Proceedings of the 1999 Underwater Intervention Conference, New Orleans, LA, January 1999.

Planned future work

Integrate stereo modeling on underwater vehicle and demonstrate in field deployment in a hydrothermal environment.

Prepared by	Org. Code	M/S	Phone
Carol Stoker	SST	245-3	(650) 604-6490

Ames Research Center

DIRECTOR'S DISCRETIONARY FUND REPORT

Fiscal Year 1999

Title of Investigation

In Search of MONSTERS (Multicellular Organisms Not Seen by Traditional Environmental Researchers)

Investigator(s) (show affilation)

Jonathan Trent and John Hines, ARC

Funding

Year initiated	FY99	Expected completion date	FY00
Total prior to FY99	0	Authorized in FY99	$40,000
		Requested for FY00 (if any)	$40,000
Total expended in FY99 (estimated)			
In-house	$20,000		
Contracts (identify)	$20,000	UCSC	
Grants (identify)			

Status of Study

Completed in FY99 [ ] Continued in FY00 with funds remaining [ ]

with FY00 funds [X]

If transitioned to other funding

to RTOP (number)

to Program (name)

to Other (identify)

Purpose of investigation

To answer the fundamental astrobiological questions:

- What are the upper temperature limits for macroscopic eukarya on Earth?
- How do environmental factors such as dissolved oxygen and pH impact such organisms in high-temperature habitats?

FY99 applications of results, patents, reports/publications, papers at meetings, awards received, etc.

Planned future work

Upgrade sensors and acquire a mobile (pioneer) camera system; and continue the search in Yellowstone National Park and in other areas.

Prepared by	Org. Code	M/S	Phone
Jonathan Trent	SSX	239-4	(650) 604-3686

Ames Research Center

DIRECTOR'S DISCRETIONARY FUND REPORT

Fiscal Year 1999

Title of Investigation

Modeling Cholera Outbreaks Using Remotely Sensed Data

Investigator(s) (show affilation)

Byron L. Wood and Brad Lobitz, ARC

Funding

Year initiated	FY99	Expected completion date	FY00
Total prior to FY99	0	Authorized in FY99	$33,000
		Requested for FY00 (if any)	$33,000

Total expended in FY99 (estimated)

In-house	$33,000		
Contracts (identify)			
Grants (identify)			

Status of Study

Completed in FY99 [ ] Continued in FY00 with funds remaining [ ]

with FY00 funds [X]

If transitioned to other funding

to RTOP (number)

to Program (name)

to Other (identify)

Purpose of investigation

To determine if a remote-sensing-based model can be developed to predict cholera outbreaks in Latin America and other coastal regions of the world.

FY99 applications of results, patents, reports/publications, papers at meetings, awards received, etc.

A preliminary model has been developed using historical data from Bangladesh and Peru.

Planned future work

To validate the preliminary model and integrate new data (SeaWiFS) on chlorophyll measurements into the model.

Prepared by	Org. Code	M/S	Phone
Byron L. Wood	SGE	242-4	(650) 604-4187

Ames Research Center

DIRECTOR'S DISCRETIONARY FUND REPORT

Fiscal Year 1999

Title of Investigation

Conceptual Design Study of a Martian Autonomous Rotorcraft for Science (MARS)

Investigator(s) (show affilation)

Larry A. Young and Robert T.N. Chen, ARC

Funding

Year initiated	FY99	Expected completion date	FY00
Total prior to FY99	0	Authorized in FY99	$40,000
		Requested for FY00 (if any)	$40,000

Total expended in FY99 (estimated)

In-house	$2000	
Contracts (identify)	$18,000	Micro Craft, Inc. (Code FMM Recom Contract)
Grants (identify)	$20,000	Carnegie Mellon University (NAG-)

Status of Study

Completed in FY99 [ ] Continued in FY00 with funds remaining [ ]

with FY00 funds [X]

If transitioned to other funding

to RTOP (number)

to Program (name)

to Other (identify)

Purpose of investigation

Establish proof-of-concept feasibility and technology challenges of autonomous rotorcraft configurations designed to conduct/support Mars exploration.

FY99 applications of results, patents, reports/publications, papers at meetings, awards received, etc.

Abstract on related work submitted and accepted for presentation at American Helicopter Vertical Lift Aircraft Design Specialist's Meeting, San Francisco, Calif., Jan. 2000. Effected Sikorsky Aircraft sponsorship of a Martian Autonomous Rotorcraft design topic for Year 2000 AHS Student Design Competition; assisted in the development of Request for Proposal for student design competition (over 50 universities have requested RFP to date).

Planned future work

1. Complete refinement of vertical lift planetary aerial vehicle preliminary design tools; use tools to update/complete MARS conceptual design. 2. Acquire/perform a conceptual design study of an autonomous control system for MARS. 3. Perform conceptual and preliminary design work for a hover/static-thrust test-stand to enable experimental testing of rotors specially designed for a test environment consistent with the Mars atmosphere. 4. Support the AHS Student Design Competition.

Prepared by	Org. Code	M/S	Phone
Larry A. Young	ARA	T12-B	(650) 604-4022

Ames Research Center

DIRECTOR'S DISCRETIONARY FUND REPORT

Fiscal Year 1999

Title of Investigation

Organic Reductant as Key to Maghemite Formation on Mars?

Investigator(s) (show affilation)

Aaron P. Zent, ARC; Janice L. Bishop and Rocco L. Mancinelli, SETI Institute, ARC

Funding

Year initiated	FY99	Expected completion date	FY00
Total prior to FY99	0	Authorized in FY99	$40,000
		Requested for FY00 (if any)	$40,000

Total expended in FY99 (estimated)

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

Status of Study

Completed in FY99 [ ] Continued in FY00 with funds remaining [ ]

with FY00 funds [X]

If transitioned to other funding

to RTOP (number)

to Program (name)

to Other (identify)

Purpose of investigation

To identify and characterize biomarker minerals on Mars, and to evaluate the iron oxide mineral maghemite (γ-Fe_2O_3) as a potential biomarker. This study involves analysis of maghemite formation under Martian environmental conditions and involves comparing maghemite synthesis in the presence and absence of organic material from other iron phases thought to be present on Mars. Maghemite is thought to be one of the magnetic components in the Martian surface material; however, it is a rare mineral on the Earth and requires a reducing agent for synthesis. Organic material serves as a reductant in maghemite formation during forest fires on Earth and could play an important role in maghemite formation on Mars as well. The hypothesis of this project is that maghemite could form on Mars from ferrihydrite and/or goethite in the presence of an organic reductant under an atmosphere containing ~0.1 percent O_2.

FY99 applications of results, patents, reports/publications, papers at meetings, awards received, etc.

None

Planned future work

This project involves two related tasks: to evaluate the influence of an organic reductant, temperature, and atmospheric O_2 levels on maghemite formation from ferrihydrite and goethite and to characterize the spectroscopic properties of maghemite and develop techniques for spectral identification of maghemite on Mars. Synthetic ferrihydrite and goethite will be heated slowly with variable amounts of an organic material and the production of maghemite and other products will be monitored as a function of temperature and atmospheric composition. The resulting iron oxide minerals will be identified using visible-infrared spectroscopy and Mössbauer spectroscopy.

Prepared by	Org. Code	M/S	Phone
Janice L. Bishop	SSX	239-4	(650) 604-0297

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Ames-Moffett Investigators

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Ames Research Center
Moffett Field, CA 94035-1000

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National Aeronautics and Space Administration
Washington, DC 20546-0001

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Point of Contact: Stephanie R. Langhoff, Ames Research Center, MS 230-3, Moffett Field, CA 94035-1000
(650) 604-6213

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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 1999 (October 1998 through September 1999). Appendices provide 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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