2002 Ames Astrobiology Academy

Research Opportunities

LIFE SCIENCES

· Charting the History of Earth's Earliest Microbial Ecosystems

Principal Investigator: David Des Marais

Microorganisms are the primary engines of our biosphere, and so they play major roles in the biogeochemical cycles of carbon, oxygen, nitrogen, sulfur and metals. The hierarchical organization of microbial ecosystems determines the rates of processes that shape Earth's environment, create the sedimentary and atmospheric signatures (biomarkers) of life, and define the stage upon which major evolutionary events occurred. To learn how microbes fulfill these roles on Earth and, potentially, other worlds, we must therefore understand the structure and function of microbial ecosystems. Photosynthetic microbial mats have been major players for billions of years. They are self-sustaining, complete ecosystems in which light energy that is absorbed over part of a diel (24 hour) cycle drives the synthesis of spatially-organized, diverse biomass. Thus mats offer an opportunity to study how microbial populations associate to control the biogeochemical cycles.

This project involves experiments with cyanobacterial microbial mats maintained in a simulated natural environment. We will explore various conditions that represent stages in the long-term (billion year) evolution of our environment. The effects of seawater composition, oxygen and dissolved inorganic carbon contents will be measured for ecosystem properties such as population sizes, elemental cycling and gas production. We will seek a better understanding of how the environment influences biomarkers such as atmospheric gases and also chemicals and minerals preserved in sedimentary rocks.

The student will participate in experiments with microbial mats as part of a team. He/she will measure the production and consumption of oxygen and carbon compounds using microelectrodes and chromatographs. These measurements will be compiled and interpreted as rates of ecosystem processes. The student will thereby contribute to an improved understanding of how ancient photosynthetic ecosystems interacted with changing environments and recorded their legacy. Coursework in chemistry and/or biology, and a working knowledge of word processing and spreadsheets, is necesssary.

· Detection of microbial activity with highly sensitive radiolabeling techniques

Principle Investigator: David P. Summers

One question of interest in the study of microbes from old samples, considering transit of materials between planets, and general studies of microbes in extreme environments is how long microbes can remain viable when they are dormant. Are the totally dormant? Or can they, under some conditions (such as frozen in ice) repair damage they occurs while dormant? This project seeks to investigate the lower limits of metabolic activity. The procedure is to take tyrosine that has been radiolabeled with 125 I and feed it to microbes to test their metabolic activity. Any radiolabel taken up can then be measured by MultiPhoton Detection, a technique that allows the detection of radioiodine at below background levels. This work would involve handling microbes, preparation of radiolabeled materials, measurement of labelling, and possibly biochemical techniques (such as polyacrylamide gel electrophoresis). A candidate ideally should have a background in biological or chemical work and be willing to work radioisotopes.

or

Another subject of interest is the detection of biomarkers. Biomarkers are compounds that mark that life had been present in samples. This can be important for issues ranging from the detection
of microbes on planetary probes to the detection of life in geological samples. This project seeks to use radiolabeling to detect proteins at very low levels. The procedure is extract the proteins and radiolabel them by standard techniques. Any radiolabel taken up can then be measured by MultiPhoton Detection, a technique that allows the detection of radioiodine at below background levels. This work would involve handling proteins & test samples, preparation of samples & radiolabeled materials, measurement of labelling, and biochemical techniques (such as polyacrylamide gel electrophoresis). A candidate ideally should have a background in biological or chemical work and be willing to work radioisotopes.

· Advanced Animal Habitat-Centrifuge Project

Principle Investigator: Paul Espinosa

Astronauts who have been exposed to long periods of microgravity have experienced harmful physiological effects. To develop countermeasures, NASA must conduct studies to improve understanding of how bones and muscles change in space and after return to Earth, and how hormones and the immune system respond to long exposure to microgravity. Because of the similarity of animal and human physiological systems, the most effective way to obtain large amounts of data is by using animals and fly them in microgravity. The Space Station Biological Research Project (SSBRP) has contracted out the development of the Advanced Animal Habitat-Centrifuge (AAH-C) to fly rats and mice on the International Space Station (ISS) beginning in 2005. The AAH-C will allow

both scientists on Earth and astronauts in space to view the animals and monitor their physiology and behavior while the rodents live in space. The rodents will be exposed to microgravity conditions or to different levels of artificial gravity created when the hardware is attached to the Space Station's centrifuge. In addition to acting as a scientific instrument, the habitat must include all the basic facilities to support the animals for up to 90 days onboard the ISS. These habitats can also be attached to an on-orbit glovebox allowing astronauts to reach into the cages to retrieve animals and perform experiments.

Although this habitat sounds rather simple to develop, it is in face very complicated requiring highly skilled engineers, and scientists to develop. Each habitat which can house up to 6 rats or 12 mice must be able to support the rodents on the station for up to 90 days. The habitats must provide air, water, food, waste management, light and dark cycles and temperature control for the rodents. It must also contain all waste and odors generated inside the cage and meet the stringent hardware fabrication requirements imposed by the space station.

The contractor developing the hardware is STAR Inc., located in Bloomington, Indiana with the support of the prime sub-contractor SHOT Inc. in Floyd Knobs, Indiana. The development, design, fabrication and testing of the hardware will be performed by the contractors. The government (Ames Research Center) stipulates the requirements for the hardware through various documents, monitors the hardware development through daily contact with the contractor to make sure the government's requirements are being met, maintains the contract, and provides technical advice, review and concurrence on tasks to the contractor. Currently the contractor is in the design phase of the project with a Critical Design Review (drawings 90% complete) scheduled for 2002/2003. The AAH-C project team at Ames Research Center, consisting of the Project Manager and Engineer with the support of other engineers and scientists, is currently supporting the development of the hardware.

The student will be a member of the NASA AAH-C project team and participate in the management of the hardware development. The student will be assigned a specific task to accomplish during the summer related to the project management aspect of the hardware design. This could include validating the technical feasibility and compliance to the specifications of a proposed aspect of the design, researching the foundation of specific requirements and recommending changes to the requirements to support problem design issues, performing tests to validate the functionality and operationally of a specific design, etc. They will be expected to attend weekly project meetings at which will be discussed the development status, problems that may have arisen, etc. and to work any actions which will be assigned to them.

This position is best suited for an engineer or scientist in an undergraduate program currently attending university. The candidate should be able to type well and have had experience with Macintosh computers and programs such as Word and Excel.

· Hypergravity Effects on the Maternal-Fetal System

Principal Investigator: April E. Ronca

Life on earth, and thus the reproductive and ontogenetic processes of all extant species and their ancestors, evolved under the constant influence of the earth's 1-g gravitational field. Opportunities to observe biological processes under gravitational conditions that deviate from earth-normal are infrequent and have historically been dedicated predominantly to understanding adult processes. Research in my laboratory focuses on the role(s) of gravity in reproductive and developmental processes in mammals with particular emphasis on effects of increased (hyper-) and decreased (hypo-) gravity on pregnancy, birth and the transition from prenatal to postnatal life. Studies of mammalian development are dynamic and complex. The mother plays crucial roles in offspring's' development, providing necessary resources that promote and foster growth and development. Offspring, in turn, provide stimulation that helps maintain and regulate maternal responses. We focus on bi-directional linkages within the maternal-offspring system and therefore, analyze the effects of altering the gravitational field on both mothers and neonates. Our approach is multidisciplinary, performing integrative analyses in conjunction with other laboratories at Ames and several universities.

The Astrobiology Academy student will participate in a project in which intrauterine pressure will be monitored in late pregnant female rats during hypergravity exposure using the Ames 24-ft centrifuge. We previously found that exposure to hypo- and hypergravity alters the frequency of labor contractions in pregnant rats. The new project will focus on concomitant changes in the force of contractions measured by telemetric biosensors in addition to changes in maternal uterine connexin proteins and in abdominal muscle. Correlated changes in neonatal neurodevelopmental outcome will also be studied.

The duties of an Astrobiology Academy student will include assisting in hypergravity experiments of the pregnant rats and their offspring and conducting data analysis using statistical programs. He/she would also be expected to attend weekly research meetings to discuss research progress and results. Background in biology and neuroscience and experience with general laboratory equipment is desirable.

· Perception of Gravity

Principal Investigator: Robert Welch

The commonsense view of the relationship between human perception and motor actions is that first we perceive our environment and then we act upon it, based on this perceptual representation. However, recent exciting neuropsychological research with both brain-damaged and brain-intact individuals contradicts this view. These data suggest instead that perception and action are parallel processes, that is, that it is possible for perception and action to be quite different from on another other. Evidence for such perception-action dissociation with respect to normal observers comes from studies in which it was

shown that, despite the presence of a strong visual illusion, subjects' motor responses are perfectly accurate. Thus, it appears to be possible for "the hand to know better than the eye." If further evidence confirms this conclusion, it would inspire a true paradigm shift from the conventional wisdom that perception always precedes and guides action.

The proposed research will systematically examine the perception-action dissociation hypothesis, using strict research criteria to rule out alternative interpretations of the data. In one study, subjects will be confronted with a pitched visual environment, which is already known from the Principal Investigator's own research to cause a very large shift in visually perceived eye level, but only minor errors in pointing. This observation must be examined more carefully to determine if it is really an example of perception-action dissociation as it appears to be. We will do this by delaying the subject's pointing responses. Previous research indicates that perception-action dissociation that is found when observers act upon a stimulus that is present in their visual field disappears, to be replaced by association, when a delay is imposed between observing the stimulus and making the motor response.
The duties of an Astrobiology Academy student would include testing human subjects, placing data in an electronic spreadsheet, and analyzing them by means of the appropriate statistical programs. He/she would also be expected to attend weekly research meetings at which will be discussed research results, problems that may have arisen, etc. The candidate should be able to type well and have had experience with Macintosh computers and programs such as Word and Excel.

· Physiology and Modeling of Neural Networks

Principal Investigator: Dr. Richard Boyle

The vestibular system is located in the inner ear and is responsible for detecting forces due to gravitoinertial and angular accelerations, and transducing these forces into a neural code that is sent to the central nervous system to control extraocular muscles, posture and coordinated self-movement. It has been shown that significant morphological and physiological changes take place in the neural networks of the vestibular systems of rats and toadfish, respectively, flown in microgravity, and it has been postulated that these neural networks undergo adaptive changes in microgravity and re-adaptation upon return to Earth's gravity. The NASA Center for Bioinformatics develops and applies advanced technologies to understanding the structural and functional responses of the terrestrial organisms to altered gravitational environments.

Results of this research are applicable to understanding not only the consequence of terrestrial organisms to life in space, but also to understanding neural diseases, trauma, and aging afflicting people here on Earth.

The Astrobiology Academy Research Associate would be able to choose from a wide variety of techniques and tools to study numerous unresolved mechanisms underlying the neural responses to the space environment. The project would involve either using new or

existing data and employing computer and engineering techniques such as modeling or 3D reconstruction, or using more conventional methods such as electrophysiological techniques or light and/or SEM and TEM microscopy .

The student selected for this project should have a strong background in biology, electrical or mechanical engineering, and/or computer science. The project is flexible and can be modified according to student interest and strengths. This project may or may not include animal experimentation.

· Advanced Life Support Systems Analysis

Prinicpal Investigator: Julie Levri

This project involves using computer-based methods to perform static (spreadsheet-based) and/or dynamic analyses (computer simulation) for trade studies of Advanced Life Support technologies for long-term space travel (Mars exploration, Mars base, Lunar base, etc.). Advanced Life Support analyses typically involve trades of technologies in the following six areas: air revitalization (O2 generation, CO2 removal, trace contaminant control), biomass production (small-scale salad crop or larger-scale crop production), food processing (ranging from preparation of prepackaged items to processing of raw crop products), water recovery and waste processing (physicochemical and/or biological treatment).

The skills needed for performing advanced life support trade studies include experience in computer programming and spreadsheet tools, as well as excellent communication skills for obtaining data and other information from technology experts. An environmental, chemical or bioresource engineering background (or comparative science background with significant computer experience) is advantageous but not required. The project will involve extensive technology background research, so attention to detail is critical. Because the areas of advanced life support (air, biomass, food, water and waste) are diverse, the project may be tailored to best suit the background of the participating student.

References:
Wieland, Paul O. (1994) “Designing for Human Presence in Space: An Introduction to Environmental Control and Life Support Systems” NASA Reference Publication 1324, George C. Marshall Space Flight Center.
Johnson Space Center Advanced Life Support web site:
http://advlifesupport.jsc.nasa.gov/

EARTH SCIENCES

- ### Measuring Solar Radiation in the Atmosphere: Implications in Climate and Remote Sensing Applications

Principle Investigator: Peter Pilewskie

The NASA Ames Radiation Group, part of the Atmospheric Physics Branch, is involved in research programs pertaining to the interaction between the earth's atmosphere and radiative energy from the sun, and the associated effects on climate processes. We are an experimental group, making both surface-based and aircraft-based observations of the spectral atmosphere. We are currently involved in a number of field programs using optical instrumentation which requires considerable laboratory and field calibration and testing. We also have data from past field experiments that will be used to infer specific properties of the atmospheres, such as cloud amount, water vapor amount,and total energy absorbed in the atmosphere. Our research has included studying the smoke fromoil fires in Kuwait; the climate effects of the eruption of Mt. Pinatubo; Arctic ozone; and the climatic effects of clouds in the tropics.

Students with strong backgrounds in physics, mathematics, computer science and engineering would find the work in our laboratory both stimulating and rewarding. Students will have the opportunity to work on some of the major climate issues of our time, for example how much energy is absorbed in the Earth's atmosphere. Student tasks will include both data collection and analysis.

- ### Mapping terrestrial vegetation density and activity from space

PI: Dr. Jennifer Dungan

The NASA Ames Ecosystem Science and Technology Branch uses images of the Earth's surface collected from space to research natural processes of plant life as well as human activity. A few of our current projects include real-time fire monitoring across the West, developing innovations in precision agriculture and modeling the "breathing" of the biosphere -- the global release and removal of atmospheric carbon dioxide by plants. The PI is especially interested in using satellite images to map the amount of green vegetation across large regions and looking at changes over the past three decades caused by human and natural disturbance.

The summer research associate will work with satellite images and models of vegetation density and activity at several scales. Images covering a few square kilometers to thousands of square kilometers will be used to develop an understanding of how density

and activity estimates change with scale. Students with backgrounds in any Earth or environmental science such as ecology or geography would be well-suited to this work. In addition, student should be capable of programming in a language such as C++ or Fortran and be comfortable with the Unix operating system.

· Use of The Martian Surface Wind Tunnel (MARSWIT) to Quantify the Boundary Layer Processes That Trigger Planetary Dust Storms.

Engineer in Charge: Jim Phoreman

Viking and Pathfinder surface operations have shown evidence of planetary scale dust storms that will impact surface operations, including landers, rovers, and eventual human exploration. Throughout July and August of 2001, Mars Global Surveyor returned data from the thermal emission spectrometer that showed a dust storm covering the entire surface of Mars. MARSWIT is a boundary layer wind tunnel contained in a low-pressure chamber capable of pressures as low as 4 mbar, making the facility a truly unique tool for studying the aeolian processes that trigger these planetary dust storms and drive the surface erosion processes on Mars.

Past experiments at MARSWIT have examined the effects of dust deposition on lander and rover equipment. Future low-pressure experiments will include the Martian Autonomous Rotorcraft for Science Hover Test, and the Arizona State University vortex/ dust-devil generator.

The student will be exposed to a multi-disciplinary research environment in which the essential tools for both Aeronautical Engineering and Planetary Geology are used regularly. The hands-on experience with equipment such as LDV, differential pressure transducers, thermo-couples, electrometers, high-speed video, and current data acquisition software will provide the student with advanced preparation for their own graduate level research. The student will also have a high degree of latitude to design, setup, and conduct safe experiments on the leading edge of space science.

SPACE SCIENCE

· Search for Comets and Asteroids

Principal Investigator: William J. Borucki

An observation program is being conducted at the Lick Observatory to search for extrasolar planets by the transit method. Each night a photometric telescope continuously monitors the brightness of 6000 stars. If a planet transits one of the stars, the star brightness will decrease for a period of a few hours. The fractional reduction in the stellar

flux provides the size of the planet relative to that of the star. The orbital period is determined from the time between transits. However many types of phenomena are also observed that serve to confuse the results. These include variable stars, aircraft passing overhead, meteors, comets, and asteroids. A method must developed to automatically identify and catalog these phenomena so that the effects of their presence can be removed.

Our project has already found methods of identifying variable stars and aircraft. A computer program that searches through the thousands of images to identify the meteors, comets, and asteroids must be developed. Because these objects are of interest to the science community, it is important to carefully characterize and catalog the comets and asteroids.

The duties of the Astrobiology Academy student would be to develop and test a computer program to identify meteors, comets, and asteroids in our data. Then the student would examine the individual images to determine their brightness and motions. For those objects that showed a substantial change in position before they faded from view, orbits will be calculated. The student will have the opportunity to participate in weekly research meetings and attend seminars. The candidate must have some programming experience in a language such as Fortran, C, or QuickBasic.

· Delivery of Meteoric Organic Matter to the Early Earth

Principle Investigator: Peter Jenniskens

Most extraterrestrial matter falling to Earth is in the form of around 200 micron sized particles causing about +8 magnitude meteors. The colliding air molecules sputter the meteoric matter which is released in the form of a cloud of atoms and molecules surrounding the meteoroid. Subsequent collisions of air molecules heat the outside of the vapor cloud and, indrectly, slow down gently the bulk of colder matter on the inside. Behind the meteoroid, hot and cold gas come together briefly in a low density warm air plasma, before cooling down and leaving a trail of neutral atoms, molecules, and solid debris.

The summer Research Associate will analyze meteor spectra obtained by new video imaging techniques to study the physical and chemical conditions in the meteor plasma and determine if organic matter can survive this ablation process. The Associate will search for the emission bands of C2 and CN that are expected if the organic matter is decomposed. Successful detection's are compared to the physical properties of the meteors in order to characterize the conditions in which these molecules are produced. The results will be interpreted in the context of seeding the early Earth with meteoric reduced organic matter, and will prepare for observations of the 2002 Leonid meteor storm.

· Landing Site Selection for Mars Missions: Analysis of the Ma'adim Vallis/Gusev Crater System and the Search of Water and Life

Principal Investigators: Nathalie A. Cabrol (PI) & Edmond A. Grin (Co-PI)

Paleolakes in impact craters have been surveyed for the past 20 years at Viking resolution. They have raised considerable interest because of their potential to help us document many of the questions that are at the heart of Mars exploration, astrobiology programs, and the search for life on the Red Planet. Recent high-resolution MOC images confirmed the existence of Martian paleolakes and are providing new data to revisit and explore these past environments at higher resolution. Martian crater paleolakes and their extraordinary potential for astrobiological investigations have made them preeminent in the selection of the 8 highest priority candidate-sites for the Mars Exploration Rover missions MER-A and MER-B in 2003. Considering NASA's priority for the exploration of Mars (Follow the Water), such sites will remain top priority for at least the next decade, including for a Sample Return mission, and their potential needs to be assessed.

The proposed project involves the reconstruction of the fluvial and lacustrine history of one of the 8 high-priority sites, namely Gusev Crater and its inflow channel Ma'adim Vallis, in support to the Surveyor Program of landing site selection for future Martian missions, starting with the two 2003 MER missions. The Gusev/Ma'adim system has an abundant coverage of Mars Global Surveyor data (MOC images, MOLA altimetry, and TES spectral data.). In order to understand the origin, distribution, and timing of the materials deposited in the Gusev crater, especially in the 2003 potential landing ellipse, the analysis of Ma'adim Vallis must be completed. The questions to be explored include: What is the origin of Ma'adim Vallis? What hydrological processes were involved in its formation? What was the dynamics of the channel? How many fluvial episodes can be deduced from the MOC imagery? How many lake episodes in Gusev can be inferred from this analysis? What were the likely parent-rocks to the sediments observed in Gusev? When and where did the last lake episode take place? What are the best sites in Gusev to search for evidence of life (extinct/extant)?

The Astrobiology Academy student will take an active part in this reconstruction of the hydrogeological activity in the Ma'adim/Gusev system. He/she will have access to the MGS data archive, extract relevant images, altimetric and spectral data, and process them. A training in image interpretation and processing will be given to the student. As the 2003 mission to Mars involves two rovers, her/his work will provide important information to designate high-priority regions to explore within the landing ellipse in Gusev and the statement of hypotheses that will support the exploration of the site.

The duties of an Astrobiology Academy student would involve observational, analytical, and theoretical work. The duties can involve one or several aspects of the following: analysis and interpretation of Mars mission data from MGS, Viking, and Pathfinder (e.g., images, altimetry, and spectral data), geological mapping, theoretical hydrogeological modeling, and participation to rover field test if field test schedule permits). The skills

required are a solid background in geology and/or physics (both preferred but not mandatory), and a strong interest in exobiology and planetary surface missions. Candidates should type well and have experience with Macintosh computers, and programs such as Word, Excel, and Adobe Photoshop. Experience in organizing web pages will be considered as a plus.

· **The Potential for Liquid Water on Mars**

Principal Investigators: Chris McKay and Jennifer Heldmann

Geologic evidence for recent liquid water outflows on Mars suggests that these events occurred under present climatic conditions with mean surface temperatures of –60°C and extensive permafrost. Such findings imply that liquid water must have been stable on the martian surface for a long enough period of time to produce the observed outflow channels and gully systems. Aqueous brine solutions would be stable against boiling on the surface of Mars due to the vapor pressure depression of the saline solution. However, the solution does not necessarily have to be above its freezing point as water will still flow before icing over.

We are examining cold perennial saline springs in the Canadian High Arctic that flow through thick continuous permafrost as a terrestrial analog for such spring activity on Mars. The results of computer modeling will be compared to data collected at the Arctic field site to place constraints on the physical processes governing the spring flows. Likewise laboratory experiments may be conducted to understand the dynamics of brine solution flows under various ambient conditions. These findings will then be extrapolated to Mars to improve our understanding of the behavior of liquid water on Mars and the potential for a past, present, or future martian biota.