



# Yellowstone National Park: A Portal to Astrobiology



A presentation by Catherine Tsairides



## Ames Astrobiology Outreach Education in Yellowstone National Park

**“Linking Our Origins to Our Future.”**



***The NASA Astrobiology  
Institute Team:***

***From left to Right:  
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***Not pictured:  
Lynn J. Rothschild,  
Tori M. Hoehler,  
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## Yellowstone Offers the Public a Portal to Astrobiology

- Each year, approximately three million U.S. and International visitors of all ages experience the diverse environments of Yellowstone National Park. The Astrobiology Planning Team has partnered with Yellowstone to develop projects that have an integrated approach for introducing these visitors to astrobiology.





## Why is NASA Interested in the Natural History of Yellowstone?

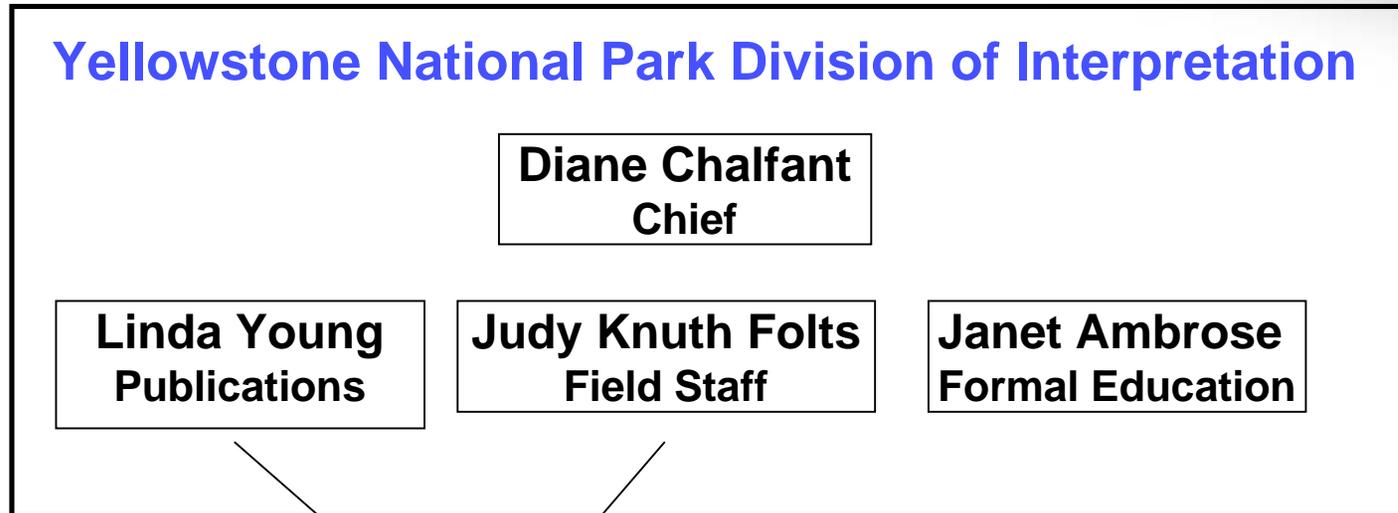
- Part of NASA's mission is to understand the origin and evolution of life in a planetary context. To understand how life began on Earth, it is necessary to study the origin of the chemical compounds that make up simple living systems as well as the physical factors needed to create an environment capable of supporting life.

### LIFE IN HOT SPRINGS: Yellowstone, Ancient Earth, Mars?





## Management Structure



### **NASA ASTROBIOLOGY INSTITUTE - AMES TEAM PROJECTS:**

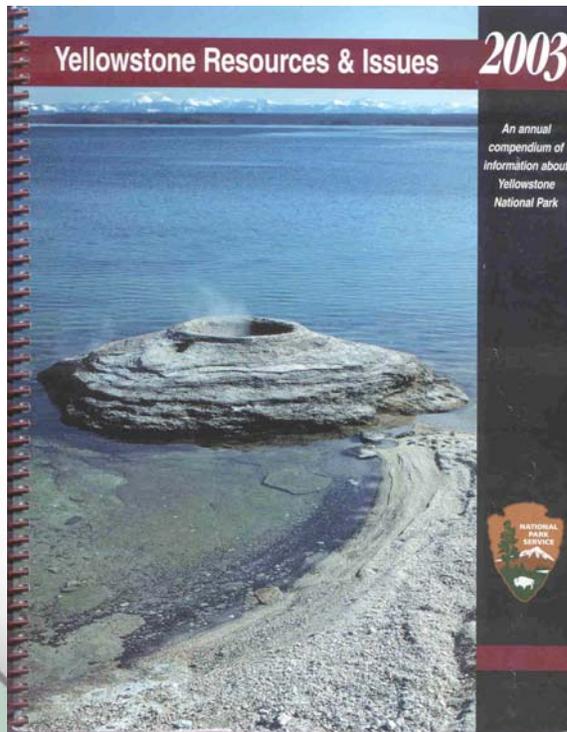
- Resources and Issues Manual chapter on microbiology/astrobiology
- Wayside exhibits – up to 8 microbiology/astrobiology signs on boardwalks
- Trail guides – future revision
- New Old Faithful Visitor Education Center



## Resource Manual Development Project

The Park's 3 million visitors often ask the question  
"What causes the colors in the hot springs?"

This was difficult to address in black and white.



### Color & Life in Hydrothermal Areas

The colors in hot springs and runoff channels result mostly from light refraction, suspended mineral particles, and large communities of microscopic organisms. These organisms are primitive lifeforms—algae, bacteria, and Archaea—that have inhabited the earth for almost four billion years. (Archaea were once considered a type of bacteria, but their DNA is now known to be completely different.) They grow in water too hot—even boiling—for most life on earth. After water cools below 160°F (70°C), the organisms grow in thick, living layers of color in many different hues.

The chemistry of the hydrothermal pools also influences the kinds and abundance of life. Cyanobacteria grow in alkaline hot water. Their colors often follow a sequence from hottest to coolest: yellow, then green, red/orange, and brown. These different pigments gather solar energy for photosynthesis. Cyanobacteria are one of the first organisms to evolve that used the energy of sunlight for life and produced free oxygen as a byproduct. They played a major role in creating an atmosphere that could support other lifeforms, including humans.

In acidic hydrothermal areas, such as Norris and Mud Volcano, different organisms grow. For example, the neon green mats in the cooler features are often due to the alga *Cyanidium*. The purple color is often *Zygonium*.

The acidic features of Norris and Mud Volcano are also colored by minerals, such as the gray of sinter (a hydrated form of silica); the yellow of sulphur; and the red, orange, and black of iron and arsenic compounds. The color of the mudpots may be due to a single mineral or to a mixture, such as the red, muddy pools

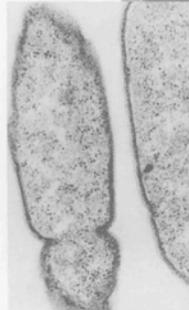
in which particles of silica or clay are coated with iron oxides. The shades of gray and black of the muds are often a result of iron sulfides.

In neutral areas, look for *Phormidium*, the organism causing orange "hug carpets" areas; *Synechococcus* and *Chloroflexus*, which form yellow and yellow-green color mats; and *Caulobacter*, which appears brown in cool, neutral runoff channels such as those of Castle Geyser (Upper Geyser Basin), and Grand Prismatic Spring (Midway Geyser Basin). These bizarre life forms are still largely a mystery to scientists. For about more the issues surrounding thermophiles, see "Bioprospecting," Chapter 8.

### Geology: Hydrothermal Features



Above: Even in black and white, the patterns caused by thermophiles can be seen. The colors of runoff channels change with the water temperature and pH—which varies with hot spring and geyser activity and also with the seasons. Left: *Thermus aquaticus*, the thermophile that sparked revolutions in science and medicine (see Chapter 8, "Bioprospecting").



*Thermus aquaticus*

The Resource Manual is the training manual for the interpreters and is also sold to the public in NPS bookstores.

The Old Resource Manual Featured:

- Black and White Printing
- 52 pages on animals
- 8 pages on plants
- 1 page on microorganisms
- 3 pages on bioprospecting
- 0 pages on astrobiology



## The New 2004 Resource Manual

The Park's 3 million visitors often ask the question  
"What causes the colors in the hot springs?"

The New Resource Manual Features:

- 2 draft chapters on microbiology of YNP & astrobiology in YNP melded into 1 chapter
- Reviewed and condensed by YNP
- Reviewed by NAI team
- Raised funds for color printing.

Color printing was a major success. For the first time, the New 2004 Edition has been "sold-out" in the YNP Bookstore.

Color publication enabled by:

- Lockheed Martin Space Operations
- Agouron Institute
- Montana State University Thermal Biology Institute
- American Soc. Microbiology

**THERMOPHILES**

**4**  
Introduction

The hydrothermal features of Yellowstone are magnificent evidence of earth's volcanic activity. Amazingly, they are also habitats in which microscopic organisms called thermophiles—"thermo" for heat, "phile" for lover—survive and thrive. Grand Prismatic Spring at Midway Geyser Basin (above) is an outstanding example of this dual characteristic. Visitors are awed by its size and admire its brilliant colors. However, the boardwalk they follow (lower right corner of photo) spans a vast habitat for a variety of thermophiles. Metabolizing and synthesizing elements and minerals, they build communities here and throughout the park.

All thermophiles require hot water but differ in other habitat needs. Some thrive in only acidic water, others require sulphur or calcium carbonate, still others live in alkaline springs. Depending on these other characteristics, some are described more specifically with terms such as thermocidophile (heat and acid lover) or extremophile or hyper-thermophile (extreme heat lover).

The number of known thermophiles in Yellowstone: XXXXXX

51

**4**  
About Microbes

**Microbe:**  
A minute lifeform; a microorganism.

**Microorganism:**  
An organism of microscopic or submicroscopic size.

**Microbes in Yellowstone**  
In addition to the thermophilic microorganisms, millions of other microbes thrive in Yellowstone's soil, streams, rivers, lakes, vegetation, and animals. Some of them are discussed in other chapters of this book; most of them are not.

When you look into Yellowstone's colorful hydrothermal pools, imagine you are looking through a window into the earth's past to the beginnings of life itself. The thermophiles that thrive in these pools and their runoff channels are heat-loving microorganisms (also called microbes), some of which are descendants of the earliest lifeforms on earth.

Scientists think that during the first three billion years of earth's history, microorganisms transformed the original, anoxic (without oxygen) atmosphere into something that could support complex forms of life. Microbes created energy from chemicals such as hydrogen, iron, and methane, in a process called **chemosynthesis**. And they did this in environments that are lethal to humans—in boiling acidic or alkaline hot springs . . . like the hot springs found in Yellowstone National Park.

Microorganisms were the first lifeforms capable of photosynthesis—using sunlight to convert carbon dioxide to oxygen and other byproducts. These lifeforms, called cyanobacteria, began to create an atmosphere that would eventually support human life. Cyanobacteria are found in some of the colorful mats and streamers of Yellowstone's hot springs.

In the last few decades, scientists have come to realize that cyanobacteria and other microbes comprise the majority of species in the world—yet less than one percent of them have been studied.

Microbial research has also led to a revised tree of life, far different from the one taught for decades. (See next page.) The "old" tree's branches—animal, plant, fungi—are now combined in one branch of the tree. The other two branches are microorganisms, including an entire branch of microorganisms not known until the 1970s—Archaea.

Yellowstone's thermophilic community includes species in all three branches. These microbes and their environments provide a living laboratory studied by a variety of scientists. Their research findings connect Yellowstone to the other ancient lifeforms on Earth, and to the possibilities of life elsewhere in our solar system. (See last section.)

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View the handbook on-line at:

<http://www.nps.gov/yell/publications/pdfs/handbook/index.html>



## Wayside Exhibits

These exhibits, located Park-wide at sites that best illustrate the most compelling aspects of astrobiology research in Yellowstone, will describe how the Park's hydrothermal features are extreme habitats for amazing life forms that may help explain the history of the Earth and provide clues in the search for life on other planets.

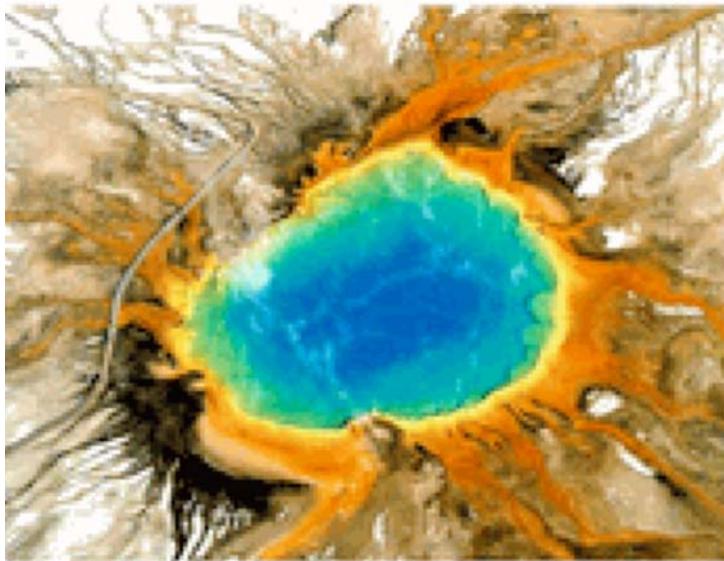


### The Wayside Exhibit Plan:

- \* 8 proposals were developed
- \* reviewed by NAI Team
- \* now in review by YNP
- \* 5 exhibits in place by end of summer 2005



## Wayside Exhibit Design Process



Each proposed exhibit considered important elements such as:

- \* subject
- \* location
- \* theme
- \* safety/preservation
- \* existing signage

<u>Spring</u>	<u>Basin</u>	<u>Possible Title</u>
Canary	MHS	Travertine tomb/fossilizing hot spring biota
Chinese	OF	Primeval Life / Microbes are windows to the past
Excelsior	Mid	Microbial forests past and present
<b>Grand Prismatic</b>	<b>Mid</b>	<b>Grand Prismatic Spring/Prism of color, spectrum of life</b>
Great Fountain	Lower	Carpets of color: microbial forests
Octopus	Lower	Preservation Yields Unexpected Benefits
Porcelain	Norris	Channels of Living Color
Roaring Mt.		Roaring Mountain / Living Landscape



## Wayside Exhibit (Draft)

### Travertine Occupants

Billions of heat-loving microorganisms called "thermophiles" live, die, and are buried at Mammoth Hot Springs. You are looking at their tomb.

#### Food for Life

**Chemical-Dependent**  
Filamentous Bacteria



Thread-like filamentous bacteria link together, creating chains that can spread into aprons. They live on hydrogen sulfide gas rising through vents—the gas you likely smell here.

#### Living on Sunshine

Cyanobacteria



Like flowering plants, colorful cyanobacteria use light for energy, or photosynthesize. If their chemical-dependent neighbors did not consume hydrogen sulfide gas near the vents, these sun-loving microbes would be poisoned.



### Perished Colonies

Heated deep below ground, water rises through buried limestone, then deposits the mineral calcium carbonate above ground. It then hardens as travertine. Wherever hot spring water flows, trees, grasses, thermophiles, and even the boardwalk are entombed!

Smothered by a coat of travertine, a fossil-like impression of thermophiles is cast in stone. Travertine textures are sometimes evidence that a colony of thermophiles once lived there.

Some scientists study Mammoth Hot Springs' formations to better understand Earth's early life forms. Other scientists use knowledge gained here as they scan the heavens looking for life beyond Earth.

This exhibit made possible by the generous grant to the Yellowstone Park Foundation from Lockheed Martin Space Operations and NASA Astrobiology Institute

•This exhibit made possible by the generous donation from the NASA Astrobiology Institute and Lockheed Martin Space Operations



## Wayside Exhibit (Draft)



### Living Thermometer

Can you imagine living in a geyser? Thermophiles—microorganisms that thrive in heat—are perfectly adapted to living in geysers and their runoff channels. Some live where temperatures are hottest, and others live in cooler areas. As you look at the colors in and around Whirligig Geyser, you are looking at a “living thermometer.”



At 122–140°F (50–60°C), Whirligig’s runoff channel is hot enough to burn you. Thermophiles living here consume iron from Whirligig’s iron-rich water, and become coated with rust.



Thermophilic algae called *Cyanidium* inhabit the green channel. These tiny single-celled plants photosynthesize, or use light for energy. They live where temperatures range from 104–133°F (40–56°C).

#### Did You Know?

- ◆ Norris Geyser Basin is highly acidic. Amazingly, thermophiles living here thrive in heat and acid.
- ◆ Scientists study thermophiles and their habitats to gain knowledge about primitive life forms.
- ◆ As explorers reach beyond Earth, they use their knowledge of thermophiles to help unfold the mysteries of possible life on other planets.

#### Communal Life

- ◆ Thermophiles are too small to see without a microscope, but their vast communities are clearly visible.
- ◆ The number of thermophiles living in a three inch cubic area may exceed the number of people on Earth!



This exhibit made possible by the generous gift to the Yellowstone Park Foundation from Lockheed Martin Space Operations and NASA Astrobiology Institute.

•This exhibit made possible by the generous donation from the NASA Astrobiology Institute and Lockheed Martin Space Operations



## News Releases & Listed Publications

**"NASA Research Focuses on Yellowstone's Hot Springs and Compares Findings to Rocks from Mars."**

**"Yellowstone Park Foundation Receives \$66,000 Grant from NASA Ames Astrobiology Institute and Lockheed Martin Corporation to Help Tell the Story."**

-- News Headlines

*Media coverage in March, 2004*

### **Publications:**

- Washington Post
- Las Vegas Sun
- USA Today
- LA Times
- Arizona Republic (Phoenix)
- Seattle Post-Intelligencer
- Pittsburg Post-Gazette
- Billings Gazette (MT)
- Livingston Enterprise (MT)

- Montana Standard (Butte, MT)
- Cody Enterprise (WY).
- Bozeman Daily Chronicle
- Los Angeles Times Outdoors Section
- NASA Office of Space Science Newsletter
- NASA Ames Research Center Astrogram
- Yellowstone National Park Annual Report
- Yellowstone Park Foundation; Protecting the Wonders & Wildlife of Yellowstone National Park.

### **News Releases:**

- CNN Headline News

### **Websites:**

- ABCNews.com
- Space.com
- NASA Astrobiology Institute website
- FreeRepublic.com
- YahooNews.com



## Thermophile Exhibit



### **Lockheed Martin Corporation's \$200,000 contribution to the Thermophile Exhibit**

**A central interpretive element for the Old Faithful Visitor Education Center will be the magic, mystery, and meaning of Yellowstone's hydrothermal features. The Old Faithful Visitor Education Center will help people understand why hydrothermal features are found in Yellowstone and the significance that they have in our everyday lives. The Park's extreme habitats may provide clues in the search for life on other planets.**



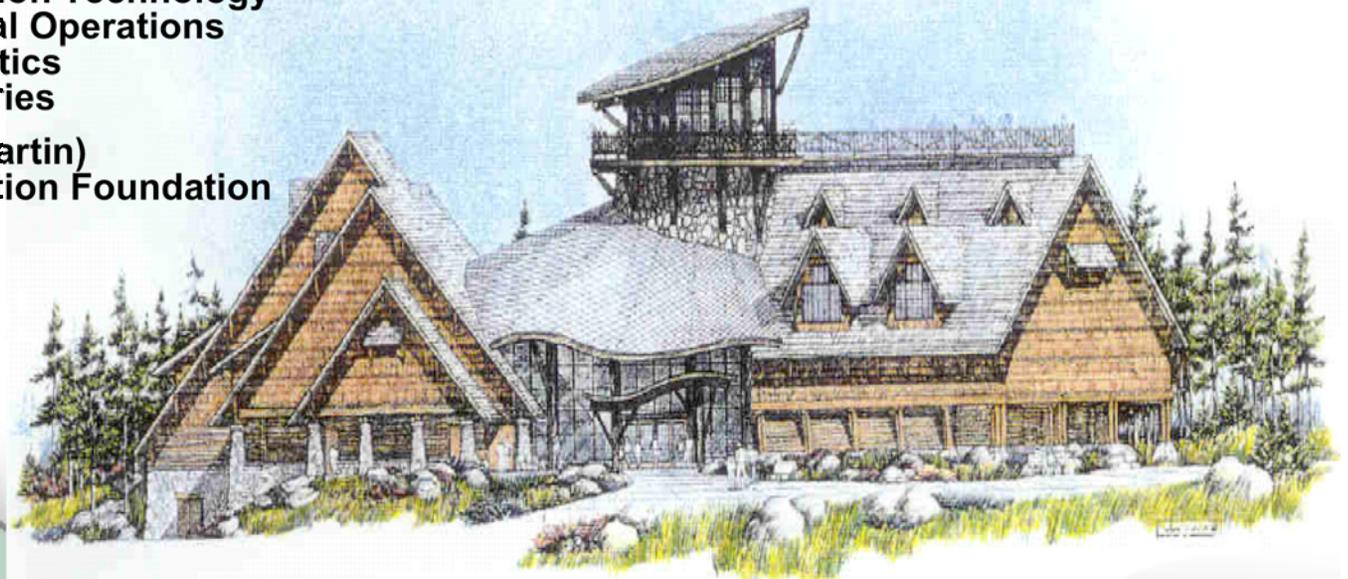


## Funding for the Old Faithful Visitor Education Center

Funding came from a \$200,000 commitment to the Yellowstone Park Foundation from Lockheed Martin Corporation to support the request for corporate sponsorship of a new high-tech visitors center at the Yellowstone Nat'l Park.

- The following business units/areas are supporting the proposal.

Lockheed Martin Space Operations  
Lockheed Martin Information & Technology Services  
Lockheed Martin Space Exploration Organization  
Lockheed Martin Space Systems Company  
Lockheed Martin Information Technology  
Lockheed Martin Technical Operations  
Lockheed Martin Aeronautics  
Sandia National Laboratories  
(Managed by Lockheed Martin)  
Lockheed Martin Corporation Foundation





## The Old Faithful Visitor Education Center



The Old Faithful Visitor Education Center focuses on helping visitors develop a deeper understanding of perhaps the most diverse and accessible hydrothermal field on Earth.



### Education Center Facts:

- 43,000 square feet
- Ground breaking in 2006
- Completion in 2008

- National Science Foundation funding for
- exhibits (8,000 sq. ft.)
  - classroom
  - web-based programs





## Extending Beyond Yellowstone. . .



Making the connections between the formal and informal education to inspire the next generation of explorers.





## NASA Explorer Institute– Earth to Sky



Above: Dr. Lynn Rothschild's Extremophile lab tour.

Right: Greenhouse tour with Dr. Tori Hoehler



### NEI Focus group:

To explore visualizations of space science and exploration.

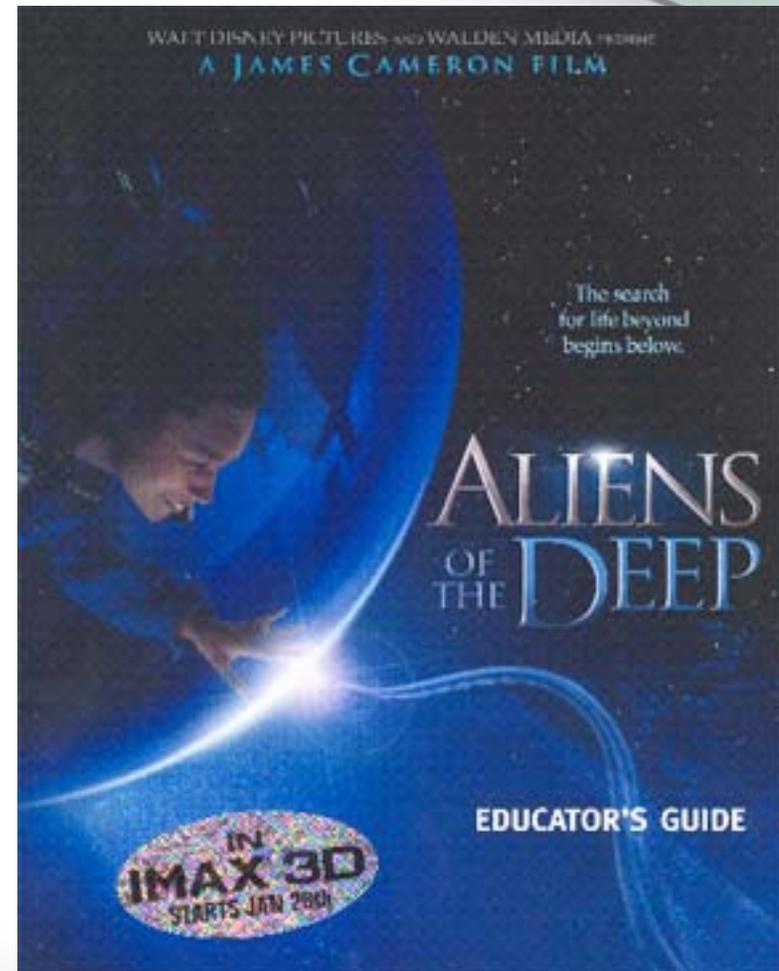
Bottom Right: NPS Interpretive discussion with researchers



## Aliens of the Deep

The search for life beyond begins below.

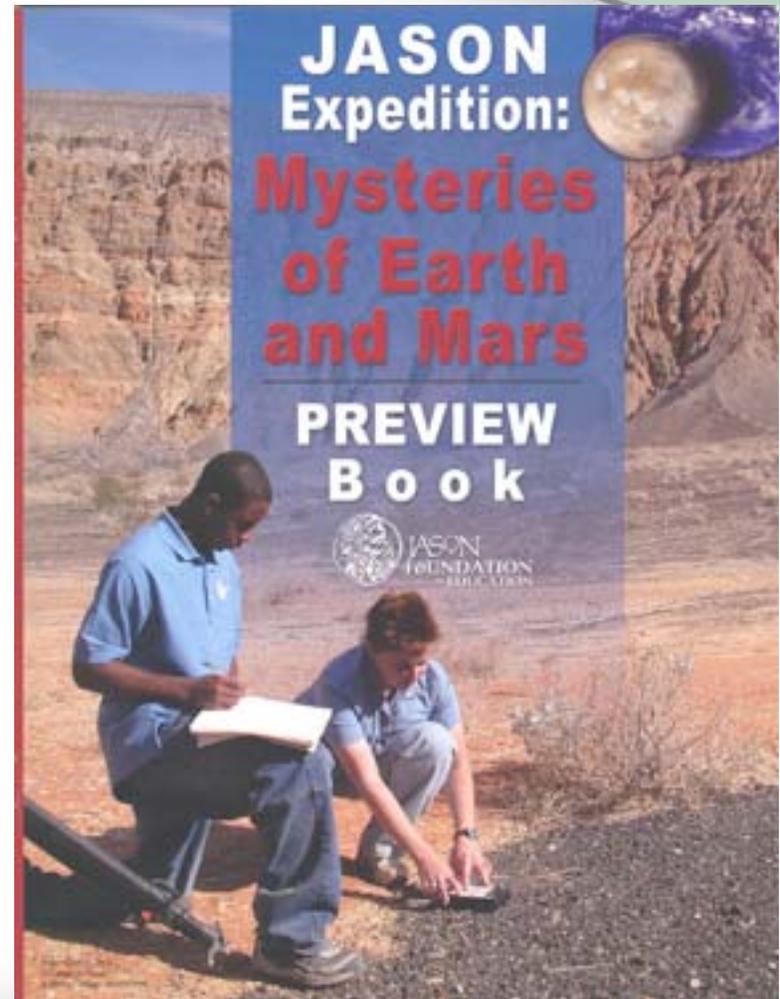
- Walt Disney Pictures and Walden Media present an Earth Ship Production "Aliens of the Deep" directed by James Cameron.
- The expedition team of astrobiologists, marine biologists, planetary scientists, and geophysicists consider connections between life under water and life we may one day find in space.
- Educator Guide developed by Walden Media and the NASA Astrobiology Institute Teams and is designed for students 5-8 to be used before or after viewing the film.
- The California Academy of Sciences has teamed with Disney to feature scientific discussions with the Astrobiology exhibit and the IMAX movie at the Metreon in San Francisco, California.





## JASON Expedition

- A team of scientists will take middle-school students and teachers on the trip of a lifetime. . . to Mars!
- The expedition will engage students in the process of scientific inquiry and will correlate to major textbooks and science kits, including:
  - Teacher's Edition text book
  - Student Activity Book
  - Introductory Video
  - Expedition Broadcast (Jan 30- Feb 4, 2006)





## Memorandum of Agreement

- **MEMORANDUM OF AGREEMENT BETWEEN THE NATIONAL PARK SERVICE AND THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
ARTICLE 1. AUTHORITY**

**This Memorandum of Agreement (MOA) is entered into by the National Aeronautics and Space Administration (NASA) and National Park Service (“NPS”), U.S. Department of the Interior, jointly referred to hereinafter as “the parties.” NASA enters this MOA under the National Aeronautics and Space Act of 1958, as amended. NPS enters this MOA pursuant to the authority of the Organic Act of the National Park Service, Executive Order 12906, Coordinating Geographic Data Acquisition and Access: The National Spatial Data Infrastructure, April 11, 1994.**

- **Both NPS and NASA provide capabilities that educate and inspire the public through discovery and interpretation of natural environments. NASA exploration and science programs offer substantial benefits to NPS interpretation that, in turn, informs and inspires park visitors about our place in the natural world and the universe.**
- **NASA seeks to form collaborations that enable the application of NASA Earth and Space science research results, observations, and outputs from predictive models for decision support and for interpretation.**



**“In the end, we will conserve only what we love,  
we will love only what we understand, and we  
will understand only what we are taught.”**

**-- Baba Dioum, “Protecting the Wonders  
& Wildlife of Yellowstone National Park”**