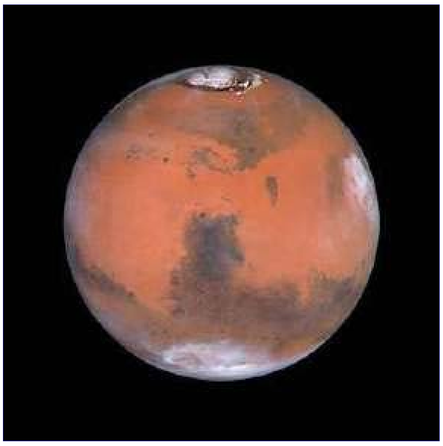
Earthfiles, news category.

# Does the Allan Hills Meteorite from Mars Contain Fossilized Microbial Life?

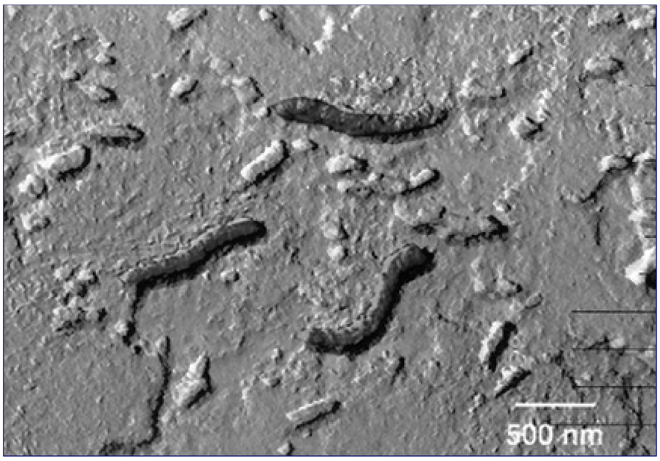


*"The Allan Hills Martian meteorite suggests there is evidence for life on ancient Mars. If that is true ... there could* still *be life – particularly in the subsurface regions of Mars"*
- Kathie Thomas-Keptra, Ph.D., NASA Johnson Space Center

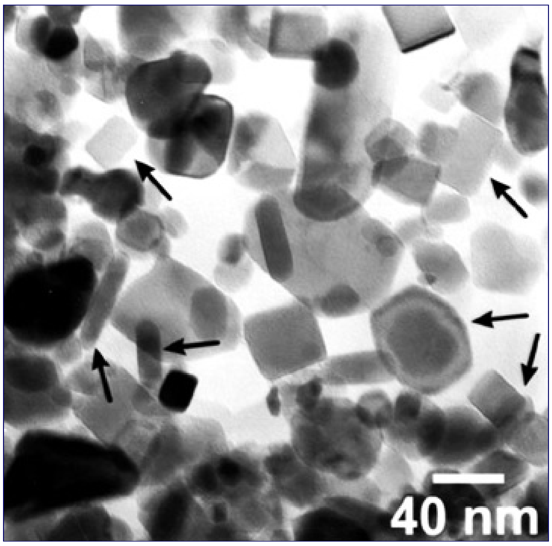


Mars by Hubble Space Telescope, June 30, 1999.

The Allan Hills meteorite (ALH84001) that crashed into Antarctica about 13,000 years ago. Scientists say gases in the meteorite definitely match 1976 Viking data about the Martian atmosphere. Allan Hills has magnetite crystals in its carbonate that match similar crystals produced by Earth bacteria. Photograph © 2000 by David J. Phillip, AP.




Three darker carbon, tiny, worm-like structures might be fossilized Martian bacteria photographed in the Allan Hills meteorite by Kathie Thomas-Keprta at the NASA Johnson Space Center, Houston, Texas. Small magnetite crystals were discovered inside the worm-like structures. Photomicrograph provided by the NASA Johnson Space Center, Houston, Texas.




Transmission electron microscopy of hexagonal-shaped magnetite crystals (arrows) found inside the carbon worm-like structures in the Allan Hills meteorite from Mars that might be fossilized bacteria. Image photographed by Kathie Thomas-Keprta at the NASA Johnson Space Center, Houston, Texas.

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**December 24, 2009 Houston, Texas -** On December 27, 1984, a team of U.S. meteorite hunters were searching in Allan Hills, Antarctica, when they discovered a 1.93 kilogram (about 4 pounds) meteorite dubbed "ALH 84001." The rock is 3.9 billion years old and an analysis of trapped gases within ALH 84001 was an identical match to the Martian atmosphere that the 1976 Viking landers analyzed. So a new category of meteorites from Mars was confirmed.

Twelve years later after its discovery, the Allan Hills meteorite made worldwide headlines in 1996 when scientists announced the rock might contain microscopic fossils of Martian bacteria. At the time, Kathie Thomas-Keprta, a biochemist and senior scientist at Lockheed Martin's Johnson Space Center in Houston, had been studying the crystal structure and purity of magnetite beads manufactured in a species of Earth-based bacteria called magnetotactic, or MV-1. The crystals work like tiny compasses sensitive to the Earth's magnetic field. When terrestrial *inorganic* magnetites are studied, none have all the properties displayed in Earth's magnetotactic bacteria.

> [ Editor's Note: *Wikipedia* - Magnetotactic bacteria (or MTB) are a class of bacteria discovered in the 1960s, that exhibit the ability to orient themselves along the magnetic field lines of Earth's magnetic field. To perform this task, these bacteria have organelles called magnetosomes that contain magnetic crystals. The biological phenomenon of microorganisms tending to move in response to the environment's magnetic characteristics is known as magnetotaxis, an instance of magnetoception. It is believed to aid these organisms in reaching regions of optimal oxygen concentration.]

Dr. Keprta then compared the Earth magnetotactic bacteria's magnetite with nearly identical magnetite crystals found in the Allan Hills meteorite from Mars. In 2000, she reported, "These populations are identical to each other. And if this Allan Hills rock were a terrestrial rock, there would be no doubt about biogenic activity associated with it. But because it comes from Mars, I'm going to have a lot of doubters!"

Doubters came forward with the hypothesis that the magnetite crystals could have resulted from thermal decomposition of the carbonate from the meteorite's impact heating.

Now nine years later and the recent development of high resolution electron microscopy, new analyses shows that at least 25% of the magnetite crystals embedded in the Allan Hills meteorite are chemically consistent with *being formed by bacteria.* Dr. Keprta and her NASA colleagues announced, "We feel vindicated about our original position that these structures are formed by bacteria on Mars."

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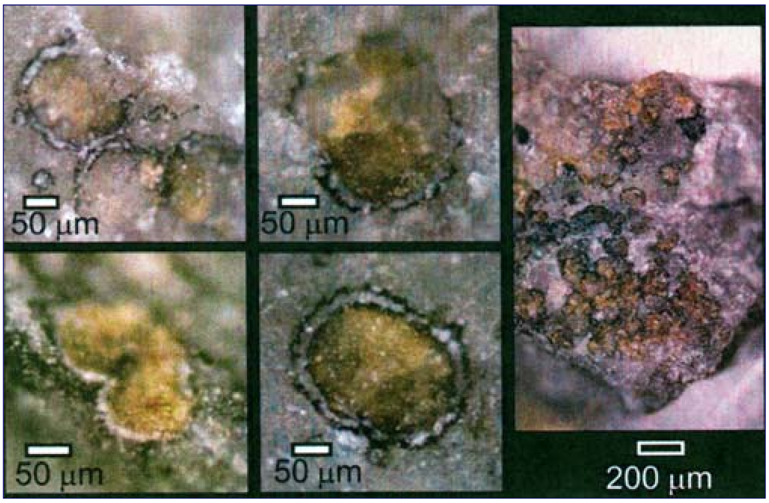
## Interview:

**Kathie Thomas-Keprta, Ph.D., Senior Scientist, Engineering and Science Contract**

**Group, ESCG/Jacobs Technology, NASA Johnson Space Center, Houston,Texas:** "There is a new technique that was developed called Focused Ion Beam Microscopy (FIBM). What you do with that is use an ion beam to go into the carbonate. You leave the carbonate inside its pit (in the meteorite). You use an ion beam and we cut this beautiful, rectangular section right out of the carbonate, lift it out and we can examine it with the transmission electron microscope.

And what is absolutely magnificent it is that I can cut across the rims, cut into the underlying pit, extract out the carbonate and know exactly where we are cutting, and lift out the entire slab to look at. That way, we preserve all of the spatial relationships of the magnetite and carbonate. You know exactly what you are looking at!

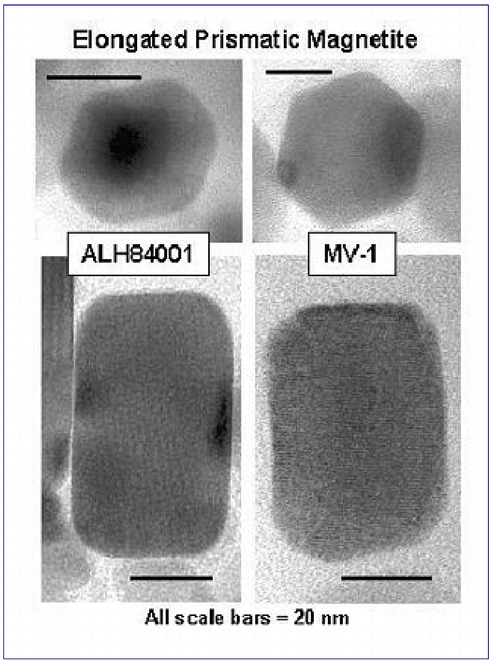



K. L. Thomas-Keprta: "Optical images of ALH84001 disk-like carbonates. These disks precipitated in fractures produced during shock impacts while the meteorite was on Mars. The majority of these carbonates appear as circular or elliptical features, which range from 10 to 300 microns along the major axis. Visually, these have colors that vary from gold to burnt orange in their centers, which are typically surrounded by a thin black-white-black rim. Some carbonates occur as single entities while others are spatially associated and occur in groups of 10s of carbonates (image at far right). The black rims typically range from 5 to 10 microns in thickness and are composed primarily of nanophase magnetite embedded in a matrix of Mg-bearing sideritic carbonate while the white bands, typically 10 to 15 microns thick, are composed of nearly pure magnesite with minor Ca and nanophase magnetite."

Also, you are not exposing the sample to things like water as we do in older cutting techniques. At each step before, you could introduce some level of contamination. We're not doing any of that now. We can cut the sample out cleanly and place it directly into a transmission electron microscope.

Magneto-fossil bacteria on Earth and under water will produce these tiny magnetite crystals within their bodies. After the organism dies, the magnetite is released from the cell and incorporated into the sediment. It's important to remember that the magnetite crystals in Allan Hills are embedded in the meteorite's carbonate and cannot be earth contamination.

Once incorporated into the sediment, these tiny magnetite crystals – same size, same shape, same chemistry as what we're seeing in the Allan Hills carbonates – become part of the rock structure and mark the time in which they are fossils of life. Rather than looking at the whole form that once was alive, we 're looking at the "bony material" formed by the creatures. That's what we're looking at in the tiny magnetite crystals.




**Left column Mars** Elongated Prismatic Magnetite Crystals from Allan Hills Meteorite: In 2000, transmission Electron microscope (TEM) images on left of elongated prismatic magnetite crystals extracted from the carbonate globules in Martian meteorite ALH84001. These crystals display a unique morphology: In one orientation they have a rectangular projection and, upon tilting the crystal, they display a hexagonal projection. These crystals also have facets on top and lower edges of the crystal. This type of morphology is displayed only by certain types of biogenic magnetite crystals on Earth. In addition, these Martian crystals are composed only of Fe (iron) and O (oxygen) and have few defects.
**Right column Earth**: In 2000, TEM images of magnetite crystals extracted from cells of magnetotactic bacteria strain MV-1 on Earth. In one orientation, the crystal has a rectangular view and when the crystal is tilted, the crystal appears to have a hexagonal view. These crystals are chemically pure and have few defects. Natural selection in terrestrial magnetotactic bacteria has optimized the stability and magnetic moment of these crystals making them uniquely identifiable as biological precipitates. The elongated prismatic magnetites from ALH84001 share these distinctive features. Thus, the presence of these prismatic magnetites in Martian meteorite ALH84001 is strong evidence for life on early Mars. Photographs courtesy NSA/JSC.

## Latest Allan Hills Meteorite Research

We took these new Focused Ion Beam Microscopy observations from Allan Hills and we took the observations from our heating studies and said, ‘Alright, how do we explain the presence of these magnetites?’ And then we looked at the other inorganic (thermal decomposition) hypotheses and we found that they are flawed. So the only hypothesis standing is the biogenic one.

WHICH IS LIFE.

Exactly.

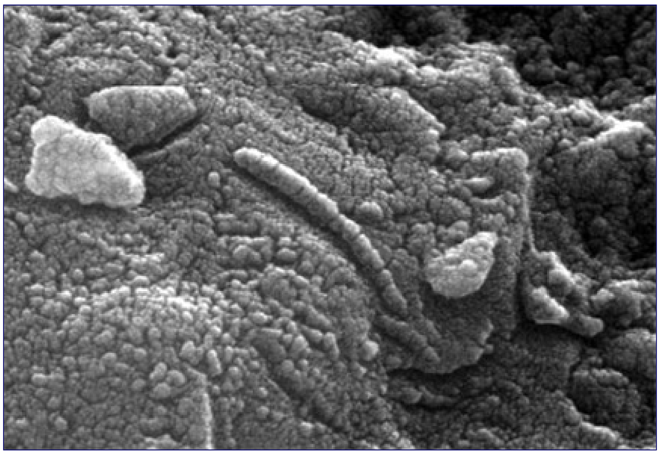
WHY IS MAGNETITE LINKED TO ORGANIC LIFE?

The magnetite crystals on Earth – and we didn’t realize this until the mid-1970s – there are these organisms called magnetotactic bacteria. That bacteria will produce a chain of these little magnetite crystals inside their bodies. What that means is that these crystals are under genetic or biological control, just like you produce a skeleton in our body and that’s under biological control and yet, it is a mineral. These tiny magnetite crystals are under genetic control of the cell. What the cell wants to do is make a good magnet because the hypothesis is that the little chain of magnets within the magnetotactic bacteria cells act like a compass for the cells. So the cells can use the Earth’s geomagnetic field lines to maneuver up and down in a water column based on the cell’s relationship to these geomagnetic field lines. The cells can only sense those field lines if they are themselves magnets.

So, the magnetotactic bacteria will produce crystals of a certain shape and size and in a certain chemical purity to make the best magnets possible.

# Were Allan Hills Magnetite Crystals Created by Worm-like Structure in Photomicrograph?

THE ORGANISM THAT MIGHT HAVE BEEN MAKING THE MAGNETITE CRYSTALS THAT YOU HAVE STUDIED SO PROFOUNDLY COULD BE IN THAT PHOTOMICROGRAPH OF WHAT LOOKS LIKE A WORM THAT DR. MC KAY HAS STUDIED?



1996 electron microscope photomicrograph revealed worm-like chain structures in meteorite fragment of the Allan Hills meteorite (ALH84001), found in Allan Hills, Antarctica on December 27, 1984 by a team of US meteorite hunters from the ANSMET project. Like other members of the group of SNCs (shergottite, nakhlite, chassignite), ALH 84001 is thought to be from Mars. On discovery, its mass was 1.93 kg. It made its way into headlines worldwide in 1996 when scientists announced that it might contain evidence for microscopic fossils of Martian bacteria. Photomicrograph provided by the NASA Johnson Space Center, Houston, Texas.

That's an interesting tie in. Some of the magnetotactic bacteria have an elongated, thin shape and some are round or spherical. So, on Earth we see there is a wide variety of types of magnetotactic organisms. They produce different shapes of crystals. But in every case, they are chemically pure because the chemically pure magnetites are better magnets.

THAT'S EXACTLY WHAT THIS WORM-LIKE CREATURE COULD BE IN THIS ONE PHOTOMICROGRAPH?

It very well might be. We still have a lot of work left to do, particularly on other Martian meteorites. Dave McKay is our resident SEM, our scanning electron microscope expert. He will be looking for forms and shapes that are similar to biological organisms on Earth. In other words, if we were to fossilize an organism, what would it look like?

IT MIGHT LOOK LIKE THAT WORM-LIKE CREATURE.

Absolutely.

# Allan Hills Meteorite and Mars Connection?

CAN YOU EXPLAIN FOR A GENERAL AUDIENCE HOW YOU KNOW THAT THE Allan HILLS METEORITE CAME FROM MARS?

One of the scientists in our building, Don Bogard, analyzed trapped gases within a meteorite. It turned out that the composition of that gas phase is an identical match to the Martian atmosphere that the Viking landers analyzed. We knew then that we could get meteorites from Mars.

It turns out with Allan Hills that we have been able to analyze the same minerals that we are finding in the other Martian meteorites that we know are from Mars. Also, we would expect because it is a planetary surface, we would expect to see different ages of rocks. Indeed, we have rocks from Mars that span from – in the case of Allan Hills – 3.9 billion years old all the way down to 165 million years of age. So, the way the minerals are put together, the gas phases in the rocks, they all support an origin of Mars.

SO THE AUDIENCE CAN GET A MENTAL PICTURE ABOUT HOW THIS MIGHT WORK, LET'S SAY THAT A METEORITE CRASHES IINTO MARS AND THROWS UP SOME ROCKS AND DUST. EVENTUALLY SOME OF THAT MATERIAL MARS GETS INTO AN ORBIT THAT CAN END UP ON EARTH? HOW DOES A ROCK ON

MARS REACH EARTH?

During an impact or collision, the rock has to reach escape velocity, which is 5.5 kilometers per second and becomes ejected from the planet's surface. If it gets close enough to Earth, that rock will be attracted by the Earth's gravitational pull.

So, we find meteorites all over the Earth's surface from Mars and from other asteroids and bodies and from the moon as well. In the case of Mars, we find Martian meteorites in Antarctica, Europe, France. You can find them all over the Earth's surface.

IS Allan HILLS THE ONLY MARTIAN METEORITE SO FAR THAT SEEMS TO HAVE FOSSILIZED BACTERIAL LIFE IN IT?

No. I think Allan Hills is the best case for fossilized bacteria. It's the one we've looked at the longest. But there is certainly interesting and compelling evidence for life in other Martian meteorites as well.

## If Magnetotactic Bacteria Were On Mars in the Past, Are They Still There Now?

IF Allan HILLS, THAT ARRIVED ON EARTH 13,000 YEARS AGO, HAS EVIDENCE OF FOSSILIZED LIFE FROM MARS GOING BACK 3.9 BILLION YEARS AGO, DO YOU THINKTHERE COULD BE LIVING BACTERIA ON MARS TODAY?

It is unlikely that once life starts that it's easy to extinguish, particularly in the case of microorganisms. The Allan Hills Martian meteorite suggests there is evidence for life on ancient Mars. If that is true, which I believe we have good evidence to support that, there could *still* be life – particularly in the subsurface regions of Mars.

IS THERE ANY REASON WHY THE OPPORTUNITY AND SPIRIT ROVERS DID NOT HAVE MACHINERY TO LOOK FOR AND ANALYZE ORGANIC MATERIALS ON MARS?

Those rovers were well-equipped to do the job they were sent to Mars to do.

THAT WAS AN INORGANIC SEARCH.

Right – that was to understand the geology of the planet and to find out whether or not there had been water on the surface of Mars and I think they have answered that beautifully.

THAT ANSWER IS DEFINITELY YES.

Absolutely!

WITH WATER ON MARS, WHATEVER THE TIME LINE, USUALLY WE WOULD ASSOCIATE WATER WITH LIFE.

And not only water in a solid phase (ice), but water in a liquid phase. As far as we know on Earth, that is imperative for life to have water in a liquid phase. That has been shown to be the case on Mars and as well in the Martian meteorites. We have evidence of mineral phases called 'clays' in the Martian meteorites and those clays were formed when the minerals came in contact with liquid water.

DO SCIENTISTS AGREE ON WHEN WAS THE LAST TIME MARS HAD RUNNING LIQUID WATER ON ITS SURFACE?

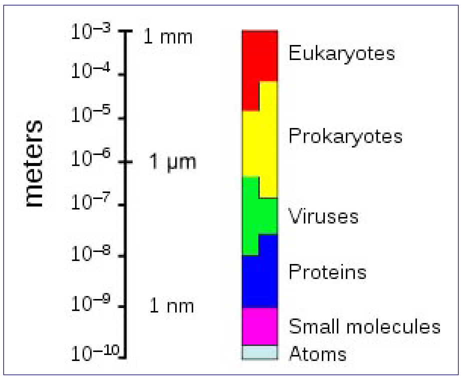
We are finding evidence of water-bearing phases in Martian meteorites as recently as 165 million years ago. The meteorites we have are like snapshots throughout time. Martian meteorites range from about 4.5 billion to 165 million years of age. In *each* time step, we find evidence for liquid water on Mars. I think that's fantastic!

IS IT POSSIBLE THAT YOU'LL END UP FINDING A METEORITE THAT CONFIRMS LIQUID WATER ON THE SURFACE OF MARS EVEN MORE RECENTLY THAN 165 MILLION YEARS AGO?

It would be great! We just have to find that meteorite! (laughs)

## Ancient Martian Life: Prokaryotic?

When there was water on Mars, there probably was simple prokaryotic life, which is consistent with magnetotactic bacteria that we find on Earth. These are simple types of organisms.




**[ Editor's Note: Wikipedia -** The **prokaryotes** are a group of organisms that lack a cell nucleus or any other membrane-bound organelles. The current model of the evolution of the first living organisms is that these were some form of prokaryotes, which may have evolved out of protobionts.They differ from the eukaryotes, which have a cell nucleus. Most are unicellular, but a few prokaryotes such as myxobacteria have multicellular stages in their life cycles. The prokaryotes are divided into two domains: the bacteria and the archaea. Archaea were recognized as a domain of life in 1990. These organisms were originally thought to live only in inhospitable conditions such as extremes of temperature, pH and radiation, but have since been found in all types of habitats.

Recent research indicates that all prokaryotes actually do have cytoskeletons, although more primitive than those of eukaryotes. At least some prokaryotes also contain intracellular structures which can be seen as primitive organelles. Most prokaryotes are between 1 micron and 10 microns, but they can vary in size from 0.2 microns to 750 microns. ]

IS IT FAIR TO SAY THAT YOU, AS A SCIENTIST WHO HAS STUDIED THE Allan HILLS METEORITE FOR A LONG TIME, ARE CONVINCED THAT IT REPRESENTS LIFE ON MARS AT A MICROBIAL LEVEL PAST, PRESENT AND MAYBE EVEN FUTURE?

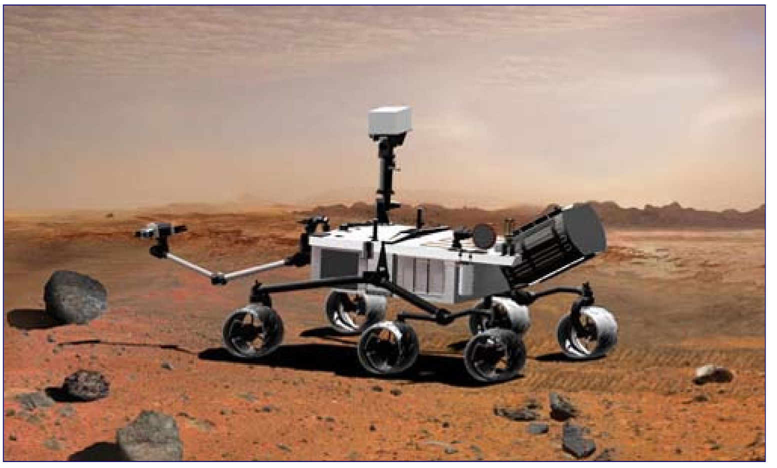
What I can say is that there is strong evidence for ancient life on early Mars because the carbonates we are looking at in the Allan Hills meteorite are 3.9 billion years of age. I can't speak to recent past or present life on Mars because I have only been looking at the Allan Hills meteorite, which is so old.

BUT THE LIKELIHOOD IS IF THERE HAS BEEN BACTERIAL LIFE ON MARS IN THE PAST, THERE IS BACTERIAL LIFE PRESENT NOW?

I would certainly say – I would say yes!"

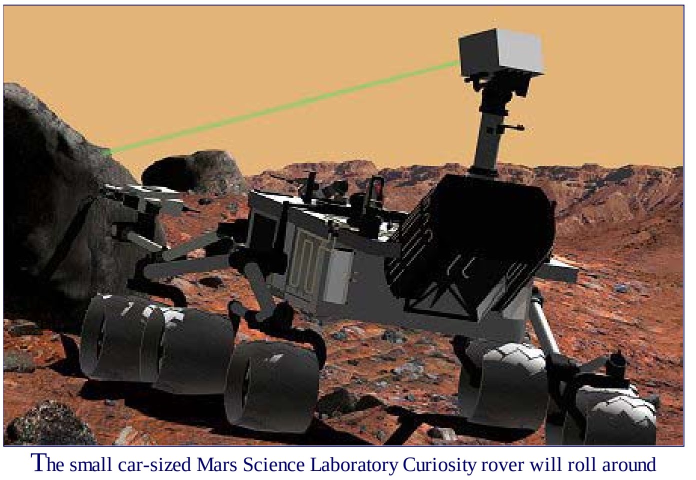
## Next NASA Mars Mission to Look for Organic Life

Scheduled to launch in the fall of 2011, Mars Science Laboratory (MSL) is part of NASA's Mars Exploration Program, a long-term effort of robotic exploration of the red planet. Mars Science Laboratory is a rover called "Curiosity" that will assess whether Mars ever was, or is still today, an environment able to support microbial life. In other words, its mission in 2012 is to determine the planet's habitability.



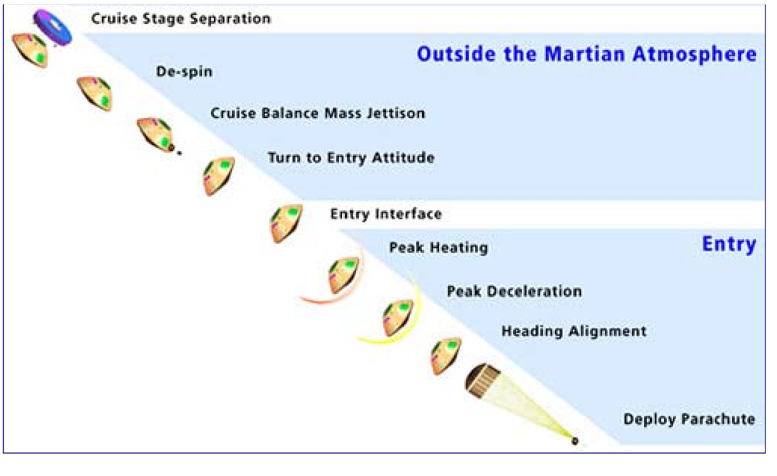
The Mars Science Laboratory rover is larger and can travel farther than Spirit and Opportunity, NASA's two Mars Exploration Rovers that began exploring the red planet in early 2004. Illustration by NASA Mars Science Lab.

To search, NASA reports that "the rover will carry the biggest, most advanced suite of instruments for scientific studies ever sent to the Martian surface. The rover will analyze dozens of samples scooped from the soil and drilled from rocks. The record of the planet's climate and geology is essentially 'written in the rocks and soil' - in their formation, structure, and chemical composition. The rover's onboard laboratory will study rocks, soils, and the local geologic setting in order to detect chemical building blocks of life such as forms of carbon on Mars and will assess what the Martian environment was like in the past."

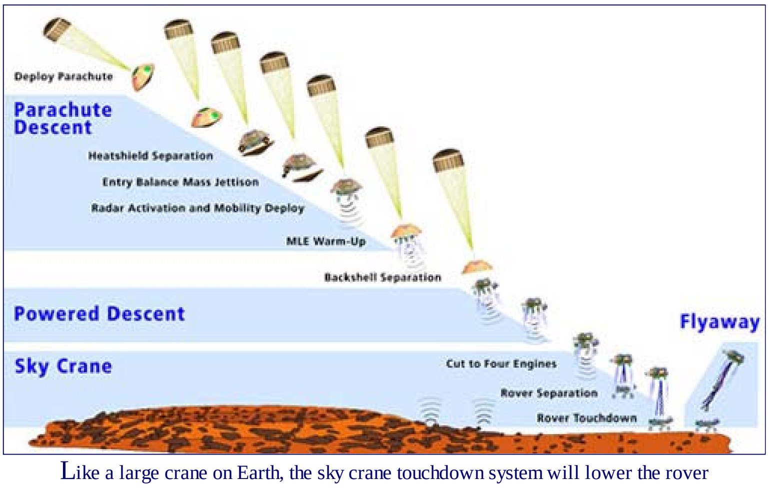


The small car-sized Mars Science Laboratory Curiosity rover will roll around the rocky surface of Mars not only brushing dust off rocks, but also vaporizing them with a laser beam, gathering samples to analyze on the spot and taking high resolution photographs. Illustration by NASA Mars Science Lab.

Mars Science Laboratory will rely on new technological innovations, especially for landing. Mars Science Laboratory will use a bold, new landing system. The spacecraft's descent into the Martian atmosphere will be guided by small rockets on its way toward the surface. As the spacecraft loses speed, rockets will fire again, controlling the spacecraft's descent until the rover separates from its final delivery system, the sky crane.



Like Viking, Pathfinder and the Mars Exploration Rovers, Mars Science Laboratory will be slowed by a large parachute. Then during the final seconds prior to landing, lower the upright rover on a tether to the surface, much like a sky crane. Once on the surface, the rover will be able to roll over obstacles up to 75 centimeters (29 inches) high and travel up to 90 meters (295 feet) per hour. On average, the rover is expected to travel about 30 meters (98 feet) per hour, based on power levels, slippage, steepness of the terrain, visibility, and other variables.




Like a large crane on Earth, the sky crane touchdown system will lower the rover to a "soft landing" - wheels down on the surface of Mars, ready to begin its mission. Illustrations by NASA Mars Science Laboratory.

NASA: "The rover will carry a radioisotope power system that generates electricity from the heat of plutonium's radioactive decay. This power source gives the mission an operating lifespan on Mars' surface of a full Martian year (687 Earth days) or more, while also providing significantly greater mobility and operational flexibility, enhanced science payload capability, and exploration of a much larger range of latitudes and altitudes than was possible on previous missions to Mars.

Arriving at Mars in 2012, Mars Science Laboratory will:

- demonstrate the ability to land a very large, heavy rover to the surface of Mars (which could be used for a future Mars Sample Return mission that would collect rocks and soils and send them back to Earth for laboratory analysis)

- demonstrate the ability to land more precisely in a 20-kilometer (12.4-mile) landing circle

- demonstrate long-range mobility on the surface of the red planet (5-20 kilometers or about 3 to 12 miles) for the collection of more diverse samples and studies."

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### More Information:


Allan Hills ALH84001 meteorite made worldwide headlines in 1996 because scientists found rice-shaped carbon globules in tiny cracks on the rock which resembled Earth bacteria. The carbon in this meteorite dates back to 3.9 billion years ago when Mars probably had water on its surface, was warmer and had a global magnetic field.

For entire technical report, see: **"Origins of magnetite nanocrystals in Martian meteorite ALH84001"**

Published in *Geochimica et Cosmochimica Acta 73* (2009), 6631-6677, by Kathie L. Thomas-Keprta, S. J. Clemett, D. S. McKay, E. K. Gibson and S. J. Wentworth, NASA Johnson Space Center, Houston, Texas.

For further information about Martian research, please see **Earthfiles Archive** (partial list below):

- 02/27/2009 — Part 2: Silicas - and Hot Springs? - Could Mean Ancient Life On Mars
- 01/25/2009 — Methane Mystery On Mars
- 08/05/2008 — Perchlorate Discovery by Phoenix Lander Does Not End Search for Life On Mars
- 05/29/2008 — Phoenix Robotic Arm Preparing to Dig Into Martian Permafrost
- 12/16/2005 — MARSIS Radar Looking Below Surface of Mars
- 08/24/2005 — Dust Devils and "Lemon Rinds" on Mars
- 03/26/2005 — Spirit Rover Finds Magnesium Sulfate Near "Larry's Lookout" in Columbia Hills on Mars.
- 02/26/2005 — Mars Spirit Rover Discovered Boundary Between Gusev Lava and Older, Water-Soaked Rocks in "Columbia Hills"
- 04/02/2004 — Updates on Spirit and Opportunity Rovers
- 03/31/2004 — Methane on Mars - Biology? Volcanic?
- 03/11/2004 — Updated - Mars Spirit and Opportunity Sol 65 and Sol 46
- 03/08/2004 — Updates from NASA's Rovers and ESA's Mars Express
- 03/05/2004 — Part 3 - Mars: A Sulfate Salty Planet - Could It Have Sulfate-Loving Microbes?
- 03/03/2004 — Part 1 - Mars: Meridiani Planum Was Once "Drenched With Water and Habitable"
- 03/01/2004 — Opportunity Grinds Bedrock; Spirit Ready to Grind "Humphrey"
- 02/10/2004 — Part 1 - Opportunity Investigating Bedrock and Spirit's Headed for Bonneville Crater
- 01/31/2004 — Opportunity Rolls Onto Martian Soil and Confirms Hematite
- 01/31/2004 — Is There Living Green Algae in the Gusev Crater on Mars?
- 01/24/2004 — Updated - Spirit Alive, But in "Critical" Condition. Mars Express Sees Water Ice and Ancient River Channel
- 01/21/2004 — Spirit Rover's First Martian Soil Analysis Has Surprises
- 01/09/2004 — Robotic "Geologists" on Mars
- 12/18/2003 — Beagle 2 Spacecraft Will Land on Mars Christmas Day.
- 12/24/2000 — Martian Bacteria?
- 12/02/1999 — Is There Water - And Life - On Mars?

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## Websites:

"Origins of magnetite nanocrystals in Martian meteorite ALH84001": **http://www.nasa.gov/centers/johnson/pdf/403099main_GCA_2009_final_corrected.pdf**

Mars Meteorites: **http://www2.jpl.nasa.gov/snc/**

Allan Hills Meteorite History: **http://en.wikipedia.org/wiki/Allan_Hills_84001**

Trapped gas analysis in meteorites: **http://ares.jsc.nasa.gov/People/bogarddon.html**

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