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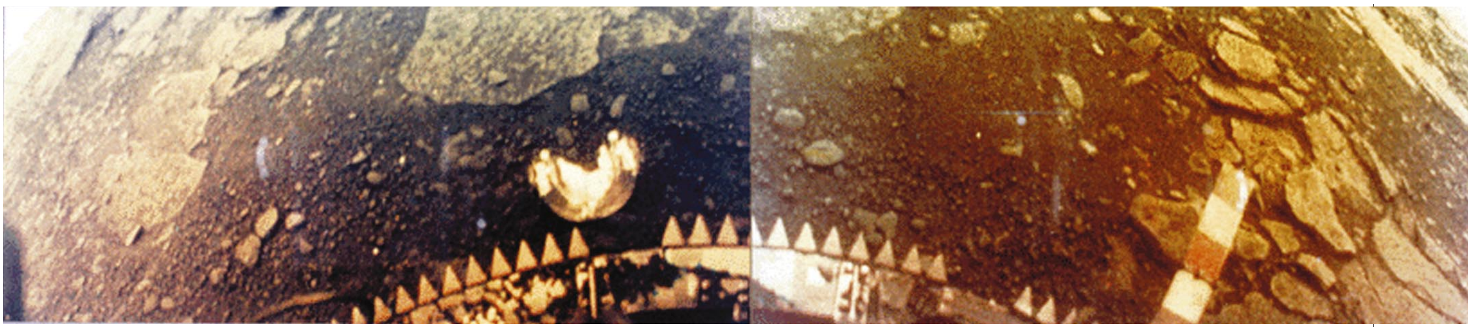

Narrow horizons in astrobiology

Mission planners must realize that astrobiology is more than a search for life.

Michael J. Drake and Bruce M. Jakosky

Astrobiology burst upon the world in the mid-1990s, as the excitement about possible life on Mars recorded in the meteorite ALH84001 (ref. 1) and the discovery of planetary systems around other stars[2] received intense international attention. Was the answer to the question that has been asked ever since humans first became sentient — "Are we alone in the Universe?" — finally within our grasp?

Astrobiology provided, for the first time since the end of the US/Soviet cold war race to the Moon, a deep rationale for the US civilian space programme. What better justification for spending more than $2 billion a year on space science than to seek the answer to an ancient and profound question? But that goal is not yet being realized. Along the way, the broad and deep concept of astrobiology has, in practice, been reduced to a very narrow interpretation.

Initial promise

Astrobiology, as originally conceived, addressed far more than just the search for life in our Solar System. It involved understanding the current states of planets; how they formed and the nature of their initial states; the evolutionary processes that, over 4.5 billion years, led to their current states; and how those same processes might have operated in other planetary systems. It was about understanding planetary habitability and planetary non-habitability, as well as the actual distribution of life in our Solar System and elsewhere in our Galaxy. (See discussions in ref. 3.)

To achieve these goals, we need to know what the 'building blocks' were at time zero, before recognizable planets emerged from the disk of gas and dust surrounding the young Sun. The young Sun itself is the product of the collapse of an irregular, cold, slowly rotating cloud of gas and dust that formed from the debris from earlier generations of stars that lived during the first 10 billion years of the Universe.

What were the diverse processes of planetary evolution? Why, for example, did Earth, Venus and Mars end up so different from each other? The study of planets and satellites that are hostile to life — as well as investigations of those that might support it — provides insight about the starting conditions and evolutionary processes that cause some of them to be hospitable to life and others sterile.

We need to know how oceans and atmospheres form and operate on some planets, but also why they do not exist on others. We need to find out why some planets have magnetic fields and some do not, the longevity and stability of these fields, and their role in the evolution of atmospheres or in protecting life from hazardous cosmic rays. We need to know the bombardment history of planets to understand whether massive impact events snuffed out early attempts by living things to flourish. We need to understand how planetary systems form — for example, is a giant planet, such as Jupiter, essential for complex life to evolve because it is a 'cosmic vacuum cleaner', sweeping up comets that might have

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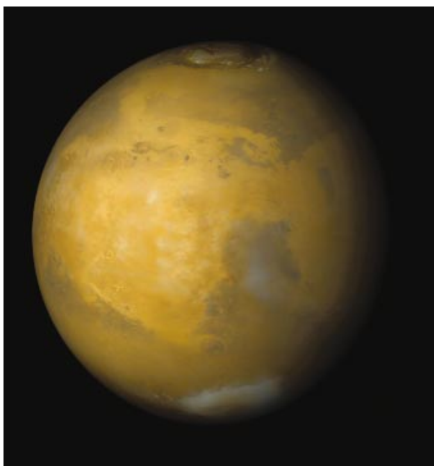
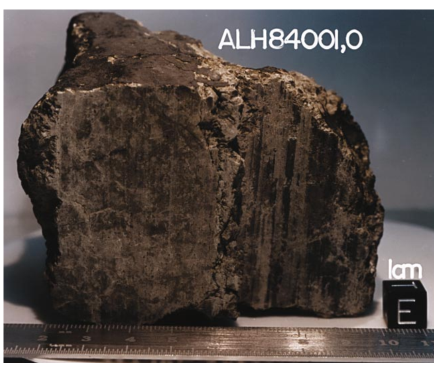
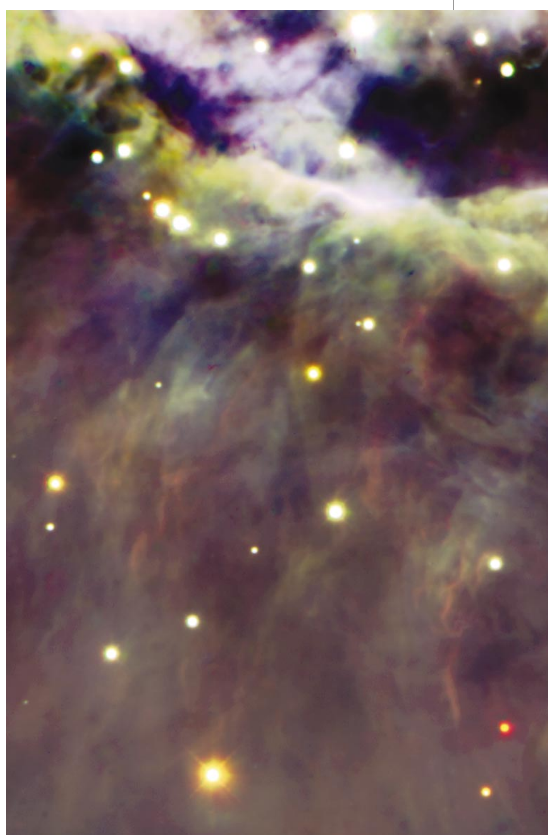
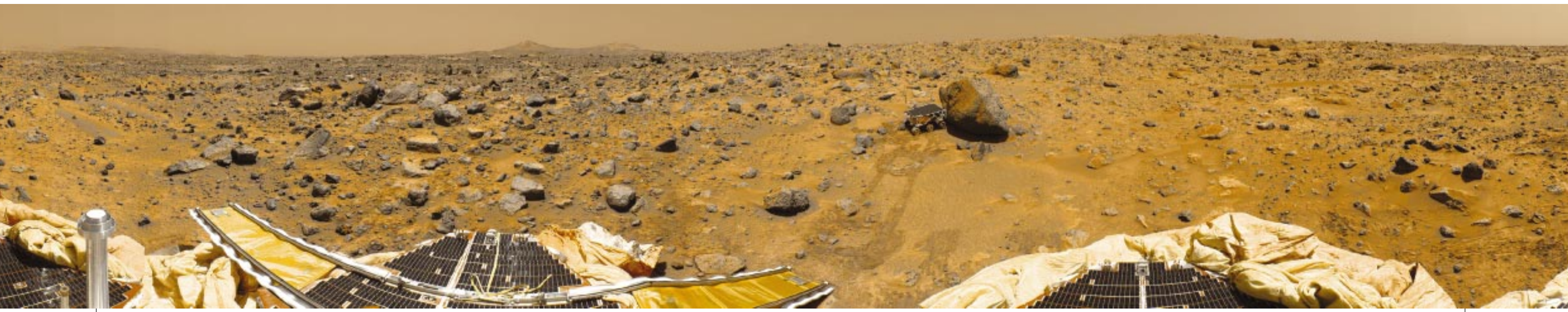






Astrobiology sparked the public imagination for exploring parts of our Universe (right) after hints of life were seen on a meteorite (above left) from Mars (top left). But inhospitable planets such as Venus (top of the page) have been passed over since the Magellan mission was approved in the early 1980s.



In vogue: Mars has proved to be the main focus of NASA's current efforts in astrobiology.

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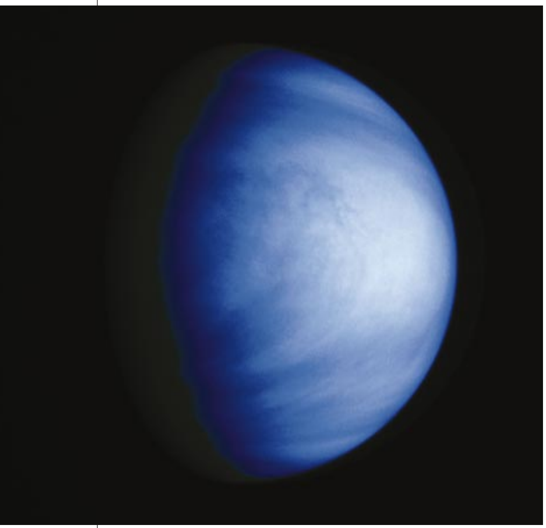
had severe impact effects on smaller planets' environments?

Astrobiology requires a rich backdrop of diverse missions, observations, laboratory experiments and theoretical calculations to achieve its promise of understanding the connection between life and planets. This broad picture is needed to understand how these same processes might have occurred in other solar systems, and whether there are likely to be habitable planets elsewhere. In addition to missions to the planets, satellites and smaller objects in our own Solar System, it requires detailed observations of other solar systems and of the characteristics of the planets that we are finding there.

In this context, astrobiology is about much more than just the search for life on Mars or Europa (one of Jupiter's moons). Although some people might expect to find evidence for current or past life on these two planetary bodies, failure to find evidence of life there does not mean that the US astrobiology programme has failed. On the contrary, it is an important scientific result that tells us much about the planetary conditions that allow life to originate or exist and those that are detrimental to life.

Evidence of the absence of life is as important in understanding where and why life exists as finding evidence for life — although, admittedly, the headlines would be less garish.

But the reality is that NASA is implementing an astrobiology programme in an emasculated form. On the one hand, the programme to understand extrasolar planets is developing quite well, with plans for Earth-orbiting telescopes to look for planets around other stars and then to determine their characteristics. But the current emphasis of Solar System spacecraft missions on the search for life, although an important intellectual element of exploration, has led to the effective exclusion of any programmes that do not have the direct and immediate goal of addressing whether life can or does exist elsewhere. The exception is the community-driven Discovery programme of small, low-cost missions, including missions to Mercury (Messenger) and to comets (Contour, Stardust and Deep Impact). The Cassini mission to Saturn, the last of the 'big budget' missions, was put in place before NASA's current mission philosophy took hold.



Missed out: a trip to Venus could offer clues to the processes that make planets hospitable.

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Restricted view

The executive branch of the US government has restricted new planetary space missions to Mars and Europa, the two most promising places after Earth where life might have emerged or persisted. These places are important targets for exploration, but they certainly do not alone constitute a programme to address the broad goals of astrobiology. Missions to Venus, Earth's twin, appear to have no place in this narrow construction of the field. What can be more important than to know why Venus, so like Earth, is so inhospitable? The trite answer, that Venus is closer to the Sun, is a cartoon approach to the problem. The current approach also does not allow room for missions that have very high priority within planetary science yet have lower priority for astrobiology, such as the Pluto flyby mission, which was funded by US Congressional action after it was left out of the president's budget for the 2002 fiscal year.

As this Commentary went to press, NASA's proposed budget for the fiscal year 2003 cancelled the New Horizons Pluto mission and Europa orbiter, replacing both with the more general New Frontiers programme.

The scientific community has to take its share of the blame for the current narrow emphasis in the interpretation of astrobiology. Few planetary scientists understand the diverse and complex relationships between different components of the system as described above. It has been easier for them to take 'astrobiology' as the narrow search for life on Mars and Europa, treating it as separate from the 'true' discipline of planetary science, and then lambast the astrobiology programme for its narrowness. Yet the same community has simultaneously allowed the Solar System exploration programme to be carried along by the public's excitement about the potential for finding life.

Returning to its roots

Astrobiology is a good idea. When taken in its broader form, it is a unifying theme that resonates with people of all ages, the scientific community and the US government, and its appeal is international. We must break free of the narrow constructionism of astrobiology currently in vogue in the United States. Yes, we would like to know if we are alone in the Universe. But to do that we need to know how solar systems form, how planets evolve, what their interiors are like, how and when oceans and atmospheres form, and how and why environments that are conducive to life emerge. We need to understand what processes resulted in the architecture we find today in our own Solar System, and then how these same processes played out to such different ends in the planetary systems we are finding elsewhere.

To accomplish this, solar-system exploration needs to be balanced and inclusive. A programme of missions, observations, calculations and experiments to address the entire breadth of goals in astrobiology is required. The current Solar System exploration programme is too narrow. Mars and Europa alone do not constitute balanced solar-system exploration, even when the Discovery programme is taken into account. Although our current efforts might, if we are lucky, allow us to answer the question, "Are we alone in the Universe?", they will not address the more important question of "Why?". ■

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3. Astrobiology Insight. *Nature* **409,** 1079–1122 (2001).